P0190 Fuel Rail Pressure Sensor Circuit Malfunction
P0191 Fuel Rail Pressure Sensor Circuit Range/Performance
P0192 Fuel Rail Pressure Sensor Circuit Low Input
P0193 Fuel Rail Pressure Sensor Circuit High Input
P0194 Fuel Rail Pressure Sensor Circuit Intermittent
P0195 Engine Oil Temperature Sensor Malfunction
P0196 Engine Oil Temperature Sensor Range/Performance
P0197 Engine Oil Temperature Sensor Low
P0198 Engine Oil Temperature Sensor High
P0199 Engine Oil Temperature Sensor Intermittent

C.1.2 P02XX Fuel and Air Metering

P0200 Injector Circuit Malfunction
P0201 Injector Circuit Malfunction - Cylinder 1
P0202 Injector Circuit Malfunction - Cylinder 2
P0203 Injector Circuit Malfunction - Cylinder 3
P0204 Injector Circuit Malfunction - Cylinder 4
P0205 Injector Circuit Malfunction - Cylinder 5
P0206 Injector Circuit Malfunction - Cylinder 6
P0207 Injector Circuit Malfunction - Cylinder 7
P0208 Injector Circuit Malfunction - Cylinder 8
P0209 Injector Circuit Malfunction - Cylinder 9
P0210 Injector Circuit Malfunction - Cylinder 10
P0211 Injector Circuit Malfunction - Cylinder 11
P0212 Injector Circuit Malfunction - Cylinder 12
P0213 Cold Start Injector 1 Malfunction
P0214 Cold Start Injector 2 Malfunction
P0215 Engine Shutoff Solenoid Malfunction
P0216 Injection Timing Control Circuit Malfunction
P0217 Engine Overtemp Condition
P0218 Transmission Over Temperature Condition
P0219 Engine Overspeed Condition
P0220 Throttle/Pedal Position Sensor/Switch B Circuit Malfunction
P0221 Throttle/Pedal Position Sensor/Switch B Circuit Range/Performance Problem
P0222 Throttle/Pedal Position Sensor/Switch B Circuit Low Input
P0223 Throttle/Pedal Position Sensor/Switch B Circuit High Input
P0224 Throttle/Pedal Position Sensor/Switch B Circuit Intermittent
P0225 Throttle/Pedal Position Sensor/Switch C Circuit Malfunction
P0226 Throttle/Pedal Position Sensor/Switch C Circuit Range/Performance Problem
P0227 Throttle/Pedal Position Sensor/Switch C Circuit Low Input
P0228 Throttle/Pedal Position Sensor/Switch C Circuit High Input
P0229 Throttle/Pedal Position Sensor/Switch C Circuit Intermittent
P0230 Fuel Pump Primary Circuit Malfunction
P0231 Fuel Pump Secondary Circuit Low
P0232 Fuel Pump Secondary Circuit High
P0233 Fuel Pump Secondary Circuit Intermittent
(R) P0234 Engine Overboost Condition
P0235 Turbocharger Boost Sensor A Circuit Malfunction
P0236 Turbocharger Boost Sensor A Circuit Range/Performance
P0237 Turbocharger Boost Sensor A Circuit Low
P0238 Turbocharger Boost Sensor A Circuit High
P0239 Turbocharger Boost Sensor B Circuit Malfunction
P0240 Turbocharger Boost Sensor B Circuit Range/Performance
P0241 Turbocharger Boost Sensor B Circuit Low
P0242 Turbocharger Boost Sensor B Circuit High
P0243 Turbocharger Wastegate Solenoid A Malfunction
P0244 Turbocharger Wastegate Solenoid A Range/Performance
P0245 Turbocharger Wastegate Solenoid A Low
P0246 Turbocharger Wastegate Solenoid A High
P0247 Turbocharger Wastegate Solenoid B Malfunction
P0248 Turbocharger Wastegate Solenoid B Range/Performance
P0249 Turbocharger Wastegate Solenoid B Low
P0250 Turbocharger Wastegate Solenoid B High
(R) P0251 Injection Pump Fuel Metering Control "A" Malfunction (Cam/Rotor/Injector)
(R) P0252 Injection Pump Fuel Metering Control "A" Range/Performance (Cam/Rotor/Injector)
(R) P0253 Injection Pump Fuel Metering Control "A" Low (Cam/Rotor/Injector)
(R) P0254 Injection Pump Fuel Metering Control "A" High (Cam/Rotor/Injector)
(R) P0255 Injection Pump Fuel Metering Control "A" Intermittent (Cam/Rotor/Injector)
(R) P0256 Injection Pump Fuel Metering Control "B" Malfunction (Cam/Rotor/Injector)
(R) P0257 Injection Pump Fuel Metering Control "B" Range/Performance (Cam/Rotor/Injector)
(R) P0258 Injection Pump Fuel Metering Control "B" Low (Cam/Rotor/Injector)
(R) P0259 Injection Pump Fuel Metering Control "B" High (Cam/Rotor/Injector)
(R) P0260 Injection Pump Fuel Metering Control "B" Intermittent (Cam/Rotor/Injector)
P0261 Cylinder 1 Injector Circuit Low
P0262 Cylinder 1 Injector Circuit High
P0263 Cylinder 1 Contribution/Balance Fault
P0264 Cylinder 2 Injector Circuit Low
P0265 Cylinder 2 Injector Circuit High
P0266 Cylinder 2 Contribution/Balance Fault
P0267 Cylinder 3 Injector Circuit Low
P0268 Cylinder 3 Injector Circuit High
P0269 Cylinder 3 Contribution/Balance Fault
P0270 Cylinder 4 Injector Circuit Low
P0271 Cylinder 4 Injector Circuit High
P0272 Cylinder 4 Contribution/Balance Fault
P0273 Cylinder 5 Injector Circuit Low
P0274 Cylinder 5 Injector Circuit High
P0275 Cylinder 5 Contribution/Balance Fault
P0276 Cylinder 6 Injector Circuit Low
P0277 Cylinder 6 Injector Circuit High
P0278 Cylinder 6 Contribution/Balance Fault
P0279 Cylinder 7 Injector Circuit Low
P0280 Cylinder 7 Injector Circuit High
P0281 Cylinder 7 Contribution/Balance Fault
P0282 Cylinder 8 Injector Circuit Low
P0283 Cylinder 8 Injector Circuit High
P0284 Cylinder 8 Contribution/Balance Fault
P0285 Cylinder 9 Injector Circuit Low
P0286 Cylinder 9 Injector Circuit High
P0287 Cylinder 9 Contribution/Balance Fault
P0288 Cylinder 10 Injector Circuit Low
P0289 Cylinder 10 Injector Circuit High
P0290 Cylinder 10 Contribution/Balance Fault
P0291 Cylinder 11 Injector Circuit Low
P0292 Cylinder 11 Injector Circuit High
P0293 Cylinder 11 Contribution/Balance Fault
P0294 Cylinder 12 Injector Circuit Low
P0295 Cylinder 12 Injector Circuit High
P0296 Cylinder 12 Contribution/Balance Fault

C.1.3 P03XX Ignition System or Misfire

P0300 Random/Multiple Cylinder Misfire Detected
P0301 Cylinder 1 Misfire Detected
P0302 Cylinder 2 Misfire Detected
P0303 Cylinder 3 Misfire Detected
P0304 Cylinder 4 Misfire Detected
P0305 Cylinder 5 Misfire Detected
P0306 Cylinder 6 Misfire Detected
P0307 Cylinder 7 Misfire Detected
P0308 Cylinder 8 Misfire Detected
P0309 Cylinder 9 Misfire Detected
P0310 Cylinder 10 Misfire Detected
P0311 Cylinder 11 Misfire Detected
P0312 Cylinder 12 Misfire Detected
P0320 Ignition/Distributor Engine Speed Input Circuit Malfunction
P0321 Ignition/Distributor Engine Speed Input Circuit Range/Performance
P0322 Ignition/Distributor Engine Speed Input Circuit No Signal
P0323 Ignition/Distributor Engine Speed Input Circuit Intermittent
P0325 Knock Sensor 1 Circuit Malfunction (Bank 1 or Single Sensor[1])

[1] Bank 1 contains cylinder #1.

(R) P0326
(R) P0327
(R) P0328
(R) P0329
P0330
P0331
P0332
P0333
P0334
P0335
P0336
P0337
P0338
P0339
P0340
P0341
P0342
P0343
P0344
P0350
P0351
P0352
P0353
P0354
P0355
P0356
P0357
P0358
P0359
P0360
P0361
P0362
P0370
P0371
P0372
P0373
P0374
P0375
P0376
P0377
P0378
P0379
(R) P0380
P0381
(R) P0382
P0385
P0386
P0387
P0388
P0389
C.1.4 P
P0400
P0401
P0402
P0403
P0404
P0405
P0406
P0407
P0408
P0410
P0411

[1] Bank 1 c

Knock Sensor 1 Circuit Range/Performance (Bank 1 or Single Sensor[1])
Knock Sensor 1 Circuit Low Input (Bank 1 or Single Sensor[1])
Knock Sensor 1 Circuit High Input (Bank 1 or Single Sensor[1])
Knock Sensor 1 Circuit Input Intermittent (Bank 1 or Single Sensor[1])
Knock Sensor 2 Circuit Malfunction (Bank 2)
Knock Sensor 2 Circuit Range/Performance (Bank 2)
Knock Sensor 2 Circuit Low Input (Bank 2)
Knock Sensor 2 Circuit High Input (Bank 2)
Knock Sensor 2 Circuit Input Intermittent (Bank 2)
Crankshaft Position Sensor A Circuit Malfunction (R)
Crankshaft Position Sensor A Circuit Range/Performance (R)
Crankshaft Position Sensor A Circuit Low Input
Crankshaft Position Sensor A Circuit High Input
Crankshaft Position Sensor A Circuit Intermittent
Camshaft Position Sensor Circuit Malfunction
Camshaft Position Sensor Circuit Range/Performance
Camshaft Position Sensor Circuit Low Input
Camshaft Position Sensor Circuit High Input
Camshaft Position Sensor Circuit Intermittent
Ignition Coil Primary/Secondary Circuit Malfunction
Ignition Coil A Primary/Secondary Circuit Malfunction
Ignition Coil B Primary/Secondary Circuit Malfunction
Ignition Coil C Primary/Secondary Circuit Malfunction
Ignition Coil D Primary/Secondary Circuit Malfunction
Ignition Coil E Primary/Secondary Circuit Malfunction
Ignition Coil F Primary/Secondary Circuit Malfunction
Ignition Coil G Primary/Secondary Circuit Malfunction
Ignition Coil H Primary/Secondary Circuit Malfunction
Ignition Coil I Primary/Secondary Circuit Malfunction
Ignition Coil J Primary/Secondary Circuit Malfunction
Ignition Coil K Primary/Secondary Circuit Malfunction (R)
Ignition Coil L Primary/Secondary Circuit Malfunction
Timing Reference High Resolution Signal A Malfunction (R)
Timing Reference High Resolution Signal A Too Many Pulses
Timing Reference High Resolution Signal A Too Few Pulses (R)
Timing Reference High Resolution Signal A Intermittent/Erratic Pulses (R)
Timing Reference High Resolution Signal A No Pulses
Timing Reference High Resolution Signal B Malfunction
Timing Reference High Resolution Signal B Too Many Pulses
Timing Reference High Resolution Signal B Too Few Pulses
Timing Reference High Resolution Signal B Intermittent/Erratic Pulses
Timing Reference High Resolution Signal B No Pulses
Glow Plug/Heater Circuit "A" Malfunction
Glow Plug/Heater Indicator Circuit Malfunction
Glow Plug/Heater Circuit "B" Malfunction
Crankshaft Position Sensor B Circuit Malfunction
Crankshaft Position Sensor B Circuit Range/Performance
Crankshaft Position Sensor B Circuit Low Input
Crankshaft Position Sensor B Circuit High Input
Crankshaft Position Sensor B Circuit Intermittent

WXX Auxiliary Emission Controls

Exhaust Gas Recirculation Flow Malfunction
Exhaust Gas Recirculation Flow Insufficient Detected
Exhaust Gas Recirculation Flow Excessive Detected
Exhaust Gas Recirculation Circuit Malfunction
Exhaust Gas Recirculation Circuit Range/Performance
Exhaust Gas Recirculation Sensor A Circuit Low
Exhaust Gas Recirculation Sensor A Circuit High
Exhaust Gas Recirculation Sensor B Circuit Low
Exhaust Gas Recirculation Sensor B Circuit High
Secondary Air Injection System Malfunction
Secondary Air Injection System Incorrect Flow Detected
P0412 Secondary Air Injection System Switching Valve A Circuit Malfunction
P0413 Secondary Air Injection System Switching Valve A Circuit Open
P0414 Secondary Air Injection System Switching Valve A Circuit Shorted
P0415 Secondary Air Injection System Switching Valve B Circuit Malfunction
P0416 Secondary Air Injection System Switching Valve B Circuit Open
P0417 Secondary Air Injection System Switching Valve B Circuit Shorted
P0418 Secondary Air Injection System Relay "A" Circuit Malfunction
P0419 Secondary Air Injection System Relay "B" Circuit Malfunction
P0420 Catalyst System Efficiency Below Threshold (Bank 1[1])
P0421 Warm Up Catalyst Efficiency Below Threshold (Bank 1[1])
P0422 Main Catalyst Efficiency Below Threshold (Bank 1[1])
P0423 Heated Catalyst Efficiency Below Threshold (Bank 1[1])
P0424 Heated Catalyst Temperature Below Threshold (Bank 1[1])
P0430 Catalyst System Efficiency Below Threshold (Bank 2)
P0431 Warm Up Catalyst Efficiency Below Threshold (Bank 2)
P0432 Main Catalyst Efficiency Below Threshold (Bank 2)
P0433 Heated Catalyst Efficiency Below Threshold (Bank 2)
P0434 Heated Catalyst Temperature Below Threshold (Bank 2)
P0440 Evaporative Emission Control System Malfunction
P0441 Evaporative Emission Control System Incorrect Purge Flow
P0442 Evaporative Emission Control System Leak Detected (small leak)
P0443 Evaporative Emission Control System Purge Control Valve Circuit Malfunction
P0444 Evaporative Emission Control System Purge Control Valve Circuit Open
P0445 Evaporative Emission Control System Purge Control Valve Circuit Shorted
P0446 Evaporative Emission Control System Vent Control Circuit Malfunction
P0447 Evaporative Emission Control System Vent Control Circuit Open
P0448 Evaporative Emission Control System Vent Control Circuit Shorted
P0449 Evaporative Emission Control System Vent Valve/Solenoid Circuit Malfunction
P0450 Evaporative Emission Control System Pressure Sensor Malfunction
P0451 Evaporative Emission Control System Pressure Sensor Range/Performance
P0452 Evaporative Emission Control System Pressure Sensor Low Input
P0453 Evaporative Emission Control System Pressure Sensor High Input
P0454 Evaporative Emission Control System Pressure Sensor Intermittent
P0455 Evaporative Emission Control System Leak Detected (gross leak)
P0460 Fuel Level Sensor Circuit Malfunction
P0461 Fuel Level Sensor Circuit Range/Performance
P0462 Fuel Level Sensor Circuit Low Input
P0463 Fuel Level Sensor Circuit High Input
P0464 Fuel Level Sensor Circuit Intermittent
P0465 Purge Flow Sensor Circuit Malfunction
P0466 Purge Flow Sensor Circuit Range/Performance
P0467 Purge Flow Sensor Circuit Low Input
P0468 Purge Flow Sensor Circuit High Input
P0469 Purge Flow Sensor Circuit Intermittent
P0470 Exhaust Pressure Sensor Malfunction
P0471 Exhaust Pressure Sensor Range/Performance
P0472 Exhaust Pressure Sensor Low
P0473 Exhaust Pressure Sensor High
P0474 Exhaust Pressure Sensor Intermittent

[1] Bank 1 contains cylinder #1.

[1] Bank 1 contains cylinder #1.

	P0475	Exhaust Pressure Control Valve Malfunction
	P0476	Exhaust Pressure Control Valve Range/Performance
	P0477	Exhaust Pressure Control Valve Low
	P0478	Exhaust Pressure Control Valve High
	P0479	Exhaust Pressure Control Valve Intermittent
(R)	P0480	Cooling Fan 1 Control Circuit Malfunction
(R)	P0481	Cooling Fan 2 Control Circuit Malfunction
(R)	P0482	Cooling Fan 3 Control Circuit Malfunction
(R)	P0483	Cooling Fan Rationality Check Malfunction
(R)	P0484	Cooling Fan Circuit Over Current
(R)	P0485	Cooling Fan Power/Ground Circuit Malfunction

C.1.5 P05XX Vehicle Speed, Idle Control, and Auxiliary Inputs

	P0500	Vehicle Speed Sensor Malfunction
	P0501	Vehicle Speed Sensor Range/Performance
	P0502	Vehicle Speed Sensor Circuit Low Input
	P0503	Vehicle Speed Sensor Intermittent/Erratic/High
	P0505	Idle Control System Malfunction
	P0506	Idle Control System RPM Lower Than Expected
	P0507	Idle Control System RPM Higher Than Expected
	P0510	Closed Throttle Position Switch Malfunction
(R)	P0520	Engine Oil Pressure Sensor/Switch Circuit Malfunction
(R)	P0521	Engine Oil Pressure Sensor/Switch Range/Performance
(R)	P0522	Engine Oil Pressure Sensor/Switch Low Voltage
(R)	P0523	Engine Oil Pressure Sensor/Switch High Voltage
	P0530	A/C Refrigerant Pressure Sensor Circuit Malfunction
	P0531	A/C Refrigerant Pressure Sensor Circuit Range/Performance
	P0532	A/C Refrigerant Pressure Sensor Circuit Low Input
	P0533	A/C Refrigerant Pressure Sensor Circuit High Input
	P0534	Air Conditioner Refrigerant Charge Loss
	P0550	Power Steering Pressure Sensor Circuit Malfunction
	P0551	Power Steering Pressure Sensor Circuit Range/Performance
	P0552	Power Steering Pressure Sensor Circuit Low Input
	P0553	Power Steering Pressure Sensor Circuit High Input
	P0554	Power Steering Pressure Sensor Circuit Intermittent
	P0560	System Voltage Malfunction
	P0561	System Voltage Unstable
	P0562	System Voltage Low
	P0563	System Voltage High
	P0565	Cruise Control On Signal Malfunction
	P0566	Cruise Control Off Signal Malfunction
	P0567	Cruise Control Resume Signal Malfunction
	P0568	Cruise Control Set Signal Malfunction
	P0569	Cruise Control Coast Signal Malfunction
	P0570	Cruise Control Accel Signal Malfunction
	P0571	Cruise Control/Brake Switch A Circuit Malfunction
	P0572	Cruise Control/Brake Switch A Circuit Low
	P0573	Cruise Control/Brake Switch A Circuit High

P0574 through P0580 Reserved for Cruise Codes

C.1.6 P06XX Computer and Auxiliary Outputs

	P0600	Serial Communication Link Malfunction
	P0601	Internal Control Module Memory Check Sum Error
	P0602	Control Module Programming Error
	P0603	Internal Control Module Keep Alive Memory (KAM) Error
	P0604	Internal Control Module Random Access Memory (RAM) Error
	P0605	Internal Control Module Read Only Memory (ROM) Error (Module Identification Defined by SAE J1979)
	P0606	PCM Processor Fault
(R)	P0608	Control Module VSS Output "A" Malfunction
(R)	P0609	Control Module VSS Output "B" Malfunction
(R)	P0620	Generator Control Circuit Malfunction
(R)	P0621	Generator Lamp "L" Control Circuit Malfunction
(R)	P0622	Generator Field "F" Control Circuit Malfunction
(R)	P0650	Malfunction Indicator Lamp (MIL) Control Circuit Malfunction
(R)	P0654	Engine RPM Output Circuit Malfunction
(R)	P0655	Engine Hot Lamp Output Control Circuit Malfunction
(R)	P0656	Fuel Level Output Circuit Malfunction

C.1.7 P07XX Transmission

	P0700	Transmission Control System Malfunction
	P0701	Transmission Control System Range/Performance
	P0702	Transmission Control System Electrical
	P0703	Torque Converter/Brake Switch B Circuit Malfunction
	P0704	Clutch Switch Input Circuit Malfunction
	P0705	Transmission Range Sensor Circuit Malfunction (PRNDL Input)
	P0706	Transmission Range Sensor Circuit Range/Performance
	P0707	Transmission Range Sensor Circuit Low Input
	P0708	Transmission Range Sensor Circuit High Input
	P0709	Transmission Range Sensor Circuit Intermittent
	P0710	Transmission Fluid Temperature Sensor Circuit Malfunction
	P0711	Transmission Fluid Temperature Sensor Circuit Range/Performance (R) (R)
	P0712	Transmission Fluid Temperature Sensor Circuit Low Input
	P0713	Transmission Fluid Temperature Sensor Circuit High Input
	P0714	Transmission Fluid Temperature Sensor Circuit Intermittent
	P0715	Input/Turbine Speed Sensor Circuit Malfunction
	P0716	Input/Turbine Speed Sensor Circuit Range/Performance
	P0717	Input/Turbine Speed Sensor Circuit No Signal
	P0718	Input/Turbine Speed Sensor Circuit Intermittent
	P0719	Torque Converter/Brake Switch B Circuit Low
	P0720	Output Speed Sensor Circuit Malfunction
	P0721	Output Speed Sensor Circuit Range/Performance
	P0722	Output Speed Sensor Circuit No Signal
	P0723	Output Speed Sensor Circuit Intermittent
	P0724	Torque Converter/Brake Switch B Circuit High
	P0725	Engine Speed Input Circuit Malfunction
	P0726	Engine Speed Input Circuit Range/Performance
	P0727	Engine Speed Input Circuit No Signal
	P0728	Engine Speed Input Circuit Intermittent
	P0730	Incorrect Gear Ratio
	P0731	Gear 1 Incorrect Ratio
	P0732	Gear 2 Incorrect Ratio
	P0733	Gear 3 Incorrect Ratio
	P0734	Gear 4 Incorrect Ratio
	P0735	Gear 5 Incorrect Ratio
	P0736	Reverse Incorrect Ratio
	P0740	Torque Converter Clutch Circuit Malfunction
	P0741	Torque Converter Clutch Circuit Performance or Stuck Off
	P0742	Torque Converter Clutch Circuit Stuck On
	P0743	Torque Converter Clutch Circuit Electrical
	P0744	Torque Converter Clutch Circuit Intermittent
	P0745	Pressure Control Solenoid Malfunction
	P0746	Pressure Control Solenoid Performance or Stuck Off
	P0747	Pressure Control Solenoid Stuck On
	P0748	Pressure Control Solenoid Electrical
	P0749	Pressure Control Solenoid Intermittent
	P0750	Shift Solenoid A Malfunction
	P0751	Shift Solenoid A Performance or Stuck Off
	P0752	Shift Solenoid A Stuck On
	P0753	Shift Solenoid A Electrical
	P0754	Shift Solenoid A Intermittent
	P0755	Shift Solenoid B Malfunction
	P0756	Shift Solenoid B Performance or Stuck Off
	P0757	Shift Solenoid B Stuck On
	P0758	Shift Solenoid B Electrical
	P0759	Shift Solenoid B Intermittent
	P0760	Shift Solenoid C Malfunction
	P0761	Shift Solenoid C Performance or Stuck Off
	P0762	Shift Solenoid C Stuck On
	P0763	Shift Solenoid C Electrical
	P0764	Shift Solenoid C Intermittent
	P0765	Shift Solenoid D Malfunction
	P0766	Shift Solenoid D Performance or Stuck Off
	P0767	Shift Solenoid D Stuck On
	P0768	Shift Solenoid D Electrical
	P0769	Shift Solenoid D Intermittent
	P0770	Shift Solenoid E Malfunction
	P0771	Shift Solenoid E Performance or Stuck Off
	P0772	Shift Solenoid E Stuck On
	P0773	Shift Solenoid E Electrical
	P0774	Shift Solenoid E Intermittent
	P0780	Shift Malfunction
	P0781	1-2 Shift Malfunction
	P0782	2-3 Shift Malfunction
	P0783	3-4 Shift Malfunction
	P0784	4-5 Shift Malfunction

P0785 Shift/Timing Solenoid Malfunction
P0786 Shift/Timing Solenoid Range/Performance
P0787 Shift/Timing Solenoid Low
P0788 Shift/Timing Solenoid High
P0789 Shift/Timing Solenoid Intermittent
P0790 Normal/Performance Switch Circuit Malfunction

(R) C.1.8 P08XX Transmission

(R) P0801 Reverse Inhibit Control Circuit Malfunction
(R) P0803 1-4 Upshift (Skip Shift) Solenoid Control Circuit Malfunction
(R) P0804 1-4 Upshift (Skip Shift) Lamp Control Circuit Malfunction

APPENDIX D
NETWORK COMMUNICATION

FOR FUTURE DEFINITION

Report of the SAE Vehicle E/E Systems Diagnostics Standards Committee approved September 1991

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4.3 Characteristics of Security
4.4 Functional Requirements

1. *Scope*—This SAE Recommended Practice establishes a uniform practice for protecting vehicle modules from "unauthorized" intrusion through a vehicle diagnostic data communication link. The security system represents a recommendation for motor vehicle manufacturers and provides flexibility for them to tailor their system to their specific needs. The vehicle modules addressed are those that are capable of having solid-state memory contents altered external to the electronic module through a diagnostic data communication link. Improper memory content alteration could potentially damage the electronics or other vehicle modules; risk the vehicle compliance to government legislated requirements; or risk the vehicle manufacturer's security interests. This document is intended to meet the "tampering protection" provisions of California Air Resources Board OBD II regulations and does not imply that other security measures are not required nor possible.

2. *References*

2.1 **Applicable Documents**—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

J1978 MAR92 OBD II Scan Tool

2.1.2 CALIFORNIA AIR RESOURCES BOARD REGULATIONS—Available from Air Resources Board, Mobile Source Division, 9528 Telstar Avenue, El Monte, CA 91731.

Mail out #91-18 (OBD II)—Title 13, California Code of Regulations, Section 1968.1 Malfunction and Diagnostic System Requirements—1994 and Subsequent Model Year, Passenger Cars, Light Duty Trucks, and Medium-Duty vehicles with Feedback Fuel Control Systems.

2.2 **Related Publications**—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

J1850 AUG91—Class B Data Communication Network Interface
J1930 SEP91—Terms, Definitions, Abbreviations and Acronyms
J1979 DEC91—E/E Diagnostic Test Modes
2.2.1.1 The following publications are under development:
J1962 Draft Diagnostic Connector
J2012 Draft Format and Messages for Diagnostic Trouble Codes
J2190 Draft Enhanced E/E Diagnostic Test Modes
J2201 Draft Universal Interface for OBD II Scan Tool
J2205 Draft Expanded Diagnostic Protocol for OBD II Scan Tool

2.2.2 ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036.

ISO/CD 9141-1 Road vehicles—Diagnostic systems—CARB requirements for April 1991 interchange of digital information.

3. *Definitions*

STANDARD SERVICE TOOL—A service tool providing basic emission related power train diagnostic tool functions, as required by CARB OBD II regulations. This service tool complies with SAE J1978 and is not necessarily limited to only OBD II functions.

ENHANCED SERVICE TOOL—A service tool providing expanded emission related power train diagnostic functions in excess of the standard service tool and/or non-power train systems diagnostic tool functions.

SECURED SERVICE TOOL—A service tool containing a feature for accessing secured data link functions. Use of this feature is limited by the vehicle manufacturer.

UNSECURED FUNCTIONS—Standard diagnostic functions that are provided by vehicle manufacturers. These are controlled and protected by the on-vehicle controller. The unsecured capability includes reprogramming of selected items for which the reprogrammer is liable.

SECURED FUNCTIONS—Manufacturer restricted functions that require "Unlocking" the on-vehicle controller to gain access. Typical functions include programming of vehicle emission systems.

READ DATA FUNCTION—Operation which reads parameters and codes via the data link.

SERVICE ALTERATION FUNCTION—Operation which temporarily alters the vehicle control system for the purpose of diagnosing the system's operation.

PERMANENT ALTERATION FUNCTION—Operation which permanently alters the operating characteristics of a vehicle module or system.

SEED—The data value sent from the on-board controller to the secured service tool.

KEY—The data value sent from the secured service tool to the on-board controller.

4. *Technical Requirements*—Proper "Unlocking" of the controller shall be a prerequisite to access certain critical on-board controller functions; the only access to the on-board controller permitted while in a "Locked" mode is through the product-specific software. This permits the product-specific software to protect itself and the rest of the vehicle control system from unauthorized intrusion.

This document does not attempt to define capability or information that is under security; this is left to the vehicle manufacturer. The security system shall not prevent basic diagnostic communications between the external tool and the on-board controller.

4.1 **Data Link Security Strategy**—As shown in Table 1, the data link access of function is divided into two classifications: Unsecured and Secured. Each of these functions are subclassified as: Read Data, Service Alteration, and Permanent Alteration. These classifications are allocated to three types of service tools: Standard Tools, Enhanced Tools, and Secured Tools. The allocation of access classification by service tool type should provide for normal service capability of the vehicle and protect the vehicle from "unauthorized" intrusion of certain critical functions.

TABLE 1—SECURITY AUTHORITY ACCESS
DATA LINK ACCESS FUNCTION (REFER TO SECTION 4.2)

Service Tool Type	Unsecured Read Data (4.2.1)	Unsecured Service Alteration (4.2.2)	Unsecured Permanent Alteration (4.2.3)	Secured Read Data (4.2.4)	Secured Service Alteration (4.2.5)	Secured Permanent Alteration (4.2.6)
Standard (SAE J1978)	X	S	S	NA	NA	NA
Enhanced	X	E	E	NA	NA	NA
Secured	X	X	X	X	X	X

X —Function Allowed
NA —Not Allowed
S —Basic Diagnostic Capability Per Vehicle Manufacturer's Specification
E —Enhanced Diagnostic Capability

4.2 **Data Link Access Function Examples**

4.2.1 UNSECURED READ DATA
Read emission related data.
Read emission related trouble codes.

4.2.2 UNSECURED SERVICE ALTERATION
Cycle device on/off.
Substitute sensor value.

4.2.3 UNSECURED PERMANENT ALTERATION
Change vehicle option/configuration data (i.e., tire size).
Reset electronic module.

4.2.4 SECURED READ DATA

Read keyless entry parameters.
Read executable code.

4.2.5 Secured Service Alteration

Vehicle assembly plant verification tests involving parameters not normally used in service.

4.2.6 Secured Permanent Alteration

Alteration of a vehicle emission calibration.
Alteration of executable code.

4.3 Characteristics of Security—A special communications mode shall be provided to "Unlock" the on-board controllers which have secured or restricted functions. The security system is intended to make the emission related controller more immune to:

a. Unauthorized intrusion into the controller without full control of the product specific software.
b. Unauthorized alteration of the on-board control system or control parameters.

Disclosure of the "Seed/Key" relationship shall be limited to those persons, authorized by the vehicle manufacturer, who are responsible for the production of the secured service tool. The security system shall not prevent basic diagnostic or vehicle communications between external devices and the on-board controller.

There shall be three parameters which control the security access of the on-board controller:

a. The "Seed" and "Key" shall each be a minimum of 2 bytes in length. The relationship between the "Seed" and "Key" is the responsibility of the vehicle manufacturer. Multiple "Seed/Key" relationships may exist for access to different functions within a controller or systems within a vehicle.
b. The Delay Time (DT) shall be a minimum of 10 seconds; the vehicle manufacturer may specify an increased delay time to suit its specific requirements.
c. The Number of False Access Attempts (NFAA) shall be a maximum of two; the vehicle manufacturer may specify a reduced number of false attempts to suit its specific requirements. When the "Key" received by the controller is not correct, it shall be considered as a false access attempt; if access is rejected for any other reason, it shall not be considered a false access attempt.

4.4 Functional Requirements—Two request/response communication message pairs (Request #1/Response #1, Request #2/Response #2) shall be used to "Unlock" the on-board controller. The specific message content is not specified by this document and is the responsibility of the vehicle manufacturer.

a. Step 1—The external device shall request the on-board controller to "Unlock" itself by sending Request #1. The controller shall respond by sending a "Seed" using Response #1. A seed value of zero shall indicate that the controller is currently unlocked.
b. Step 2—The external device shall respond by returning a "Key" number back to the controller using Request #2. The controller shall compare this "Key" to one internally determined and issue Response #2.

If the two numbers agree, then the controller shall enable ("Unlock") the external device's access to secured communication modes.

If, upon "NFAA" attempts, the two keys do not compare (false attempt), then the controller shall insert the DT before allowing further attempts. The DT shall also be required at each controller power-up.

Three on-board controller responses shall be decoded by the external device:

a. Accept—The controller has "Unlocked" its access.
b. Invalid Key—The access attempt was rejected because the key was determined to be invalid by the controller; the access attempt was false.
c. Process Error—The access attempt was rejected for reasons other than receiving the wrong key; this shall not be counted as a false access attempt.

Termination of security access, "Locking" the product, shall result after any of the following conditions:

a. Each time the product is "powered up."
b. Upon commanding the product to a normal operational mode.
c. Conditions at the vehicle manufacturers discretion.

If an attempt is made to communicate with a "Locked" on-board controller and access a "Secured" function, the controller may return a special response indicating that the controller is "Locked" and cannot respond as requested.

Report of the SAE Vehicle E/E System Diagnostics Standards Committee approved June 1993.

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Appendix A - Diagnostic Test Mode Assignments

1. Scope—This SAE Recommended Practice describes the implementation of Enhanced Diagnostic Test Modes, which are intended to supplement the legislated Diagnostic Test Modes defined in SAE J1979. Modes are defined for access to emission related test data beyond what is included in SAE J1979, and for non-emission related data. This document describes the data byte values for diagnostic messages transmitted between diagnostic test equipment, either on-vehicle or off-vehicle, and vehicle electronic control modules. No distinction is made between test modes for emission related and non-emission related diagnostics. These messages can be used with a diagnostic serial data link such as described in SAE J1850 or ISO 9141-2.

For each test mode, this document includes a functional description of the test mode, request and report message data byte content, and an example if useful for clarification.

2. References

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1850—Class B Data Communication Network Interface

SAE J1930—E/E Systems Diagnostic Terms, Definitions, Abbreviations and Acronyms

SAE J1962—Diagnostic Connector

SAE J1978—OBD II Scan Tool

SAE J1979—E/E Diagnostic Test Modes

SAE J2012—Recommended Format and Messages for Diagnostic Trouble Codes

SAE J2178—Class B Data Communication Network Messages

SAE J2186—E/E Data Link Security

2.1.2 ISO PUBLICATIONS—Available from ANSI, 1 West 42nd Street, New York, NY 10036-8002.

ISO 9141-2—Road vehicles—Diagnostic systems—CARB requirements for interchange of digital information

2.1.3 CALIFORNIA ARB DOCUMENTS

Mail out #93-27—Title 13, California Code of Regulations, Section 1968.1 Malfunction and Diagnostic System May 31, 1993Requirements—1994 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles and Engines

2.1.4 FEDERAL EPA DOCUMENTS

40 CFR Part 86—Control of Air Pollution From New Motor Vehicles and New Motor Vehicle Engines; Federal Register Regulations Requiring On-board Diagnostics

2.2 Definitions

2.2.1 DATA BYTES—Bytes between header bytes and error detection byte.

2.2.2 DIAGNOSTIC TEST MODE—See SAE J1930.

2.2.3 OFFSET—A number used to refer to a data value by specifying its relative position in a list of data values.

2.2.4 PID—PARAMETER IDENTIFICATION NUMBER—A unique identifier used to refer to a specific data value within a module.

2.2.5 SEED / KEY—See SAE J2186.

2.2.6 DPID—DATA PACKET IDENTIFICATION NUMBER—An identifier used to refer to a set of data values within a module.

2.2.7 BYTE—A group of eight bits of data, bits 0 through bit 7, where bit 7 is the most significant bit and bit 0 is the least significant bit.

2.2.8 $—Prefix defining a hexadecimal number.

2.2.9 NIBBLE—Four bits of data. A byte may be split into two nibbles.

2.2.10 EPA—ENVIRONMENTAL PROTECTION AGENCY (FEDERAL AGENCY)

2.2.11 CARB—CALIFORNIA AIR RESOURCES BOARD (STATE AGENCY)

2.2.12 OBD II—Second generation of On-Board Diagnostic regulations required by the California Air Resources Board.

3. *Technical Requirements*

3.1 Test Mode Values—Figure 1 indicates the assignment of test mode values, and indicates the type of message and where they are defined, either in SAE J1979, this document, or by the manufacturer.

Test mode values $00 - $0F and $40 - $4F are reserved to be defined in SAE J1979, which currently only includes functionally addressed messages. Usage of shaded test mode values will be defined in this document. Appendix A indicates the test mode values currently defined by both SAE J1979 and SAE J2190.

There is a one-to-one correspondence between request messages and response messages, with bit 6 of the test mode value indicating the message type.

Test Mode Value	Message Type (bit 6)	Where Defined
$00 - 0F	Request (bit 6 = 0)	SAE J1979
		SAE J2190
$40 - 4F	Response to Modes $00-$0F (bit 6 = 1)	SAE J1979
		SAE J2190
$10 - 3F	Request (bit 6 = 0)	Reserved for future expansion as needed
$41 - 5F		Defined by vehicle manufacturer
$60 - 7F	Response to Modes $40-$5F (bit 6 = 1)	Reserved for future expansion as needed
$61 - 7F		Defined by vehicle manufacturer

FIGURE 1—TEST MODE VALUES

3.2 Physical Addressing—Physical addressing is used for all diagnostic test mode messages defined in this document. Typically when using SAE J1850, this type of addressing requires that the target address of the device for which the message is intended be included in the header of the message. In ISO 9141, the addressing is typically done during initialization. Only that device being addressed will respond to the request. Each device will need to be assigned a unique address to be used for communication purposes.

3.3 Miscellaneous Requirements

3.3.1 MESSAGE RESPONSE TIME—The vehicle controllers should respond to a diagnostic request within 100 ms of a request. If there is no response within this time period, the tool can assume no response will be received.

3.3.2 AUTOMATIC RETURN TO NORMAL OPERATION—During a diagnostic procedure, the on-board controllers will often be put into an abnormal mode of operation to aid in diagnostics. Examples are to report diagnostic data periodically, to disable normal message transmission, or substitute an input or output parameter. In practice, the test procedure should return all on-board controllers to a normal mode of operation at the end of the procedure.

If a test device is disconnected from the vehicle before the on-board controllers have returned to normal operation, the controllers should automatically detect that the tool is disconnected and return to a normal mode of operation. This should be accomplished by the on-board controller looking for a diagnostic message from the test device, which should be apparent from the message header. If a diagnostic message is not received for a 5 s period of time, the on-board controller should automatically return to normal operation.

Some diagnostic procedures may require more than 5 s without a required diagnostic message. For these cases, this document specifies a "test tool present" message to be transmitted by the test device at least once every 5 s if there is no other message. On-board controllers should consider this as a diagnostic message and continue in the current mode of operation.

On-board controllers should also return to normal operation at power up or after a controller reset.

3.3.3 DIAGNOSTIC MESSAGE LENGTH—This document only defines the data bytes to be used in a diagnostic message. The actual number of data bytes in a message, referred to as "n" in the message data byte descriptions in this document, depends on the requirements of the test mode and the maximum number of bytes available in a diagnostic message. The maximum number of bytes available depends on the maximum allowable message length and the number of bytes used as a message header, error detection byte(s), or for other protocol specific purposes.

For example, the SAE J1850 data link effectively limits the total number of bytes in a message to 12. If the message strategy includes a 3 byte header, 1 byte CRC, and 1 byte in-message response, then 7 data bytes are available for SAE J2190 functionality. If the message strategy includes a 3 byte header and 1 byte CRC, then 8 data bytes are available.

If other data links are used as the diagnostic data link, such as ISO 9141, there may be other message length limitations and, therefore, different limits on the number of data bytes available for SAE J2190 functionality.

3.3.4 MESSAGE RESPONSE—All diagnostic request messages, except "Test Device Present (Mode $3F)," should receive a response from the target module. A response is optional for the "Test Device Present" message. There are two types of response messages, specific and general. Specific response messages are uniquely paired with each request message, and repeat enough data bytes of the request message to identify the specific request. The "General Response Message (Mode $7F)" has a single test mode value. The response message to be used for a request depends on the type of the request and whether or not the module can perform the request.

When the request is for data and the module can perform the request (positive response), only the specific form of the response can be used. The response will either be a single message, multiple messages with additional data, or periodic multiple messages with updated data values.

If the request is for action, such as a request for entering a mode of operation or command to perform a function, and the module can perform the request (positive response), either the specific response message or general response message can be used. Those requests for which either response type is a valid response have both response types indicated in this document.

If the request for either data or action cannot be performed by the module (negative response), only the general response message can be used.

Figure 2 summarizes the valid response types for different types of requests.

	Positive response	Negative response
Request for data	Specific response only	General response only
Request for action	Specific or general response allowed	General response only

FIGURE 2—VALID RESPONSE TYPES

With the General Response Message a response code is returned. Response codes can indicate a negative or positive response. Standard response codes are included in the section with the definition of the General Response Message.

4. Test Modes

4.1 Modes $00 through $0F—Physically Addressed SAE J1979 Messages—Modes $00 through $0F are reserved to be defined in SAE J1979. The data byte content of the response to an SAE J1979 request when the device is addressed physically should be identical to the data byte content of the response when the device is addressed functionally. The only device that will respond to this request is the device to which the request is directed.

The response to one of these requests will be a Mode $40 through $4F message.

The same PID list as specified in SAE J1979 will apply when the device is physically addressed using the same test mode value. Although SAE J1979 reserves 256 PID values to be defined in that document, SAE J1979 specifies that PID values $21 to $3F are reserved to be defined in this document. Possible values which may be considered to be included are:

Number of header bytes and format
Use of CRC versus checksum for error detection
Use of in-message response
Maximum number of data bytes allowed (based on header and in-message response)
Use of manufacturer specific pins in the SAE J1962 connector

4.2 Mode $10—Initiate Diagnostic Operation

4.2.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to inform devices on the serial data link that a diagnostic tool is ready to start diagnostic procedures using the data link. The on-board devices may need to alter their normal operation in order for the diagnostic procedures to be effective. One example is that the system may need to reduce the amount of data being sent on the data link to make more time available for the diagnostic messages. Another possibility is that the system may need to degrade its normal operation in order to be able to process the diagnostic requests. Systems that rely on data from modules being diagnosed may not receive data from those modules as frequently as normal. Use of this mode could inform the receiving modules that diagnostic procedures are in progress and they should not set diagnostic trouble codes based on not receiving data at the normal frequency.

An optional "level of diagnostics" byte may be used to indicate how much the normal operation must be altered in order to accommodate the extra diagnostic procedures. These levels and their corresponding amount of change must be predefined in the module by the module manufacturer. The level of diagnostics can be changed by sending a subsequent Mode $10 command.

4.2.2 MESSAGE DATA BYTES—(See Figure 3.)

	Data Bytes (Hex)			
	#1	#2	#3 to #n-1	#n
Request from Tool to Vehicle				
Request diagnostic operation	10	Level (opt.)		
Positive Response from Vehicle to Tool (either of the following is a valid response)				
Confirm diagnostic operation	50	Level (opt.)		
General response	7F	Optional data bytes may be included (see Mode $7F description)		Resp. Code - 00

FIGURE 3—MESSAGE DATA BYTES FOR MODE $10

4.3 Mode $11—Request Module Reset

4.3.1 FUNCTIONAL DESCRIPTION—This mode requests the module to effectively perform a module power on reset. The response message may be sent either before or after the module is reset. The response message may also be sent by modules whenever they perform a power on reset, whether requested by this test mode or not.

An optional data byte may be included in the request to indicate different levels of reset. Examples are:

First time ever connected to vehicle
First time after battery disconnect
After a full normal power down / power up cycle
After minor power supply interruption

4.3.2 MESSAGE DATA BYTES—(See Figure 4.)

	Data Bytes (Hex)			
	#1	#2	#3 to #n-1	#n
Request from Tool to Vehicle				
Request module reset	11	Level (opt.)		
Positive Response from Vehicle to Tool (either of the following is a valid response)				
Confirm module reset	51	Level (opt.)		
General response	7F	Optional data bytes may be included (see Mode $7F description)		Resp. Code - 00

FIGURE 4—MESSAGE DATA BYTES FOR MODE $11

4.4 Mode $12—Request Diagnostic Freeze Frame Data

4.4.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to allow access to data values which were stored during freeze frame conditions specified by the vehicle manufacturer. Data content, data format, and method of retrieval are specified by the vehicle manufacturer. Typical uses for this mode are to report data stored upon detection of a system malfunction. Multiple frames of data may be stored before and/or after the malfunction is detected. The request for information includes a frame number followed by an optional indication of the data requested.

If the optional data byte is not used, or is $00, then all data for the requested freeze frame will be reported. If the optional byte is used, then the vehicle manufacturer will define the different methods used to specify which data is requested.

The on-board module will respond to this message by transmitting the requested data.

4.4.2 MESSAGE DATA BYTES—(See Figure 5.)

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n	
Request from Tool to Vehicle					
Request diagnostic freeze frame data	12	Frame No.	Method to request data (optional) examples are: Request all data (not included or 00) Request by offset (1 byte) Request by PID (2 bytes) Request by memory address (3 bytes) Request by Data Packet ID Request starting address for data DTC which caused data to be stored Other manufacturer specific method		
Positive Response from Vehicle to Tool					
Report diagnostic freeze frame data	52	Frame No.	Data byte	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes	

FIGURE 5—MESSAGE DATA BYTES FOR MODE $12

4.5 Mode $13—Request Diagnostic Trouble Code Information

4.5.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to enable a diagnostic test tool to obtain stored emission and non-emission related diagnostic trouble code (DTC) information.

This mode includes the option to request DTC information by function, where function is either powertrain, body, chassis, or undefined. These are the functions used in SAE J2012 to group trouble codes. The first two bits of the first nibble for requests by function are encoded using the same convention as when codes are reported:

00 - powertrain

OMEGA EXHIBIT 2036

01 - chassis
10 - body
11 - undefined

For requests by function using this test mode, the second two bits of the first nibble are 00, and the second nibble is all zeroes. This translates to the following function groups for DTC requests:

$00 - powertrain codes
$40 - chassis codes
$80 - body codes
$C0 - undefined

In addition, this document defines $FF as the function group to request DTC information for all functions.

This test mode can be used to either request diagnostic trouble codes, or request the number of diagnostic trouble codes. There are two ways this mode can request DTCs.

All codes can be requested by including only the test mode value in the request.

Codes can be requested by function group (Powertrain, Chassis, Body, Undefined, or All) by sending the function group followed by $00 as data bytes 2 and 3 ($00 00, $40 00, $80 00, $C0 00, or $FF 00). Requesting codes for all function groups by including $FF 00 yields the same response as not including function group in the request, but may be desired by a manufacturer for consistency with other messages.

There are also two ways this mode can request the number of DTCs.

Number of codes can be requested by including the function group as data byte 2, and not including data byte 3 ($FF as data byte 2 must be supported as a minimum to request the total number of DTC).

Number of codes can be requested by function group (Powertrain, Chassis, Body, Undefined, or All) by sending the function group followed by $FF as data bytes 2 and 3 ($00 FF, $40 FF, $80 FF, $C0 FF, or $FF FF). Requesting number of codes for all function groups by including $FF FF yields the same response as including only $FF as data byte 2 in the request, but may be desired by a manufacturer for consistency with other messages.

The response to a Mode $13 request for DTC will be one or more Mode $53 messages. If no codes are stored in the module, then the module will respond with one of the following:

Mode $53 with no additional data bytes
Mode $53 padded with $00 00 to fill response

Diagnostic trouble codes are transmitted as two bytes. The first two bits (high order) of the first byte for each code will be zeroes to indicate a powertrain code (refer to SAE J2012 - "Recommended Format and Messages for Diagnostic Trouble Codes" for additional interpretation of this structure). The second two bits will indicate the first digit of the diagnostic code (0 through 3). The second nibble of the first byte and the entire second byte are the next three digits of the actual code reported as Binary Coded Decimal (BCD). A powertrain trouble code transmitted as $0143 should be interpreted as P0143, as shown in Figure 6.

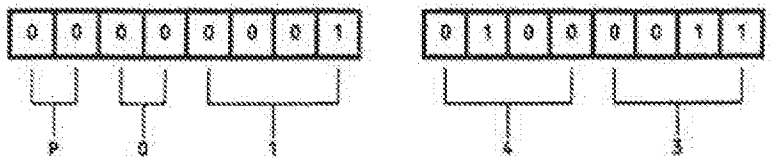

FIGURE 6—DIAGNOSTIC TROUBLE CODE EXAMPLE

4.5.2 MESSAGE DATA BYTES—(See Figure 7.)

	Data Bytes (Hex)			
	#1	#2	#3	#4 to #n
Request from Tool to Vehicle (either of the following messages can be used to request DTC)				
Request all DTC	13			
Request DTC by function group where group is: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	13	Group	00	
Request from Tool to Vehicle (either of the following messages can be used to request number of DTC)				
Request number of DTC by function where group is: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	13	Group		
FF in byte 3 is an optional byte used to maintain a fixed length request	13	Group	FF	
Positive Response from Vehicle to Tool (Multiple messages may be received to report the DTCs)				
Report stored DTC - response to request for DTC	53	Diagnostic trouble code or 00 00 (optional)		Additional optional diagnostic trouble codes may be added to fill the message up to the maximum number of available data bytes.
Report # of stored DTC - response to request for number of DTC	53	Number of codes		

NOTE—Refer to SAE J2012 for encoding method for trouble codes.

FIGURE 7—MESSAGE DATA BYTES FOR MODE $13

4.6 Mode $14—Clear Diagnostic Information

4.6.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to provide a means for the external test device to command on-board modules to clear all diagnostic information. This information includes primarily diagnostic trouble codes, but can also include freeze frame data or other on-board test results that may be stored as a result of the trouble code being set. This extra information is device dependent.

There are three ways this mode can be used. If only the test mode value is included in the request, then all diagnostic information stored in the module is to be cleared.

Diagnostic information can optionally be cleared by function (Powertrain, Chassis, or Body) by sending P0000, C0000, or B0000 as data bytes 2 and 3. These must be encoded using the same convention as when codes are reported (see description for Mode $13). The first two bits of the first nibble are:

00 - powertrain
01 - chassis
10 - body
11 - undefined

This translates to the following values for data bytes #2 and #3:

$00 00 - powertrain codes
$40 00 - chassis codes
$80 00 - body codes
$C0 00 - undefined

Diagnostic information can also optionally be cleared for a single trouble code by including the trouble code to clear as optional bytes in the request. The information stored with an individual trouble code would need to be clearly identified within the module and cleared at the same time.

Caution when clearing by single trouble code: This capability should not be provided and used unless consideration is given to the possible consequences of this option. If a single fault caused multiple trouble codes to be set, and a service technician found a defective component, repaired it, and cleared a single trouble code associated with that fault, then the device would still contain trouble codes that were set based on that fault. The next technician to check codes would read those codes, and if he did not know the vehicle history, he may try to repair the vehicle based only on the remaining trouble codes, which could waste time and result in replacement of good components.

Allowing use of this feature to clear emission related trouble codes should be considered very carefully to guard against improper diagnosis. Difficult interpretation can result if the system allowed clearing a single emission related trouble code. CARB required information could report that trouble codes are stored, but they would not be reported when an SAE J1979 Mode $04 message is sent to request those codes. Freeze frame data could be stored for a given trouble code, but that code would not be reported as stored.

4.6.2 MESSAGE DATA BYTES—(See Figure 8.)

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Clear stored diagnostic information	14	Data bytes 2 and 3 are optional: # not used - clear all information # 00 00 - clear all powertrain information # 40 00 - clear all chassis information # 80 00 - clear all body information # C0 00 - clear all On-Board DTC information # FF 00 - clear all information Any other value - trouble code to clear			
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Diagnostic information cleared	54	repeat data bytes 2 and 3 of request, if used			
General response	7F	Optional data bytes may be included (see Mode $7F description).			Reject Code - 00

FIGURE 8—MESSAGE DATA BYTES FOR MODE $14

4.7 Mode $17—Request Status of Diagnostic Trouble Codes

4.7.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to provide a means to determine the status of diagnostic trouble codes.

This mode is nearly identical in operation to Mode $13, except that only a single DTC, followed by the status of that DTC, is reported in a single response. This mode also allows a request for the status of a single DTC. The discussion of function groups and the method of reporting DTCs is identical to the description in Mode $13.

This test mode can be used to either request status of diagnostic trouble codes, or request the number of diagnostic trouble codes with a status bit set. There are three ways this mode can request DTCs.

All codes can be requested by only including the test mode value in the request.

Codes can be requested by function group (Powertrain, Chassis, Body, Undefined, or All) by sending the function group followed by $00 as data bytes 2 and 3 ($00 00, $40 00, $80 00, $C0 00, or $FF 00). Requesting codes for all function groups by including $FF 00 yields the same response as not including function group in the request, but may be desired by a manufacturer for consistency with other messages.

Status of a single trouble code can be requested by including the trouble code as data bytes 2 and 3 in the request.

There are two ways this mode can request the number of DTCs with a status bit set.

Number of codes can be requested by including the function group as data byte 2, and not including data byte 3 ($FF as data byte 2 must be supported as a minimum to request the total number of DTC).

Number of codes can be requested by function group (Powertrain, Chassis, Body, Undefined, or All) by sending the function group followed by $FF as data bytes 2 and 3 ($00 FF, $40 FF, $80 FF, $C0 FF, or $FF FF). Requesting number of codes for all function groups by including $FF FF yields the same response as including only $FF as data byte 2 in the request, but may be desired by a manufacturer for consistency with other messages.

Multiple Mode $57 response messages may be reported due to a single Mode $17 request message, depending on the type of request and the number of diagnostic trouble codes stored in the module. Each response message will report the status of a single DTC. If no codes are stored in the module, then the module will respond with one of the following:

Mode $57 with no additional data bytes

Mode $57 with $00 00 for DTC and $00 for status

4.7.2 MESSAGE DATA BYTES—(See Figure 9.)

	Data Bytes (Hex)			
	#1	#2	#3	#4
Request from Tool to Vehicle (any of the following messages can be used to request DTC)				
Request status of all DTC	17			
Request status of DTC by function group where group: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	17	Group	00	
Request status of specific DTC	17	Diagnostic Trouble Code		
Request from Tool to Vehicle (either of the following messages can be used to request number of DTC)				
Request number of DTC with a status bit set by function where group is: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	17	Group		
FF in byte 3 is an optional byte used to maintain a fixed length request	17	Group	FF	
Positive Response from Vehicle to Tool (Multiple messages may be required to report the DTCs)				
Report status of stored DTC	57	Diagnostic trouble code or 00 00 (optional)		Status of DTC or 00 (optional if DTC not reported); same definition as Data Byte #2 for Mode $18
Report # of stored DTC with any status bit set	57	Number of codes		

FIGURE 9—MESSAGE DATA BYTES FOR MODE $17

4.8 Mode $18—Request Diagnostic Trouble Codes by Status

4.8.1 FUNCTIONAL DESCRIPTION—This mode is used to retrieve diagnostic trouble codes based on the status by which they have been stored. There are various conditions under which codes are generated, for example, under normal customer driving conditions versus "on demand" codes which are generated by tests performed by the service technician. Another difference is that some codes illuminate a warning lamp while other codes do not. Some codes are retained in memory for at least 40 warmup cycles while some codes are retained only for one ignition/power up cycle.

This test mode is similar in operation to Mode $17, except that an additional data byte is inserted as data byte #2 to indicate the specific status bits of interest. Data bytes #3 and #4 in Mode $18 requests have the same meaning as data bytes #2 and #3 in Mode $17 requests.

There are many philosophies among the various manufacturers for storing codes. Bit definitions have been assigned to the more commonly accepted methods. Codes stored under that definition can be requested by setting the appropriate bit(s) to "1" to retrieve the set of desired codes.

Table 1 shows the interpretation of each bit of the status byte. This definition is used for both Modes $17 and $18. Multiple bits can be set to "1". When requesting codes using Mode $18, codes with any of the requested status bits will be reported.

Multiple Mode $58 response messages may be reported to a single request, depending on the number of diagnostic trouble codes stored in the module. Each response message will report up to three DTCs for which at least one of the requested status bits is set. If no codes are stored in the module that meet the requested status, then the module will respond with one of the following:

Mode $58 with Status Requested and no additional data bytes

Mode $58 with $00 00 as data bytes 3 and 4

Mode $58 with $00 00 repeated to fill response

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TABLE 1—INTERPRETATION OF EACH BIT OF THE STATUS BYTE

Bit	Status
7	Warning lamp illuminated for this code
6	Warning lamp pending for this code, not illuminated but malfunction was detected
5	Warning lamp was previously illuminated for this code, malfunction not currently detected, code not yet erased
4	Stored trouble code
3	Manufacturer specific status
2	Manufacturer specific status
1	Current code - present at time of request
0	Missing/Undetermined code - insufficient data to consider as a malfunction

4.8.2 MESSAGE DATA BYTES—(See Figure 10.)

	Data Bytes (Hex)				
	#1	#2	#3	#4	#5 to #n
Request from Tool to Vehicle (either of the following messages can be used to request DTC)					
Request all DTC with status	18	Status			
Request all DTC with status and function group where group is: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	18	Status	Group	00	
Request from Tool to Vehicle (either of the following messages can be used to request number of DTC)					
Request number of DTC with any specific status bits set by function group: 00 - powertrain 40 - chassis 80 - body C0 - undefined FF - all	18	Status	Group		
FF in byte 4 is an optional byte used to maintain a fixed length request	18	Status	Group	FF	
Positive Response from Vehicle to Tool					
Report DTC by status - response to request with last mode and status	58	Status req'd	Diagnostic trouble code or 00 00 (optional)		Additional optional diagnostic trouble codes may be added to fill the message up to the maximum number of available data bytes
Report DTC by status - response to request with last mode, status, and data byte #3	58	Status req'd	number of DTC with req'd status		

FIGURE 10—MESSAGE DATA BYTES FOR MODE $18

4.9 Mode $20—Return to Normal Operation

4.9.1 FUNCTIONAL DESCRIPTION—The on-board device will return to the normal mode of operation when this message is received. All normal algorithms and normal communications will be resumed. All active diagnostic modes will be terminated without sending additional request or response messages. If the module had been unlocked using security access, then the module should also be locked.

4.9.2 MESSAGE DATA BYTES—(See Figure 11.)

	Data Bytes (Hex)		
	#1	#2 to #n-1	#n
Request from Tool to Vehicle			
Request return to normal operation	20		
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Confirm return to normal operation	60		
General response	7F	Optional data bytes may be included (see Mode $7F description)	Resp. Code = 00

FIGURE 11—MESSAGE DATA BYTES FOR MODE $20

4.10 Modes $21 to $23—Request Diagnostic Data

4.10.1 FUNCTIONAL DESCRIPTION—The purpose of these modes is to request data values, such as analog inputs and outputs, digital inputs and outputs, freeze frame data, calculated values, bit mapped fault code data, and system status information. The request for information can be by one of three methods:

Mode $21 - Offset (1 byte)
Mode $22 - Parameter Identification (PID) value (2 bytes)
Mode $23 - Memory Address (3 bytes)

System designers have the flexibility to maintain a table including PID numbers and data values, without having consecutive PID numbers. In this case, the tool can request either by PID number or offset. A request by offset is generally an easier method for the software to retrieve data because it does not need to search for the PID in the table. Mode $24 allows use of the PID number one time to get the offset, with successive requests by offset for better system performance.

Figure 12 is an example of a table that could be included in the system module to utilize all of these modes. The offset is the row number of the table and is not a table entry. The location of the information within this table can be calculated by multiplying the offset times the number of bytes in each row. The location in memory can then be calculated by adding the location within the table to the base location of the table in memory.

Offset	PID1	PID2	ADDR1	ADDR2	ADDR3	SCALING1	SCALING2
00	0C	01	00	1B	FE		
01	00	0A	00	2C	1C		
02	01	FE	00	8A	1F		
..	..	..	..	..	..	..	..
..	..	..	..	..	..	..	..
nn	34	3C	00	85	8A		

FIGURE 12—OFFSET/PID/ADDRESS TABLE EXAMPLE

A Mode $21 request by offset would calculate the location of the offset information in the table, find the address and scaling for that value, and return the appropriate number of bytes of information starting at that address.

A Mode $22 request by PID would search through the table for the requested PID, find the address and scaling for that value, and return the appropriate number of bytes of information starting at that address.

A Mode $23 request by address would ignore this table and report data starting at the address specified in the request.

4.10.2 MODE $21 MESSAGE DATA BYTES—(See Figure 13.)

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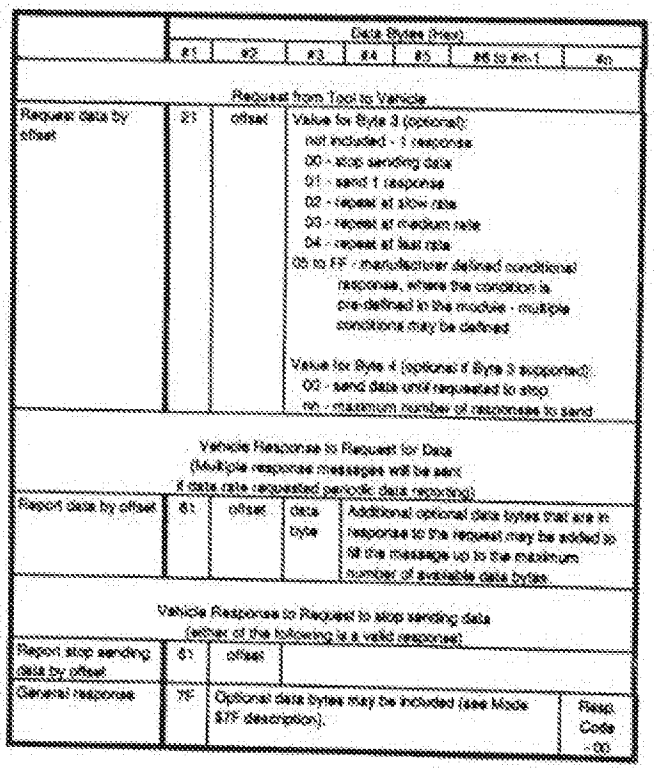

FIGURE 13—MESSAGE DATA BYTES FOR MODE $21

4.10.3 MODE $22 MESSAGE DATA BYTES—(See Figure 14.)

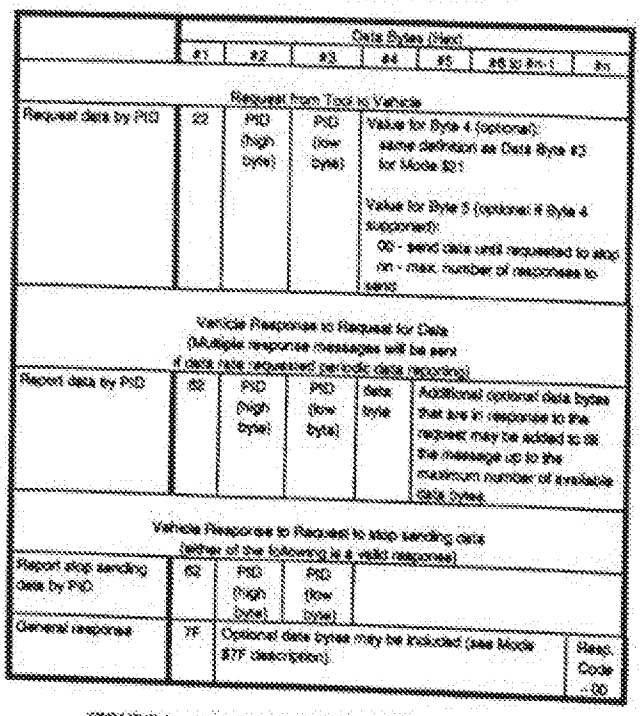

FIGURE 14—MESSAGE DATA BYTES FOR MODE $22

4.10.4 MODE $23 MESSAGE DATA BYTES—(See Figure 15.)

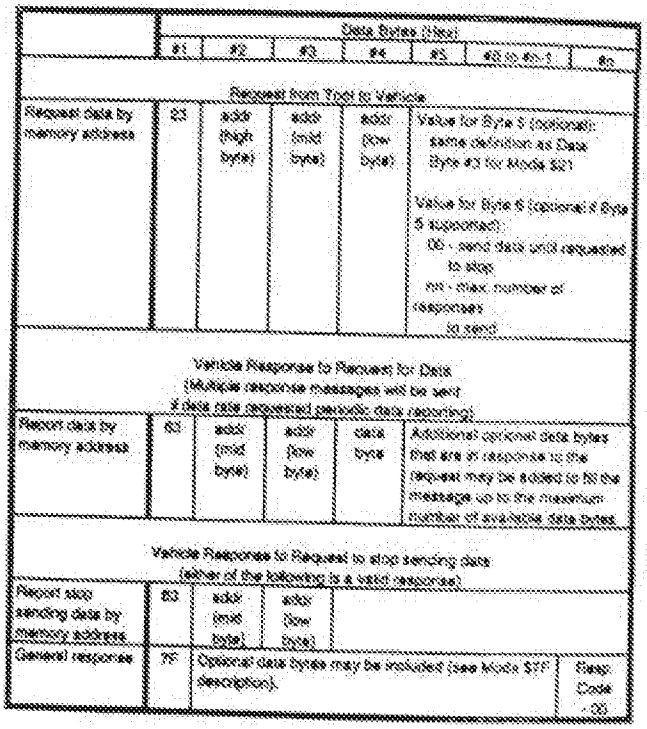

FIGURE 15—MESSAGE DATA BYTES FOR MODE $23

4.11 Mode $24—Request Scaling and Offset / PID

4.11.1 FUNCTIONAL DESCRIPTION—The purpose of Mode $24 is to request either scaling and PID information by specifying offset, or request scaling and offset information by specifying PID. $FF should be included in the request for the data byte value not being specified. If both offset and Parameter ID are specified, and the parameter ID is not correct for the offset specified, unexpected data values can be returned. Operation of this mode is similar to either Mode $21 or $22, depending on which value was specified in the request. The response would include offset, PID, and scaling for the requested entry. Any data byte values not supported by the module would report $FF.

Mode $24 can also be used to determine the PID table by incrementing the offset in repeated Mode $24 requests.

4.11.2 MESSAGE DATA BYTES—(See Figure 16.)

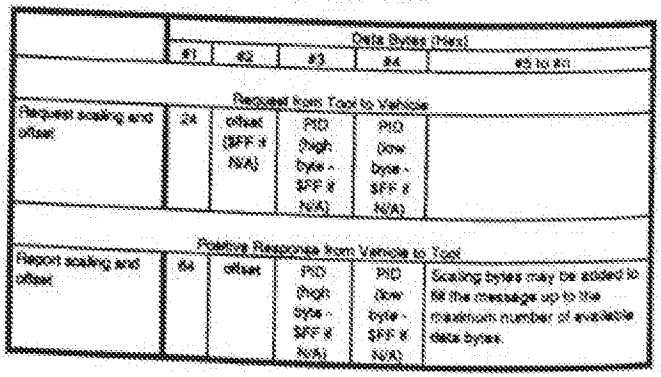

FIGURE 16—MESSAGE DATA BYTES FOR MODE $24

4.11.3 SCALING BYTE 1
High nibble (bits 7 to 4)

data type
0000 - Unsigned numeric (1 to 4 bytes)
0001 - Signed numeric (1 to 4 bytes)
0010 - Bit mapped, reported without mask
0011 - Bit mapped, reported with mask
0100 - BCD (1 to 4 bytes)
0101 - State encoded
0110 - ASCII
0111 - Signed floating point (ANSI/IEEE Std 754-1985)
1000 - Packet
1001 - Formula
1010 thru 1111 - Reserved

Low nibble (bits 3 to 0)
number of bytes of value
0000 - Reserved
0001 - 1 byte
0010 - 2 bytes
0011 - 3 bytes
0100 - 4 bytes
0101 thru 1111 - Reserved - may be greater than 4 for non-numeric data (ASCII or bit-mapped)

The high order nibble of the first byte defines the type of information encoding which is used to represent the parameter. The low order nibble can be read directly to determine the number of bytes used to represent the parameter.

4.11.3.1 Unsigned Numeric—This encoding uses a common binary weighing scheme to represent a value by means of discrete incremental steps. One byte affords 256 steps; two bytes yields 65 536 steps, etc. For example, vehicle speed may be encoded with a single unsigned numeric parameter ranging from 0 to 255 km/h. This unsigned numeric value may be up to 4 bytes in length.

4.11.3.2 Signed Numeric—This encoding uses a two's complement binary weighing scheme to represent a value by means of discrete incremental steps. One byte affords 256 steps; two bytes yields 65,536 steps, etc. A value can be encoded with a single unsigned numeric parameter ranging from -127 to 128. This signed numeric value may be up to 4 bytes in length.

4.11.3.3 Bit Mapped—Bit mapped encoding uses individual bits or small groups of bits to represent status. For every bit which represents status, a corresponding mask bit is required as part of the parameter definition. The mask indicates the validity of the bit for particular applications. A bit mapped parameter may contain 2 bytes; one representing status and one containing the validity mask, or 4 bytes; the first two representing status and the second two containing validity masks. Reference J2178, Part 2 for a discussion of bit mapped data values.

4.11.3.4 BCD—Conventional BCD encoding is used to represent two numeric digits per byte. The upper nibble is used to represent the most significant digit (0 - 9), and the lower nibble the least significant digit (0 - 9). Up to 8 characters (4 bytes) may comprise a single parameter.

4.11.3.5 State Encoded—This encoding uses a common binary weighting scheme to represent up to 256 distinct states. An example is a parameter which represents the status of the ignition switch. Codes "00," "01," "02," and "03" may indicate ignition off, locked, run, and start, respectively. The representation is always limited to 1 byte.

4.11.3.6 ASCII—Conventional ASCII encoding is used to represent up to 128 standard characters (MSB = logic 0). An additional 128 custom characters may be represented with MSB = logic 1. Up to four ASCII characters may comprise a single parameter.

4.11.3.7 Signed Floating Point—Floating point encoding is used for data that needs to be represented in floating point or scientific notation. Standard IEEE formats shall be used.

4.11.3.8 Packet—Packets contain multiple data values, usually related, each with unique scaling. Scaling information is not included for the individual values.

4.11.3.9 Formula—Different formulas are currently being discussed to be included. The formula type and constant values used in those formulas will be specified in scaling bytes, or reported as a different test mode.

4.11.4 SCALING BYTE 2—This byte is only relevant for signed and unsigned numbers and for bit mapped parameters. For other parameter types, this field is "padded" with $00. When used with signed and unsigned numbers, this byte specifies scaling by indicating the binary point location. The binary point may be moved 127 places to the right ($FF) or 128 places to the left ($00). The binary point is initially assumed to be to the right of the LSB without this information.

When this byte is used for bit mapped parameters that are reported without a mask, this byte indicates which bits of the PID are supported for the current application. When bit mapped data is reported with a mask, this byte is not used.

When the data type is "formula," this byte is used to indicate the formula type, where:

$00 - $7F are reserved for SAE to define
$80 - $FF are reserved for the manufacturer to define

4.11.5 SCALING BYTES 3 TO N—Optional bytes to be included if multiple bytes of bit mapped data are reported. This mode is more limiting in the number of masks that can be reported than the modes that allow retrieval of the data.

4.12 Mode $25—Stop Transmitting Requested Data

4.12.1 FUNCTIONAL DESCRIPTION—The purpose of Mode $25 is to stop all data transmission that was started by any test mode that can request repetitive data. If only an individual data request is to be stopped, then that value can be stopped by sending a request message for the mode that requested the data with a "0" for the data rate. In practice, if a message is already in an outgoing message queue ready to be sent, this would probably not remove that message from the queue, but it would prevent additional messages from being added to the queue. Response is either Mode $65 or general response.

4.12.2 MESSAGE DATA BYTES—(See Figure 17.)

	Data Bytes (Hex)		
	#1	#2 to #n-1	#n
Request from Tool to Vehicle			
Request all data stop	25		
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Confirm all data stopped	65		
General response	7F	Optional data bytes may be included (see Mode $7F description)	Resp. Code - 00

FIGURE 17—MESSAGE DATA BYTES FOR MODE $25

4.13 Mode $26—Specify Data Rates

4.13.1 FUNCTIONAL DESCRIPTION—The purpose of Mode $26 is to specify the setting of data rates for data to be transmitted by request messages that can request repetitive data. These modes include "Data Rate" as a data byte in the request message. Modules will normally have default rates associated with slow, mid, and fast. The slow rate should be about one or two samples per second, the mid rate should be normal handheld scan tool rates of about four to ten samples per second, and the fast rate 20 or more samples per second. Default rates are defined within each module and should be based on the frequency of change typical for the value reported, uses for that data, and the capability of the processor.

4.13.2 MESSAGE DATA BYTES—(See Figure 18.)

	Data Bytes (Hex)					
	#1	#2	#3	#4	#5 to #n-1	#n
Request from Tool to Vehicle						
Request data rate values	26	Slow Rate * - 40 msec per bit	Mid Rate * - 8 msec per bit	Fast Rate * - 1 msec per bit		
Positive Response from Vehicle to Tool (either of the following is a valid response)						
Confirm data rate values set	66					
General response	7F	Optional data bytes may be included (see Mode $7F description)				Resp. Code - 00

* NOTE: A value of $00 should cause the data to be reported as fast as possible. A value of $FF will cause no change in the current data rate.

FIGURE 18—MESSAGE DATA BYTES FOR MODE $26

4.14 Mode $27—Security Access Mode

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4.14.1 FUNCTIONAL DESCRIPTION—The primary purpose of this mode is to restrict unauthorized intrusion into the on-board controller. Improper programs could potentially damage the electronics or other vehicle components or risk the vehicle's compliance to emission or safety standards. This mode is intended to be used to implement the data link security measures defined in SAE J2186.

The external device will request the controller to "Unlock" itself by sending Request #1. The controller will respond by sending a "Seed" using Response #1. The external device will respond by returning a "Key" number back to the controller using Request #2. The controller would compare this "Key" to one internally stored. If the two numbers agree, then the controller will enable ("Unlock") the external device's access to specific test modes and indicate that with Mode $67, Response #2. If upon two attempts of a Request #2 where the two keys do not compare, then the controller will insert a 10 s time delay before allowing further attempts. This time delay will also be required before responding to a Mode $27 request #1 for each controller power-on.

If a device supports security, but is already unlocked when a Request #1 is received, that device should respond with a Response #1 message with a seed of $00 00. A test device could use this method to determine if a device is locked by checking for a non-zero seed.

The security system will not prevent normal diagnostic or vehicle communications between external devices and the on-board controller. Proper "Unlocking" of the controller is a prerequisite to the external device's ability to perform some of the more critical functions such as reading specific memory locations within the controller, downloading information to specific locations, or downloading routines for execution by the controller. In other words, the only access to the controller permitted while in a "locked" mode is through the product specific software. This permits the product specific software to protect itself from unauthorized intrusion.

Devices that provide security should support reject messages if a secure mode is requested while the device is locked. The reject message to be returned is a general response message Mode $7F, with a response code $33 to indicate the product is secured.

Some devices could support multiple levels of security, either for different functions controlled by the device, or to allow different capabilities to be exercised. These additional levels of security can be accessed by using requests #3 and #4, etc. The second data byte of the request for seed should always be an odd number, and the second data byte of the message to send the key should be the next even number.

4.14.2 MESSAGE DATA BYTES—(See Figure 19.)

	Data Bytes (Hex)					
	#1	#2	#3	#4	#5 to #n-1	#n
Request #1 from Tool to Vehicle (data byte #2 can be an odd number greater than $01 if additional levels of security are supported)						
Request for "Seed"	27	01 (03, etc.)				
Positive Response #1 from Vehicle to Tool						
Return "Seed"	67	01 (03, etc.)	Seed ($0 00 if module is not locked)		Optional data bytes may be specified by the vehicle manufacturer	
Request #2 from Tool to Vehicle (data byte #2 can be an even number one greater than data byte #2 of request #1 if additional levels of security are supported)						
Send "Key"	27	02 (04, etc.)	Key			
Positive Response #2 from Vehicle to Tool						
Security access	67	02 (04, etc.)	Optional data bytes may be specified by the vehicle manufacturer			
General response	7F	Optional data bytes may be included (see Mode $7F description)				Resp. Code - 00

FIGURE 19—MESSAGE DATA BYTES FOR MODE $27

4.15 Mode $28—Disable Normal Message Transmission

4.15.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to inhibit the on-board device from transmitting normal operating data on the link, while still performing other functions normally. The device will continue to operate in whatever diagnostic mode it was operating in prior to the Mode $28 command.

If an unsafe or undesirable vehicle operating condition would result from the lack of normal messages, then this mode could cause all nonessential messages to be inhibited. The optional manufacturers specific "level" data byte could be used to indicate which normal mode messages to disable. Defining which messages to disable is determined by the system designer to ensure safe vehicle operation. When using this test mode, some provision must be made to allow for other devices that rely on information from the silenced device so that they do not set diagnostic trouble codes due to the lack of required information.

One use for this test mode is to reduce message traffic on the data link. This would make more time available for diagnostic messages. Another use for this mode is to allow the test equipment to emulate the remote device for diagnostic purposes. In this scenario, the test device would send a Mode $28 request to the device to be emulated. The test device would then respond to all normal communication request messages directed to that device, most likely with data intended to cause a known response by a system that uses the information in the response. The test device can then observe the actions of those systems.

4.15.2 MESSAGE DATA BYTES—(See Figure 20.)

	Data Bytes (Hex)			
	#1	#2	#3 to #n-1	#n
Request from Tool to Vehicle				
Request disable normal message transmission	28	Level (opt.)		
Positive Response from Vehicle to Tool (either of the following is a valid response)				
Confirm normal message transmission disabled	68	Level (opt.)		
General response	7F	Optional data bytes may be included (see Mode $7F description)		Resp. Code - 00

FIGURE 20—MESSAGE DATA BYTES FOR MODE $28

4.16 Mode $29—Enable Normal Message Transmission

4.16.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to cause an on-board device to resume normal communications after previously disabling those messages by a Mode $28 command. The device will continue to operate in whatever diagnostic modes were set by previous messages, such as executing on-board routines.

4.16.2 MESSAGE DATA BYTES—(See Figure 21.)

	Data Bytes (Hex)		
	#1	#2 to #n-1	#n
Request from Tool to Vehicle			
Request enable normal message transmission	29		
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Confirm normal message transmission enabled	69		
General response	7F	Optional data bytes may be included (see Mode $7F description)	Resp. Code - 00

FIGURE 21—MESSAGE DATA BYTES FOR MODE $29

4.17 Mode $2A—Request Diagnostic Data Packet(s)

4.17.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to request diagnostic data packets that contain data values, such as analog inputs and outputs, digital inputs and outputs, freeze frame data, calculated values, bit mapped fault code data, and system status information. This Mode differs from Modes $21 through $23 in that multiple data packets can be requested, each containing multiple data values. These data packets can either be predefined in the on-board control module or dynamically defined using Mode $2B or $2C.

The on-board module will respond to this message by transmitting multiple response messages specific to that device. The data packet ID Bytes in the request allow multiple Mode $2A data packets to be requested. Data packets should be defined which include data that is commonly used together, or changes together.

Uses for these different data packets include data such as wheel speeds for an ABS system. Data can be returned quickly with a minimal length request and response. Another use for these different data packets is to return values that do not change, such as VIN and option content. These values need to be known one time only during testing. Other data bytes may contain present values of analog and discrete device I/O, device software flags and status words, and failure codes.

4.17.2 MESSAGE DATA BYTES—(See Figure 22.)

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Request diagnostic data packets	2A	Data rate *	DPID #	Additional optional data packet IDs may be requested to fill the message up to the maximum number of available data bytes.	
Positive Response from Vehicle to Tool (Multiple response messages will be sent if multiple DPIDs requested, or if data rate requested periodic data reporting)					
Report of diagnostic data packet - repeated for each requested data packet	6A	DPID #	Data Byte	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.	
Vehicle Response to Request to stop sending data (either multiple $6A messages or a single $7F message is a valid response)					
Report stop sending diagnostic data packets	6A	DPID# of DPID req.	(any additional DPID #s in this message could appear to be data)		
Repeat report stop sending diagnostic data packets for each DPID # requested	6A	DPID # of DPID req			
General response	7F	Optional data bytes may be included (see Mode $7F description)			Resp. code - 00

* same data rate definition as Data Byte #3 for Mode $21

FIGURE 22—MESSAGE DATA BYTES FOR MODE $2A

4.18 Mode $2B—Dynamically Define Data Packet by Single Byte Offsets

4.18.1 FUNCTIONAL DESCRIPTION—This test mode can be used to dynamically define data packets that can subsequently be requested using a Mode $2A request. This mode is a special case alternative to using multiple Mode $2C messages, because a single request message can be used to completely define the contents of a data packet. All other methods to specify the data values to be included in data packets using Mode $2C would also require multiple messages, therefore, special modes to build data packets by PID or memory address are not included.

If the parameter for any offset value is longer than 1 byte, then offset data bytes in the request should be filled with $FF for each additional byte in the data value requested (see message example). This forces the data value byte locations in the response message to mirror the offset value byte locations in the request message.

4.18.2 MESSAGE DATA BYTES—(See Figure 23.)

4.18.3 MESSAGE EXAMPLE—Figure 24 is an example of messages required to define a data packet by offset and then request that data packet. The data packet can be defined with a single message and requested with another message.

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Define diagnostic data packet	2B	DPID #	Offset	Additional optional data offset values may be added to fill the message up to the maximum number of available data bytes.	
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Confirm diagnostic data packet defined	6B	DPID #			
General response	7F	Optional data bytes may be included (see Mode $7F description)			Resp. Code - 00

FIGURE 23—MESSAGE DATA BYTES FOR MODE $2B

	Data Bytes (Hex)							
	#1	#2	#3	#4	#5	#6	#7	#8
Define Diagnostic Data Packet #22 consisting of: Value at offset $30 (1 byte value) Value at offset $12 (2 byte value) Value at offset $26 (2 byte value) Value at offset $05 (1 byte value)								
Define diagnostic data packet #22	2B	22	30	12	FF	26	FF	05
Positive Response from Vehicle to Tool (either of the following is a valid response)								
Confirm data packet defined #22	6B	22						
General response	7F	2B	22	Resp. Code - 00				
Request from Tool to Vehicle								
Request data packet #22	2A	Data rate	22					
Positive Response from Vehicle to Tool								
Report data packet #22	6A	22	1 byte value from offset $30	2 byte value from offset $12	2 byte value from offset $26	1 byte value from offset $05		

FIGURE 24—DATA PACKET EXAMPLE

4.19 Mode $2C—Dynamically Define Diagnostic Data Packet

4.19.1 FUNCTIONAL DESCRIPTION—This test mode can be used to dynamically define data packets that can subsequently be requested using a Mode $2A request. This single test mode is an alternative to multiple modes to define data packets by offset, PID, and memory address.

This mode allows data packets to be defined in different ways, and also allows a single data packet to include data specified in different ways. Multiple messages must be sent to define a single data packet. Each message constructs a portion of the data packet, and includes an indication of how the data is being requested, the starting byte of the data packet, and the number of bytes to be specified for the data packet.

Data packets can be shortened by sending a data packet definition with the starting byte indicating the first data byte not to be included, and 0 as the length. This should be interpreted as 0 bytes at the starting location, which means that data byte is not in the response message.

Data packet definitions can be cleared by sending a message with 1 as the starting data byte and 0 as the number of bytes. Requesting this data packet would result in a response which would include the mode value, data packet ID, and no data.

Data packet definitions can be removed by sending a message with 0 as the starting data byte and 0 as the number of bytes. This would free memory space, if needed.

An optional feature of this mode is to request the present definition for the data packet. This is accomplished by sending a Mode $2B with the data packet ID as the only additional data byte. The result is multiple $6B responses, each including data bytes that resemble the $2B messages that created the data packet.

4.19.2 MESSAGE DATA BYTES—(See Figure 25.)

	Data Bytes (hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Define diagnostic data packet	2C	DPID #	Data byte #3 bits 7,6 8 00 - define by offset (1 byte) 8 01 - define by PID (2 bytes) 8 10 - define by memory address (3 bytes) 8 11 - manufacturer defined bits 5-4,3 starting byte for data, where 001 is the first byte after the DPID # bits 2,1,0 number of data bytes for this parameter Data bytes starting at byte #4 contain either the offset, PID, memory address, or manufacturer defined value for the data to be included in the packet.		
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Confirm diagnostic data packet defined	6C	DPID #	Request data byte #3		
General response	7F	Optional data bytes may be included (see Mode $7F description)			Resp. Code - 2C

FIGURE 25—MESSAGE DATA BYTES FOR MODE $2C

4.19.3 MESSAGE EXAMPLE—Figure 26 shows the messages required to define a data packet and then request that data packet. Data packet #26 is to be defined as:

Value for PID $01 04 (1 byte data value)
Value at offset $32 (2 byte data value)
2 bytes of data at memory address $24 81 70

This definition requires three sets of request / report messages, and the data packet request requires one set of messages.

4.20 Mode $2F—Input/Output Control by PID

4.20.1 FUNCTIONAL DESCRIPTION—This capability allows the tester to verify proper operation of external input and output components and circuitry by isolation techniques. Real world sensor inputs can be temporarily bypassed, and direct control of output devices can be achieved. Since substitution may cause the control module to operate in a manner which is unsuitable or unsafe for "on-the-road" operation, precautions must be taken to ensure safe operation. The substituted value is used only for the duration of the diagnostic procedure, and when the module is returned to normal operation, or control of the data value is returned to the vehicle, then the substituted value reverts back to the normal value determined by the control system.

Parameter IDs (PIDs) are assigned by the manufacturer for those input, output, and intermediate (calculated) values that are allowed to be substituted. The PID assignments can be the same PID values that are used with a Mode $22 request for data by PID.

4.20.2 MESSAGE DATA BYTES—(See Figure 27.)

	Data Bytes (hex)						
	#1	#2	#3	#4	#5	#6	#7
Request from Tool to Vehicle							
PID $01 04 is 1 byte value to be included at data byte 3 (1 byte after DPID #)	2C	88	49 ..... 01 001 001 1 1	01	04		
Positive Response from Vehicle to Tool (either of the following is a valid response)							
PID $01 04 at data byte 3	6C	28	49				
General response	7F	2C	28	49	Resp. Code - 00		
Request from Tool to Vehicle							
Offset $32 is 2 byte value to be included at data byte 4 (2 bytes after DPID #)	2C	88	12 ..... 00 010 010 2 2	32			
Positive Response from Vehicle to Tool (either of the following is a valid response)							
Offset $32 starting at data byte 4	6C	28	12				
General response	7F	2C	28	12	Resp. Code - 00		
Request from Tool to Vehicle							
2 bytes starting at address $24 81 70 to be included at data bytes 6 and 7	2C	88	A2 ..... 10 100 010 4 2	24	81	70	
Positive Response from Vehicle to Tool (either of the following is a valid response)							
Addresses $24 81 70 and $24 81 71 at data bytes 6 and 7	6C	28	A2				
General response	7F	2C	28	A2	Resp. Code - 00		
After the data packet is defined, the tool can request the data packet from the vehicle							
Request data packet #26	2A	28					
Positive Response from Vehicle to Tool							
Report data packet #26	6A	28	1 byte value for PID $01 04	2 byte value from offset $32	2 bytes at memory address $24 81 70		

FIGURE 26—DATA PACKET DEFINITION EXAMPLE

4.21 Mode $30—Input/Output Control by Data Value ID

4.21.1 FUNCTIONAL DESCRIPTION—This mode is identical in purpose and function to Mode $2F, except that the parameter to be controlled is specified by a 1 byte Data Value ID instead of a 2 byte PID.

Data value IDs are assigned by the manufacturer for those input, output, and intermediate (calculated) values that are allowed to be substituted.

4.21.2 MESSAGE DATA BYTES—(See Figure 28.)

	Data Bytes (Hex)					
	#1	#2	#3	#4	#5 to #n-1	#n
Request from Tool to Vehicle						
Request Input/Output control by PID	2F	PID (High byte)	PID (low byte)	Data Byte #4 (optional) If not specified - control of identified data value is disabled If specified - value is substituted for identified data value in the module Data Bytes after #4 may be used if needed to specify substitute value		
Positive Response from Vehicle to Tool (either of the following is a valid response)						
Confirm Input/Output control by PID	6F	PID (High byte)	PID (low byte)	Resp. data byte # (opt)		
General response	7F	Optional data bytes may be included (see Mode $7F description).				Resp. Code - 00

FIGURE 27—MESSAGE DATA BYTES FOR MODE $2F

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Request Input/Output control by data value ID	30	Data value ID	Data Byte #3 (optional) If not specified - control of identified data value is disabled If specified - value is substituted for identified data value in the module Data Bytes after #3 may be used if needed to specify substitute value		
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Confirm Input/Output control by data value ID	70	Data value ID	Resp. data byte 3 (opt)		
General response	7F	Optional data bytes may be included (see Mode $7F description).			Resp. Code - 00

FIGURE 28—MESSAGE DATA BYTES FOR MODE $30

4.22 Modes $31 to $33—Perform Diagnostic Routine by Test Number

4.22.1 FUNCTIONAL DESCRIPTION—The purpose of these modes is to execute diagnostic tests and obtain test results. The diagnostic routines are manufacturer defined and executed in the control module by referencing the test number. Each module may support up to 255 distinct diagnostic routines. Definition of the routines is defined by the module manufacturer.

Reported results may consist of any set of return information, such as measured test values or fault codes.

Three sets of messages are used to perform tests resident in an on-board control module. These messages perform three functions:

Mode $31 - Enter/start Diagnostic Routine by Test Number
Mode $32 - Exit/stop Diagnostic Routine by Test Number
Mode $33 - Request Diagnostic Routine Results by Test Number

The tests are known by the module and identified by a test number. They are usually permanently stored in the module, but may have been downloaded by Modes $34 and $36.

These test numbers could either be tests that run instead of normal operating code, or could be routines that are enabled in this mode and execute with the normal operating code. In the first case, normal system operation for the controller being tested is not possible. In the second case, multiple diagnostic routines can be enabled that run while all other parts of the system are functioning normally.

Any combination of the messages can be used, depending on the implementation in the module. Some examples are:

Tester sends a Mode $31 message to start a test. The module reports that the test has started with a Mode $71 and runs the test until a Mode $32 is sent to stop the test. The module exits the test and informs the tester with a Mode $72 that the test has stopped. The tester then requests test results with a Mode $33, and the module reports the results with a Mode $73 message.

Tester sends a Mode $31 message to start a test. The Module confirms the test has started, exits when the test is done and reports results using Mode $73.

Tester sends a Mode $31 message to start a test. The Module starts the test and periodically reports results using Mode $73 until a Mode $32 is sent to stop the test.

The on-board controller starts a test automatically, stops the test automatically and reports results using a Mode $73 message automatically. This requires no request messages from the tester.

These examples demonstrate both maximum and minimum use of the available message. Test equipment needs to know what tests are available, which messages are required, and how to interpret the results.

The general purpose response, Mode $7F, may also be used instead of a Mode $71 or Mode $72 message to acknowledge entry or exit from a diagnostic routine.

4.22.2 MESSAGE DATA BYTES—(See Figure 29.)

	Data Bytes (Hex)				
	#1	#2	#3	#4 to #n-1	#n
Request from Tool to Vehicle					
Request entry by test number	31	Test #	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.		
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Report entry by test number	71	Test #	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.		
General response	7F	Optional data bytes may be included (see Mode $7F description).			Resp. code - 00
Request from Tool to Vehicle					
Request exit by test number	32	Test #	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.		
Positive Response from Vehicle to Tool (either of the following is a valid response)					
Report exit by test number	72	Test #	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.		
General response	7F	Optional data bytes may be included (see Mode $7F description).			Resp. code - 00
Request from Tool to Vehicle					
Request results by test number	33	Test #	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.		
Positive Response from Vehicle to Tool					
Report results by test number	73	Test #	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.		

Note: Mode $30 reports the results of a test that was run on request from a tool. This differs from Mode $06, which reports the results of the latest on-board monitoring test that was run to meet OBD regulations.

FIGURE 29—MESSAGE DATA BYTES FOR MODES $31 THROUGH $33

4.23 Modes $34 to $37—Data Transfer

4.23.1 FUNCTIONAL DESCRIPTION—These modes allow the transfer of data either from a tester to an on-board module or from an on-board module to a tester. Modes defined are:

Mode $34 - Request Download - tool to module
Mode $35 - Request Upload - module to tool

Mode $36 - Data Transfer
Mode $37 - Request Data Transfer Exit

Download is defined as data transfer from the tool to the controller in the vehicle. Upload is defined as data transfer from the controller in the vehicle to the tool.

4.23.2 MESSAGE DATA BYTES—(See Figure 30.)

	Data Bytes (Hex)		
	#1	#2 to #n-1	#n
Request from Tool to Vehicle			
Request download	34	Messages used to request download are defined by the vehicle/module manufacturer. This Mode value is reserved for a download request message.	
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Report download status	74	Messages used to request download are defined by the vehicle/module manufacturer. This Mode value is reserved for the response to a Mode $34.	
General response	7F	Optional data bytes may be included (see Mode $7F description).	Resp. code - 00
Request from Tool to Vehicle			
Request upload	35	Messages used to request upload are defined by the vehicle/module manufacturer. This Mode value is reserved for an upload request message.	
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Report upload status	75	Messages used to request download are defined by the vehicle/module manufacturer. This Mode value is reserved for the response to a Mode $35.	
General response	7F	Optional data bytes may be included (see Mode $7F description).	Resp. code - 00
Transfer Data			
Data transfer	36	Messages used to perform the data transfer are defined by the vehicle/module manufacturer. This Mode value is reserved for the data transfer request message.	
Data transfer	76	Messages used to perform the data transfer are defined by the vehicle/module manufacturer. This Mode value is reserved for the response to a Mode $36.	
Request from Tool to Vehicle			
Request exit	37	Messages used to exit data transfer are defined by the vehicle/module manufacturer. This Mode value is reserved for the exit data transfer request message.	
Positive Response from Vehicle to Tool (either of the following is a valid response)			
Report exit	77	Messages used to exit data transfer are defined by the vehicle/module manufacturer. This Mode value is reserved for the response to a Mode $37.	
General response	7F	Optional data bytes may be included (see Mode $7F description).	Resp. code - 00

FIGURE 30—MESSAGE DATA BYTES FOR MODES $34 THROUGH $37

4.24 Modes $38 to $3A—Perform Diagnostic Routine at a Specified Address

4.24.1 FUNCTIONAL DESCRIPTION—These test modes are used to execute code resident in the on-board controller at the specified address. This executable code may be permanently stored in the controller or may have been downloaded using Modes $34 and $36.

These three sets of messages are used to perform tests resident in an on-board control module. These messages perform three functions:

Mode $38 - Enter Diagnostic Routine by Address
Mode $39 - Exit Diagnostic Routine by Address
Mode $3A - Request Diagnostic Routine Results

4.24.2 MESSAGE DATA BYTES—(See Figure 31.)

	Data Bytes (Hex)						
	#1	#2	#3	#4	#5	#6 to #n-1	#n
Request from Tool to Vehicle							
Request test entry by starting address	38	Starting Address: High byte	Starting Address: mid byte	Starting Address: low byte	(opt)	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.	
Positive Response from Vehicle to Tool (either of the following is a valid response)							
Report entry	78	Starting Address: High byte	Starting Address: mid byte	Starting Address: low byte	(opt)		
General response	7F	Optional data bytes may be included (see Mode $7F description).					Resp. Code - 00
Request from Tool to Vehicle							
Request test exit by starting address	39	Starting Address: High byte	Starting Address: mid byte	Starting Address: low byte	(opt)	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.	
Positive Response from Vehicle to Tool (either of the following is a valid response)							
Report exit by starting address	79	Starting Address: High byte	Starting Address: mid byte	Starting Address: low byte	Exit Status (opt)	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.	
General response	7F	Optional data bytes may be included (see Mode $7F description).					Resp. code - 00
Request/Report Diagnostic Routine Results							
Request results	3A	(opt.)	Additional optional data bytes may be added to the request to fill the message up to the maximum number of available data bytes.				
Positive Response from Vehicle to Tool							
Report results	7A	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.					

FIGURE 31—MESSAGE DATA BYTES FOR MODES $38 THROUGH $3A

4.25 Mode $3B—Write Data Block

4.25.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to provide a means for the external test device to change the contents of a data block. The data block numbers and associated memory locations need to be known by the on-board device. This mode does not allow off-board test equipment to change any memory locations other than for those data blocks predefined in the on-board device.

The number of data bytes included in the request message for each block number depends on the system design and intent of the usage for that block.

Possible uses for this mode are:

Clear non-volatile memory
Reset learned values in a single table
Set option content
Set Vehicle Identification Number (VIN)
Change calibration values

This mode can be used to clear or reset tables stored in non-volatile memory. A data block number could be defined as memory locations that need to be either cleared or reset to predefined initial values, such as learned values in a table. Sending the data block number with no data bytes could cause the on-board system to clear/reset all learned values associated with that data block number to known nominal values.

Another use is to allow the VIN to be input. A data block number could be defined to accept a portion of the VIN. Multiple messages would be required to send the entire 17-character VIN. Whatever data values were included in the request message would be stored in the memory locations known by the on-board system for VIN.

In some systems, this mode could be used for programming calibrations or vehicle specific information in the assembly plant or service without using secured methods for reprogramming. If desired that those values not be changed after production, the capability to modify those data blocks could be disabled after the initial change.

4.25.2 MESSAGE DATA BYTES—(See Figure 32.)

	Data Bytes (Hex)			
	#1	#2	#3 to #n-1	#n
Request from Tool to Vehicle				
Request to write data block	3B	Block number	Additional optional data value bytes to be written to memory may be added to fill the message up to the maximum number of available data bytes.	
Positive Response from Vehicle to Tool (either of the following is a valid response)				
Confirm data block written	7B	Block number		
General response	7F	Optional data bytes may be included (see Mode $7F description).		Resp. code - 00

FIGURE 32—MESSAGE DATA BYTES FOR MODE $3B

4.26 Mode $3C—Read Data Block

4.26.1 FUNCTIONAL DESCRIPTION—The purpose of this mode is to provide a means for the external test device to read the contents of a data block. The data block numbers and associated memory locations need to be known by the on-board device. This mode does not allow off-board test equipment to read any memory locations other than for those data blocks predefined in the on-board device.

The number of data bytes included in the Response for each block number depends on the system design and intent of the usage for that block.

Possible uses for this mode are to read:

Learned values in a single table
Option content
Vehicle Identification Number (VIN)
Calibration values

4.26.2 MESSAGE DATA BYTES—(See Figure 33.)

	Data Bytes (Hex)		
	#1	#2	#3 to #n
Request from Tool to Vehicle			
Request to read data block	3C	Block number	
Positive Response from Vehicle to Tool			
Report contents of data block	7C	Block number	Additional optional data bytes that are in response to the request may be added to fill the message up to the maximum number of available data bytes.

FIGURE 33—MESSAGE DATA BYTES FOR MODE $3C

4.27 Mode $3F—Test Device Present (no operation performed)

4.27.1 FUNCTIONAL DESCRIPTION—This mode can be used to indicate a tool or test device is present. This message may be required, in the absence of other diagnostic messages, to prevent modules from automatically returning to normal operation. The presence of this message will indicate that the system should remain in a diagnostic mode of operation.

This message will normally be sent to all modules in the vehicle. Because this message is not a specific request for a controller to do something, there is no required response message to the test tool present message. However, if the message strategy includes a response to this, a general response message should be used. If the vehicle contains multiple modules, then multiple responses will be sent, using available data link time.

4.27.2 MESSAGE DATA BYTES—(See Figure 34.)

	Data Bytes (Hex)		
	#1	#2 to #n-1	#n
Request from Tool to Vehicle			
Test tool present	3F		
Positive Response from Vehicle to Tool (optional)			
General response	7F	Optional data bytes may be included (see Mode $7F description).	Resp. Code - 00

FIGURE 34—MESSAGE DATA BYTES FOR MODE $3F

4.28 Mode $7F—General Response Message

4.28.1 FUNCTIONAL DESCRIPTION—Physical requests for information must be responded to by the intended receiver of the request. This message is intended to be a generic response to any request message when data does not need to be returned to the test device. This is an alternative to a specific response when the request is for an action to be performed by the controller. This is also a reject message (negative response) for requests for data or for an action to be performed. See the "Message Response" section for a more detailed discussion about the use of this message.

The response may be an acknowledge that the message was received, or may include a code indicating the reason for rejection if a valid response is not possible. This response assumes that a valid message has been received, and is not intended to inform the sender of an invalid message or to report system failures. Valid response codes are included in this section. Response codes from $00 to $7F are reserved to be defined in this document, and codes from $80 to $FF are reserved to be defined by the vehicle manufacturer.

The format for the general response message is a $7F for the first data byte after the header, optional data bytes that repeat data bytes of the request, and the response code. If a fixed message length is required and there are not enough data bytes in the request, the message should be padded with $00 to fill the remaining data bytes.

4.28.2 MESSAGE DATA BYTES—(See Figure 35.)

	Data Bytes (Hex)				
	#1	#2 to #n-1 (optional)			#n
Response from Vehicle to Tool					
General response	7F	Optional data bytes that repeat data bytes in the request message, in order to uniquely identify the request message, or in order to maintain a minimum message length, may be inserted between the Mode Value and the Response Code. The last data byte of the message is always the response code.			Resp. Code
	Request Mode value (3xH)	Data byte #2 of request (xxH)	Data byte #3 of request (xxH)	etc.	

FIGURE 35—MESSAGE DATA BYTES FOR MODE $7F

4.28.3 MESSAGE EXAMPLES—Figure 36 shows an example of a Mode $3B request containing 8 data bytes. Four valid general response messages are shown, with others possible to be defined by the vehicle manufacturer. Note that the response code is always the last data byte of the response message.

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	Data Bytes (Hex)							
	#1	#2	#3	#4	#5	#6	#7	#8
Example Request from Tool to Vehicle								
Request to write block of memory	3B	Block number	Data value #1	Data value #2	Data value #3	Data value #4	Data value #5	Data value #6
Example Responses from Vehicle to Tool (any of the following is a valid response)								
Simplest form of general response	7F	Resp. Code						
Include test mode value to identify test mode requested	7F	3B	Resp. Code					
Include test mode value and block number requested	7F	3B	Block number	Resp. Code				
Include as much of request message as will fit in response	7F	3B	Block number	Data value #1	Data value #2	Data value #3	Data value #4	Resp. Code

FIGURE 36—GENERAL RESPONSE EXAMPLES

4.28.4 RESPONSE CODES—Figure 37 includes response codes and descriptions to be used with the general response messages.

Resp Code	Response Code Description
00	AFFIRMATIVE RESPONSE This response code is used to indicate affirmative response to a request message. It indicates that the requested action will be taken or is already complete.
10	GENERAL REJECT This response code is used to indicate a negative response to a request message. No reason or explanation for the rejection is given.
11	MODE NOT SUPPORTED This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the ECU does not support the requested mode.
12	SUB-FUNCTION NOT SUPPORTED or INVALID FORMAT This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the ECU does not support the arguments of the requested mode or the format of the argument bytes do not match the prescribed format for the specified mode.
21	BUSY – REPEAT REQUEST This response code indicates that the ECU is temporarily too busy to perform the requested operation. In this circumstance repetition of the request will eventually result in an affirmative response. This code may be returned while an ECU is in the process of clearing stored codes or fetching information. Whenever completion of the requested operation will exceed the maximum response time limit, it is appropriate to use the BUSY – REPEAT REQUEST message to lengthen the acceptable response period.
22	CONDITIONS NOT CORRECT or REQUEST SEQUENCE ERROR This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the ECU prerequisite conditions are not met. This request may affect an affirmative response at another time. This code may occur when sequence sensitive requests are issued in the wrong order.
23	ROUTINE NOT COMPLETE This response code is used to indicate that the message was properly received and the routine is in process, but not yet completed.
31	REQUEST OUT OF RANGE This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the ECU detects the request message contains a data byte which attempts to substitute a value beyond its range of authority (ex: attempting to substitute a data byte of 111 when the data is only defined to 100).

Continued

FIGURE 37—GENERAL RESPONSE CODES

33	SECURITY ACCESS DENIED This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the ECU's security strategy has not been satisfied by the tester.
34	SECURITY ACCESS ALLOWED This response code is used to indicate positive response to a request message. It indicates that the ECU's security strategy has been satisfied by the tester.
35	INVALID KEY This response code is used to indicate negative response to a request message. It indicates that security access has not been given because the ECU's security key was not matched by the tester (this counts as an attempt to gain security access).
36	EXCEED NUMBER OF ATTEMPTS This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the Tester has unsuccessfully attempted to gain security access more times than the ECU's security strategy will allow.
37	REQUIRED TIME DELAY NOT EXPIRED This response code is used to indicate negative response to a request message. It indicates that the requested action will not be taken because the tester's latest attempt to gain security access was initiated before the ECU's required timeout period had elapsed.
40	DOWNLOAD NOT ACCEPTED This response code indicates that an attempt to download to an ECU's memory cannot be accomplished due to some fault condition.
41	IMPROPER DOWNLOAD TYPE This response code indicates that an attempt to download to an ECU's memory cannot be accomplished because the module does not support the type of download being attempted.
42	CAN'T DOWNLOAD TO SPECIFIED ADDRESS This response code indicates that an attempt to download to an ECU's memory cannot be accomplished because the module does not recognize the target address for the download as being available.
43	CAN'T DOWNLOAD NUMBER OF BYTES REQUESTED This response code indicates that an attempt to download to an ECU's memory cannot be accomplished because the module does not recognize the number of bytes requested for the download as being available.
44	READY FOR DOWNLOAD This response code indicates that a download to an ECU's memory can be accomplished.
50	UPLOAD NOT ACCEPTED This response code indicates that an attempt to upload from an ECU's memory cannot be accomplished due to some fault condition.
51	IMPROPER UPLOAD TYPE This response code indicates that an attempt to upload from an ECU's memory cannot be accomplished because the module does not support the type of upload being attempted.
52	CAN'T UPLOAD FROM SPECIFIED ADDRESS This response code indicates that an attempt to upload from an ECU's memory cannot be accomplished because the module does not recognize the target address for the upload as being available.
53	CAN'T UPLOAD NUMBER OF BYTES REQUESTED This response code indicates that an attempt to upload from an ECU's memory cannot be accomplished because the module does not recognize the number of bytes requested for the upload as being available.
54	READY FOR UPLOAD This response code indicates that an upload from an ECU's memory can be accomplished.
61	NORMAL EXIT WITH RESULTS AVAILABLE This response code is used to indicate response to a request message. It indicates that the requested test action will be taken, or is already complete, and that additional information is available in the form of data, stored codes, or PIDs.

Continued

FIGURE 37—GENERAL RESPONSE CODES (CONTINUED)

82	NORMAL EXIT WITHOUT RESULTS AVAILABLE This response code is used to indicate response to a request message. It indicates that the requested exit action will be taken, or is already complete, but no additional information is available in the form of data, stored codes, or PIDs.
83	ABNORMAL EXIT WITH RESULTS This response code is used to indicate response to an exit request message. It indicates that the requested exit action will be taken, or is already complete. It is also indicated that the requested execution did not occur in the expected manner and that additional information is available in the form of data, stored codes, or PIDs.
84	ABNORMAL EXIT WITHOUT RESULTS This response code is used to indicate response to a exit request message. It indicates that the requested exit action will be taken, or is already complete. It is also indicates that the requested execution did not occur in the expected manner, but additional information is not available.
91	TRANSFER SUSPENDED This response code indicates that a block transfer operation was halted due to some fault, but will be completed later.
92	TRANSFER ABORTED This response code indicates that a block transfer operation was halted due to some fault, and will not be completed later.
93	BLOCK TRANSFER COMPLETE / NEXT BLOCK This response code indicates that a block transfer operation has been completed successfully.

Continued

FIGURE 37—GENERAL RESPONSE CODES (CONTINUED)

74	ILLEGAL ADDRESS IN BLOCK TRANSFER This response code indicates that the starting address included in the block transfer request message is either out of range, protected, the wrong type of memory for receiving data, or cannot be written to for some reason.
75	ILLEGAL BYTE COUNT IN BLOCK TRANSFER This response code indicates that the number of data bytes included in the block transfer request message is either more than the block transfer can accommodate, requires more memory than is available at the requested starting address, or cannot be handled by the block transfer software.
76	ILLEGAL BLOCK TRANSFER TYPE This response code is used to indicate that the block transfer type included in the request for block transfer is not valid for this application.
77	BLOCK TRANSFER DATA CHECKSUM ERROR This response code is used to indicate that the block transfer data checksum calculated for the block transfer message does not agree with the expected value.
78	BLOCK TRANSFER MESSAGE CORRECTLY RECEIVED This response code is used to indicate that the block transfer message was received correctly, and that any parameters included in the message were valid, but the action to be performed may not be completed yet. This response code can be used to indicate that the message was properly received and does not need to be retransmitted, but the receiving device is not yet ready to receive another block transfer.
79	INCORRECT BYTE COUNT DURING BLOCK TRANSFER This response code indicates that the number of bytes that was expected to be sent was not the same as the number of bytes received.
80 to FF	MANUFACTURER SPECIFIC CODES These response codes are reserved to be specified by the vehicle manufacturer.

FIGURE 37—GENERAL RESPONSE CODES (CONTINUED)

APPENDIX A
DIAGNOSTIC TEST MODE ASSIGNMENTS

A.1 See Table A1.

TABLE A1—DIAGNOSTIC TEST MODE ASSIGNMENTS

Mode	Message Name
00	
01	Request Current Powertrain Diagnostic Data
02	Request Powertrain Freeze Frame Data
03	Request Powertrain Diagnostic Trouble Codes
04	Request to Clear/Reset Diagnostic Trouble Codes
05	Request Oxygen Sensor Monitoring Test Results
06	Request On-Board Monitoring Test Results
07	Request Pending Powertrain Trouble Codes
08	
09	
0A	
0B	
0C	
0D	
0E	
0F	
10	Initiate Diagnostic Operation
11	Request Module Reset
12	Request Diagnostic Freeze Frame Data
13	Request Diagnostic Trouble Code Information
14	Clear Diagnostic Information
15	
16	
17	Request Status of Diagnostic Trouble Codes
18	Request Diagnostic Trouble Codes by Status
19	
1A	
1B	
1C	
1D	
1E	
1F	
20	Return to Normal Operation
21	Request Diagnostic Data by Offset
22	Request Diagnostic Data by PID
23	Request Diagnostic Data by Memory Address
24	Request Scaling and Offset/PID
25	Request to Stop Transmitting Data
26	Specify Setting of Data Rates
27	Data Link Security Access
28	Disable Normal Message Transmission
29	Enable Normal Message Transmission
2A	Request Diagnostic Data Packet(s)
2B	Define Diagnostic Data Packet by Offset
2C	Define Diagnostic Data Packet
2D	
2E	
2F	Input/Output Control by PID
30	Input/Output Control by Data Value ID
31	Request Start Diagnostic Routine by Test No.
32	Request Stop Diagnostic Routine by Test No.
33	Request Diagnostic Routine Results by Test No.
34	Request Download
35	Request Upload
36	Transfer Data

Mode	Message Name
37	Request Stop Data Transfer
38	Request Start Diagnostic Routine by Address
39	Request Stop Diagnostic Routine by Address
3A	Request Diagnostic Routine Results by Address
3B	Write Data Block
3C	Read Data Block
3D	
3E	
3F	Test Device Present - No Operation Performed
40	
41	Report Current Powertrain Diagnostic Data
42	Report Powertrain Freeze Frame Data
43	Report Powertrain Diagnostic Trouble Codes
44	Report Diagnostic Trouble Codes Cleared
45	Report Oxygen Sensor Test Results
46	Report On-Board Monitoring Test Results
47	Report Pending Powertrain Trouble Codes
48	
49	
4A	
4B	
4C	
4D	
4E	
4F	
50	Confirm Diagnostic Operation
51	Confirm Module Reset
52	Report Diagnostic Freeze Frame Data
53	Report Diagnostic Trouble Code Information
54	Confirm Diagnostic Information Cleared
55	
56	
57	Report Status of Diagnostic Trouble Codes
58	Report Diagnostic Trouble Codes by Status
59	
5A	
5B	
5C	
5D	
5E	
5F	
60	Confirm Normal Operation
61	Report Diagnostic Data by Offset
62	Report Diagnostic Data by PID
63	Report Diagnostic Data by Memory Address
64	Report Parameter Offset and Scaling/Mask
65	Confirm Data Stopped
66	Confirm Data Rates Set
67	Confirm Security Access
68	Confirm Normal Message Transmission Disabled
69	Confirm Normal Message Transmission Enabled
6A	Report Diagnostic Data Packet(s)
6B	Confirm Data Packet Defined by Offset
6C	Confirm Data Packet Defined
6D	
6E	
6F	Confirm Input/Output Control by PID
70	Confirm Input/Output Control by Data Value ID
71	Confirm Diagnostic Routine Started by Test No.
72	Confirm Diagnostic Routine Stopped by Test No.
73	Report Diagnostic Routine Results by Test No.
74	Report Download Status
75	Report Upload Status
76	Data Transfer
77	Confirm Data Transfer Stopped
78	Confirm Diagnostic Routine Started by Address
79	Confirm Diagnostic Routine Stopped by Address
7A	Report Diagnostic Routine Results by Address
7B	Confirm Data Block Written
7C	Report Contents of Data Block
7D	
7E	
7F	General Response Message (accept/reject)

Report of the Vehicle E/E System Diagnostics Standards Committee and the Vehicle Network for Multiplexing and Data Communications Standards Committee approved June 1993

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1. Scope—SAE J1978 defines the requirements of the OBD II scan tool. SAE J2201 defines the minimum requirements of the vehicle communications interface for the SAE J1978 OBD II scan tool. This interface connects the SAE J1962 test equipment connector to the hardware/software of the SAE J1978 OBD II scan tool that will use this interface to communicate with vehicles for the purpose of accessing required OBD II functions.

Included in this SAE Recommended Practice are several definitions relating to the interface, and interface functionality evaluation.

Appendix A - Examples include several example interface circuit implementations, which are believed to meet the requirements of this document and of SAE J1978. These examples are NOT requirements of this document. They are provided to assist circuit designers in developing interface circuits.

Appendix B - Supporting Documents includes a list of supporting documents for the examples shown in Appendix A.

1.1 SAE Document Interrelationships—Figure 1 shows the interrelationships between SAE J1978, SAE J1962, and this document.

NOTE—See SAE J1962 Diagnostic Connector for pin assignments.

Where any conflict may exist between the requirements contained in SAE J1978 and this document, SAE J1978 is the overriding document.

2. References—The terms, definitions, abbreviations, and acronyms contained in SAE J1930 are included by reference.

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1850—Class B Data Communication Network Interface

SAE J1930—Electrical/Electronic Terms, Definitions, Abbreviations, and Acronyms

SAE J1962—Diagnostic Connector

SAE J1978—OBD II Scan Tool

SAE J1979—Diagnostic Test Modes

SAE J2205—Expanded Diagnostic Protocol

2.1.2 CALIFORNIA AIR RESOURCE BOARD DOCUMENTS

California Code of Regulation, Title 13, 1968.1 - Malfunction and Diagnostic System Requirements – 1994 and Subsequent Model-Year Passenger Cars, Light-Duty Trucks, and Medium-Duty Vehicles With Feedback Fuel Control Systems

2.1.3 EPA REGULATIONS

Federal Register Tuesday September 24,1991, Part II Environmental Protection Agency 40 CFR Part 86 - Air Pollution Control; New Motor Vehicles and Engines: On-Board Diagnostic Systems on 1994 and Later Model Year Light-Duty Vehicles and Light-Duty Trucks; Proposed Rule

2.1.4 ISO DOCUMENTS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 9141-2—Road vehicles—Diagnostic systems—CARB requirements for interchange of digital information ISO/TC 22/SC 3/WG 1 - N 425 E/REV April 1991

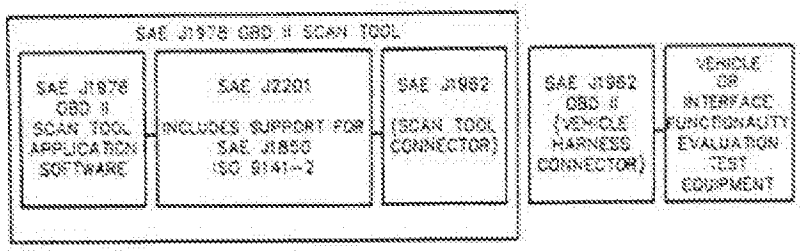

FIGURE 1—SAE DOCUMENT INTERRELATIONSHIPS

2.2 Terms and Definitions

2.2.1 APPLICATION SOFTWARE—As used in this document, this term refers to the microprocessor programming that controls the external equipment/scan tool hardware so as to perform required SAE J1978 OBD II Scan Tool functions.

2.2.2 DLCS—(Data Link Controller Serial) refers to the integrated circuit family developed by General Motors that supports SAE J1850 10.4 Kbps VPW CRC communication.

2.2.3 HBCC—(Hosted Bus Controller Circuit) refers to the integrated circuit developed by Ford Motor Co. that supports SAE J1850 41.6 Kbps PWM CRC communication.

2.2.4 OBD II—(On Board Diagnostics II) common term that refers to the requirements of the California legislation - California Code of Regulations, Title 13, 1968.1.

2.2.5 PCI—(Programmable Communications Interface) refers to a set of integrated circuits which includes a control microcomputer, the Symbol Encoder Decoder (SED) and the Integrated Driver Receiver (IDR). The PCI was developed by Chrysler Corporation and supports SAE J1850 10.4 VPW communication with both CRC and Checksum error techniques.

2.2.6 SCI—(SAE J1850 Communications Interface) refers to an integrated circuit manufactured by Motorola which supports both SAE J1850 10.4 VPW with CRC and SAE J1850 41.6 PWM with CRC communication.

2.3 Acronyms and Abbreviations

CRC - Cyclic Redundancy Check
CS - Checksum
EDP - Enhanced Diagnostic Protocol (SAE J2205)
IBS - Inter-Byte Separation
IFR - In-Frame Response
NRZ - Non Return to Zero
PWM - Pulse Width Modulation
SCI - Serial Communications Interface
SPI - Serial Peripheral Interface
UART - Universal Asynchronous Receiver/Transmitter
VDD - 5.0 VDC from Regulated Power Supply
VPW - Variable Pulse Width Modulation
"-" - Indicates Active Low Signals

3. Requirements—This section defines the required message structure support, signal ground, chassis ground, minimum scan tool connector cable length, and other requirements for the interface to be used by an SAE J1978 OBD II scan tool.

3.1 Interface and Message Protocol Support—The interface defined in this document must support the interface requirements and message protocol requirements of SAE J1978.

3.2 In-Frame Response—When a single byte in-frame response (IFR) is required during the reception of a 41.6 Kbps PWM SAE J1979 message, the interface will support the transmission of the node address as a single byte IFR.

3.3 Signal Ground—The Signal Ground pin of the scan tool side of the SAE J1962 diagnostic connector must be used as the signal ground reference for all interface transceivers required by this document.

3.4 Maximum Voltage Differentials—The interface described in this document includes any required interface transceivers and the cabling connecting the interface transceivers to the scan tool side of the SAE J1962 connector. Any interface connected to a vehicle through the SAE J1962 diagnostic connector is considered a part of the vehicle network and must operate within the limits of that network, which are described in SAE J1850 and ISO 9141-2.

The maximum voltage differential, e.g., due to load current, noise, etc., between any two nodes of a vehicle data communication network, where the interface described in this document is considered as a node on the vehicle network when connected to the vehicle, must be less than the limits specified in SAE J1850 and ISO 9141-2.

The following are maximum voltage differential values for the interface described in this document (as measured between the signal ground connection of all interface transceivers and the Signal Ground pin on the vehicle side of the SAE J1962 diagnostic connector) are:

0.25 V peak noise
0.1 VDC offset

3.5 Chassis Ground—The Chassis Ground pin of the scan tool side of the SAE J1962 diagnostic connector is available for any use, with the exception that the minimum DC impedance between the Chassis Ground and the Signal Ground is 1 MΩ.

3.6 Minimum Connector Cable Length—The minimum length between the ground reference connection of each interface transceiver and the Signal Ground connection of the vehicle side of the SAE J1962 diagnostic connector is 2 m.

3.7 Other Requirements—The interface must support the requirements of SAE J1850, SAE J1962, SAE J1978, SAE J1979, SAE J2205, and ISO 9141-2.

4. Interface Functionality Evaluations—The functionality of any proposed interface implementations must be evaluated by either of the following:

a. The use of multiplex bus interface equipment from I+ME, or equivalent equipment, that with appropriate software simulates vehicles that use the required implementations of SAE J1850 and ISO 9141-2, or
b. The use of representative vehicles of motor vehicle manufacturers that use the required implementations of SAE J1850 and ISO 9141-2.

APPENDIX A
EXAMPLES

A.1 General Example Information—This section shows example interface implementations that are believed to meet the requirements of this document.

These examples are NOT requirements of this document. These examples are intended as an assist to interface circuit designers.

Table A1 illustrates a summary of some of the capabilities available with these examples that are over and above the requirements of this document and some that are required.

TABLE A1—SUMMARY OF CAPABILITIES FOR THE FOLLOWING EXAMPLES

	DLCS & HBCC Section A.2	PCI & HBCC Section A.3	STP Section A.4	PWM & PPWT Section A.5	J1D Section A.6
Error Checking	CRC	CS & CRC	CS & CRC	CS & CRC	CRC
Compliments IBS[2]	No	Yes	Yes	Yes	No
Header Bytes	3	1 & 3	1 & 3	1 & 3	3
Generate Break	Yes	Yes	Yes	Yes	Yes
Control Function[3]	No	Yes	Yes	No	No
Host Required	Yes	Optional[1]	Optional[1]	Yes	Yes

Error checking (CS or CRC), IBS, header bytes, and the Break signal are defined in SAE J1850.

1 Host Required refers to the need for a host microcomputer to perform the functionality of SAE J1978. Some interface implementations include a microcomputer as a part of the interface. In some of these implementations, this microcomputer may have enough excess capability so as to also be able to perform "host microcomputer" functions.

2 IBS is part of only 10.4 Kbps VPW networks. It is not a part of 41.6 Kbps PWM networks, nor a part of ISO 9141-2 networks.

3 Control Function refers to parts of an interface that are implemented in software and executed by some form of microcomputer.

A.1.1 Transient Protection—While some of the examples may show transient protection, this document does not specify or require transient protection.

A.1.2 Host Support Not Included—The examples shown here support a minimal type of host interface and are not meant to be directly applicable to any particular host microprocessor, host interface, and/or host software. The host application software (e.g., interface drivers, message building routines, message processing routines, etc.) and/or additional hardware (e.g., signal buffers, signal inverters, clock synchronization circuits, etc.) required to complete the interface in the example circuits shown in this document is the responsibility of the designer/implementer and is not shown here.

A.1.3 Supporting Documents—Appendix B - Supporting Documents identifies documentation that may be used to aid in the understanding of the examples shown in this document.

A.1.4 Common ISO 9141-2 Support—Many of the examples include a common implementation for ISO 9141-2. This common implementation is described here (see Figure 2-D ISO 9141-2).

The ISO 9141-2 document describes the requirements of the ISO 9141-2 interface. This interface is an asynchronous serial communication link using NRZ bit encoding. A 5 bps bit rate is used during module communication initialization and a 10.4 Kbps bit rate is used for all further communications.

This interface includes a K line which is bidirectional and used for all communication phases, and a L line which is output only from the scan tool and is only used during the 5 bps module communication initialization phase. When used to transmit data to a vehicle, both the L and K lines are driven to either ground or battery level, through a 510 Ω resistor, depending on the data value. When used to receive data from a vehicle, the K line is referenced to 1/2 the battery voltage, with a small amount of hysteresis for noise immunity, to determine the logic value of the data being transmitted by a vehicle module.

In all of the examples, the L and K lines are connected to the SCI port of either the host or a control microprocessor. A select signal from the host/control microprocessor is used to enable the L line when necessary.

A.1.5 Electromagnetic Compatibility—The Electromagnetic Compatibility (EMC) characteristics of these examples have not been investigated nor estimated. The ability of the examples to meet EMC or noise radiation requirements is unknown.

A.1.6 No Responsibility Assumed By Contributors—No responsibility is assumed by Chrysler Corporation, Ford Motor Co., General Motors Corporation, Delco Electronics Corporation, SAE, SGS-Thomson, Silicon Systems, Motorola, or any other company for use of any of the examples or products shown in this document nor for any infringements of patents and trademarks or other rights of other parties resulting from the use of these examples or products. No license is granted under any patents, patent rights, or trademarks of the previously named parties.

A.1.7 Additional Capabilities of Examples—Many of the examples support capabilities beyond the requirements of this document. Such capabilities are discussed in a separate section of each example.

A.2 DLCS, HBCC, and ISO 9141-2 Interface Example—This example (see Figure A1a) combines the use of the Data Link Controller Serial (DLCS) integrated circuit developed by Delco Electronics, the Hosted Bus Controller Circuit (HBCC) integrated circuit developed by Ford, a discrete 41.6 Kbps transmit driver, and the common ISO 9141-2 interface to provide the required interface support. (Figure A1b shows the detail of the DLCS. Figure A1c shows the detail of the HBCC with its Transmit Driver, and Figure A1d shows the detail for the common ISO 9141-2.)

The DLCS and HBCC communicate with the host through the host's SPI port, while the ISO 9141-2 interface communicates with the host through the host's SCI port. Separate logic interface lines are used by the host to individually select communication between the host and either the DLCS and HBCC, and to enable the L line.

A.2.1 General Overview—The DLCS and HBCC perform as communication peripheral integrated circuits. Following initialization, they isolate the host from bus communications tasks and are only serviced by the host when the host is loading a message for transmission or unloading a received message. The host receives an interrupt when a received message is available and when message transmission is completed. The host only handles communications as full messages. Several control and status registers are available in both the DLCS and HBCC to control their operation and indicate the status of their communications tasks.

This example uses chip select lines from the host to select which peripheral the host wishes to communicate with. Control data from the host enables and disables the DLCS and HBCC interfaces.

Because these devices are available from semiconductor suppliers who are also supplying them to major automotive manufacturers for use in production vehicles, compatibility with those vehicles should be readily verifiable.

The ISO 9141-2 interface is as described in A.1.4. The host uses its SCI interface to communicate with a vehicle through the ISO 9141-2 interface. A logic line is used by the host to enable the L line when necessary.

A.2.2 DLCS Operation—The DLCS contains a logic section and an analog section in a single integrated circuit. The logic section includes the SPI interface to the host, a transmit buffer, a receive buffer, status and control registers, bit timing, and symbol encoding and decoding logic. The analog section includes the transceiver circuitry. Data transfer between the host and the DLCS is done with two byte SPI transfers. The host sends to the DLCS a command byte and a data byte, while the DLCS sends to the host a status byte and a data byte. The content of the data bytes is dependent on the command.

a. Commands sent to the DLCS include:
   (1) General commands (e.g., send break, go to sleep, terminate transmit retry, load configuration data)
   (2) Transmit commands (e.g., load transmit data, transmit message)
   (3) Receive commands (e.g., unload receive data, flush byte, flush message)

b. Status data send from the DLCS indicate the following:
   (1) Receive status (e.g., buffer contains bytes or messages)
   (2) Transmit status (e.g., buffer contains bytes or messages)
   (3) Data link status (e.g., data link shorted)

Operation of the DLCS consists primarily of three functions: initialization, transmission of a message, and reception of a message. Each of these will be discussed in more detail as follows:

A.2.2.1 INITIALIZATION—Initialization is accomplished by sending the DLCS a command byte to load the accompanying data from the host as configuration data. The DLCS can be configured to enable or disable it to interrupt the host, thereby allowing either polling or interrupt based signalling schemes to be used, and to configure the oscillator divisor. Once the DLCS is initialized, normal transmission and reception can begin.

A.2.2.2 MESSAGE TRANSMISSION—Loading a message from the host to the DLCS for transmission on the bus is done by several 2 byte SPI transfers. Each transfer contains a command byte to load the accompanying data as transmit data. Loading the first and last byte of the message must be done with specific command bytes. Once the command to load the accompanying data as the last transmit data byte is received by the DLCS, the DLCS will begin an attempt to transmit the message on the bus. With each 2 byte SPI transfer with the DLCS, a status byte and data byte will be transferred to the host. The status byte is used to determine the status of the transmit buffer, i.e., empty, contains some bytes, full, etc. The status byte also contains receive status. When loading a transmit message into the DLCS, the data bytes returned by the DLCS to the host are ignored.

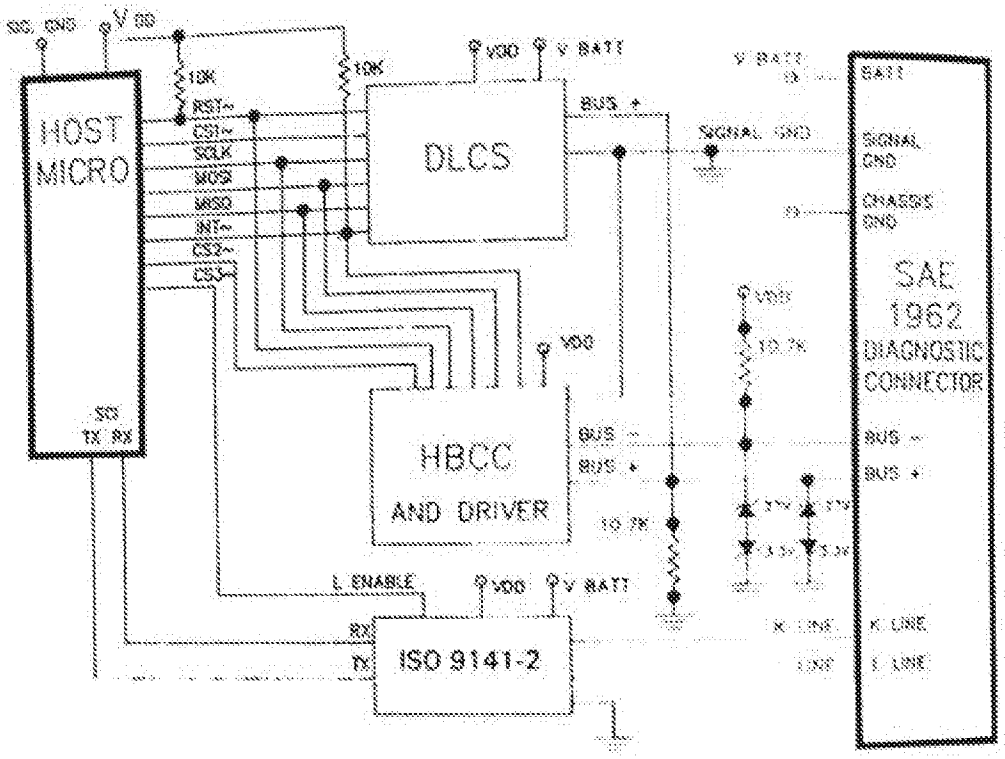

FIGURE A1a—DLCS, HBCC, AND ISO 9141-2 EXAMPLE

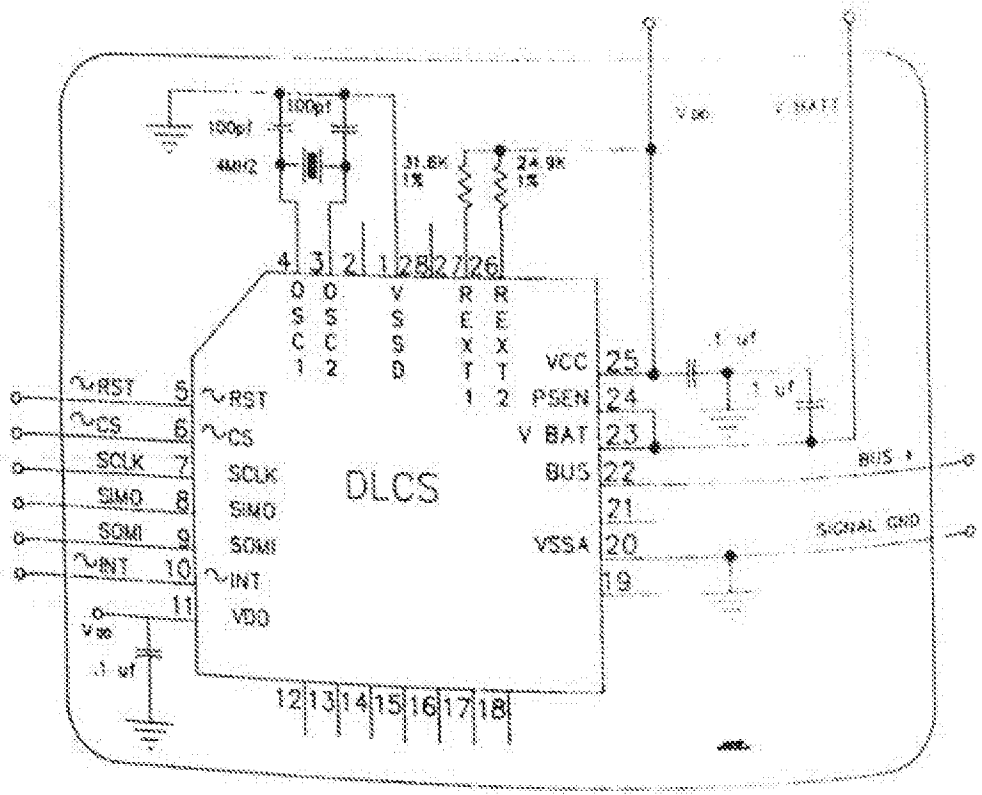

FIGURE A1b—DLCS DETAIL

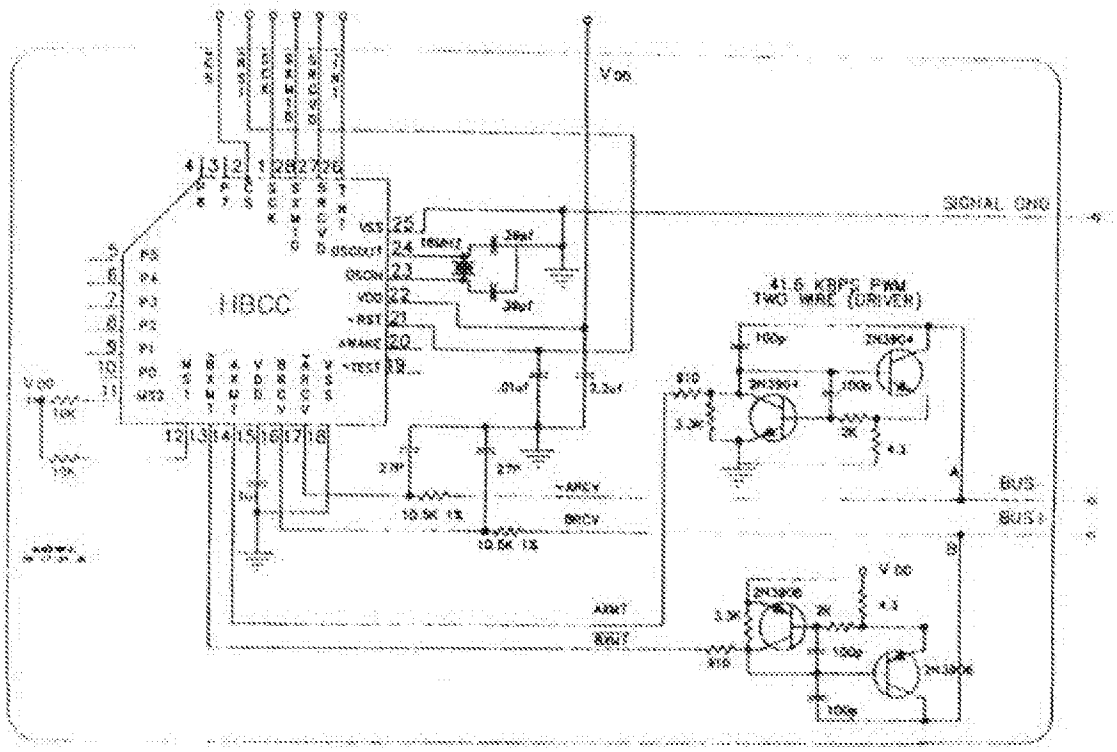

FIGURE A1c—HBCCC AND TRANSMIT DRIVER DETAIL

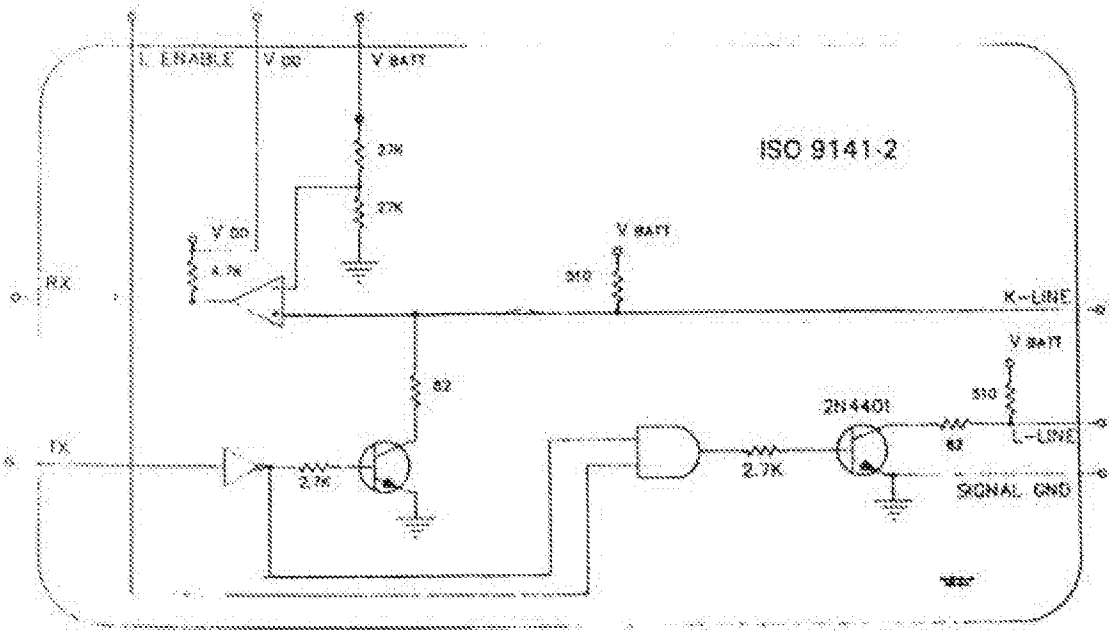

FIGURE A1d—ISO 9141-2 DETAILS

The DLCS handles all data link access responsibilities, i.e., idle bus detection, arbitration, automatic retry (if enabled), etc.

A.2.2.3 MESSAGE RECEPTION—The DLCS on its own receives and buffers a complete message from the bus, checks the received CRC, sets a status flag indicating a message has been received and if any errors occurred and, if enabled, interrupts the host. Retrieving a message received by the DLCS is done first by either polling the DLCS to determine if a message has been received, or by servicing an enabled interrupt that occurs upon reception of a message. (The remainder of this discussion assumes the interrupt method is used.)

Upon receiving an interrupt, performing a 2 byte SPI transfer with the DLCS will result in the transfer of status and data to the host. The status byte is used to determine if the receive buffer contains any bytes of a message or a complete message(s), and the status of the transmit buffer. Once all the bytes of a message have been received by the DLCS an indicator will be set in the status byte and, if enabled, an interrupt will be generated for the host. The status byte will also indicate whether the message was received correctly or that an error occurred, i.e., CRC error, incomplete byte, and bit timing error. If the message uploaded from the DLCS was received while the DLCS was attempting to transmit a message, the status byte will also indicate transmission status values such as overrun or underrun and whether bus arbitration was won or lost.

A.2.3 DLCS Pin Names and Descriptions—The names and descriptions of the pins of the DLCS are shown in Table A2.

TABLE A2—DLCS PIN NAMES AND DESCRIPTIONS

Pin Number	Pin Name	Description
1	Vssd	Digital Ground
2	LOTI	Logic Out Transmitter In (Test)
3	OSC2	Oscillator 2
4	OSC1	Oscillator 1
5	RST-	Reset - (Active Low)
6	CS-	Chip Select - (Active Low)
7	SCLK	SPI Serial Clock
8	SIMO	SPI Slave In Master Out
9	SOMI	SPI Slave Out Master In
10	INT-	Interrupt - (Active Low)
11	Vdd	Digital Voltage Supply (+5 V)
12	N/A	Not Used
13	N/A	Not Used
14	N/A	Not Used
15	N/A	Not Used
16	N/A	Not Used
17	N/A	Not Used
18	N/A	Not Used
19	N/A	Not Used
20	Vssa	Analog Ground
21	LOAD	Bus Load
22	BUS	Bus Output
23	Vbat	Battery Voltage
24	PSEN	Power Supply Enable
25	Vdd	Analog Voltage Supply (+5 V)
26	REXT2	External Resistor 2
27	REXT1	External Resistor 1
28	LITO	Logic In Transmitter Out (Test)

A.2.4 HBCC Operation—The HBCC contains a logic section and an analog section in a single integrated circuit. The logic section of the HBCC supports two types of serial and two parallel host interfaces. This allows for the HBCC to interface with standard Intel or Motorola microprocessors or others which have compatible ports. For this example, the Motorola SPI interface has been used. The logic section also includes a transmit buffer, a receive buffer, status and control registers, bit timing, symbol encoding, and decoding logic. The analog section is limited to the receiver circuitry. The transmitter driver circuit and receiver input noise filter are implemented by external discrete devices.

Data transfer between a host and the HBCC is done with 2 byte SPI transfers. The host transfers an indirect address control byte (ACB) and a data byte to the HBCC. Generally the indirect address points to one of the internal registers of the HBCC and the data sent from the host is stored in the addressed register. During a 2 byte SPI transfer, the host receives a status byte and a data byte from the HBCC. Special address conventions also allow for block type data transfers between the host and the HBCC message buffers.

a. Commands sent to the HBCC include:
   (1) General commands (e.g., initialize node address)
   (2) Transmit commands (e.g., load transmit buffer)
   (3) Receive commands (e.g., read receive buffer)
b. Status data received from the HBCC include the following:
   (1) Receive status (e.g., received byte count)
   (2) Transmit status (e.g., transmission completed OK)
   (3) Network wire status (e.g., network wire shorted)

The operation of the HBCC consists primarily of three functions: initialization, transmission of a message, and reception of a message. Each of these will be discussed in more detail as follows:

A.2.4.1 INITIALIZATION—Initialization is accomplished by sending the HBCC commands to load the accompanying data as configuration information. The HBCC can be configured to enable or disable interrupts to the host, thereby allowing a polling scheme to be used, and to select the bus bit rate. Receive message filter look up tables can also be loaded to screen incoming messages, thus reducing host burden. Once the HBCC is initialized, normal transmission and reception can begin.

A.2.4.2 SENDING A MESSAGE—Loading a message into the HBCC for transmission on the bus is done by several SPI transfers. Each transfer contains an indirect address byte which defines where to store the accompanying data byte into the HBCC transmit buffer. Once the entire message has been loaded into the transmit buffer, the command to transmit the message is sent to the HBCC. The HBCC will then on its own begin to synchronize with the activity on the bus and transmit the message on the bus. The HBCC handles all data link access responsibilities, i.e., idle bus detection, arbitration, and automatic retry. When a message transmit attempt is completed, an interrupt is generated and the host can check the resultant status, including the status of an in-frame response.

A.2.4.3 RECEIVING A MESSAGE—Receiving bus messages using an HBCC is generally based on servicing the interrupt that occurs, if enabled, at the completion of message reception. The HBCC can be configured with interrupts either enabled or disabled, but for this example, interrupts are assumed to be enabled. Upon receiving an interrupt, the host will perform a two byte SPI transfer and receive from the HBCC a status byte and a data byte. The status byte can be used to determine how full the receive buffer is, and whether certain receive errors have occurred. A received message can subsequently be transferred from the HBCC to the host.

A.2.5 HBCC Pin Descriptions—The names and descriptions of the pins of the HBCC are shown in Table A3.

TABLE A3—HBCC PIN NAMES AND DESCRIPTIONS

Pin Number	Pin Name	Description
1	SCLK	Serial Clock
2	CS-	Chip Select - (Active Low)
3	USER7	User Input 7
4	USER6	User Input 6
5	USER5	User Input 5
6	USER4	User Input 4
7	USER3	User Input 3
8	USER2	User Input 2
9	USER1	User Input 1
10	USER0	User Input 0
11	MS2	Mode Select 2
12	MS1	Mode Select 1
13	BDRT-	Network B Drive - (Active Low)
14	ADRT	Network A Drive
15	Vdd	Analog Voltage Supply (+5 V)
16	BRDV	Network B Receive
17	ARDV-	Network A Receive (Active Low)
18	GND	Analog Ground
19	TESTENA-	Test Enable A (Active Low)
20	AWAKE	HBCC Awake
21	RST-	Reset - (Active Low)
22	Vdd	Digital Voltage Supply (+5 V)
23	OSCIN	Oscillator 1
24	OSCOUT	Oscillator 2
25	GND	Digital Ground
26	INT-	Interrupt - (Active Low)
27	SPIOVSIODAT	Serial Data Receive/Serial Data I/O
28	SXMTDOR	Serial Data Transmit/Data Direction

A.2.6 Additional Capabilities—Both the DLCS and HBCC include support for both transmit and receive message buffering and automatic message retransmission. The HBCC also includes support for receive message filtering, wake up, and 41.6 Kbps PWM bus physical layer fault tolerance. The DLCS also includes support to send and receive Break and for wake up.

A.3 PCI, HBCC, and ISO 9141-2 Interface Example—This example (see Figure A2a) combines the use of the Programmable Communication Interface (PCI) developed by Chrysler, the Hosted Bus Communication Controller (HBCC) developed by Ford, a discrete 41.6 Kbps transmit driver, and the common ISO 9141-2 interface to provide the required interface support. (Figure A2b shows the detail of the PCI.)

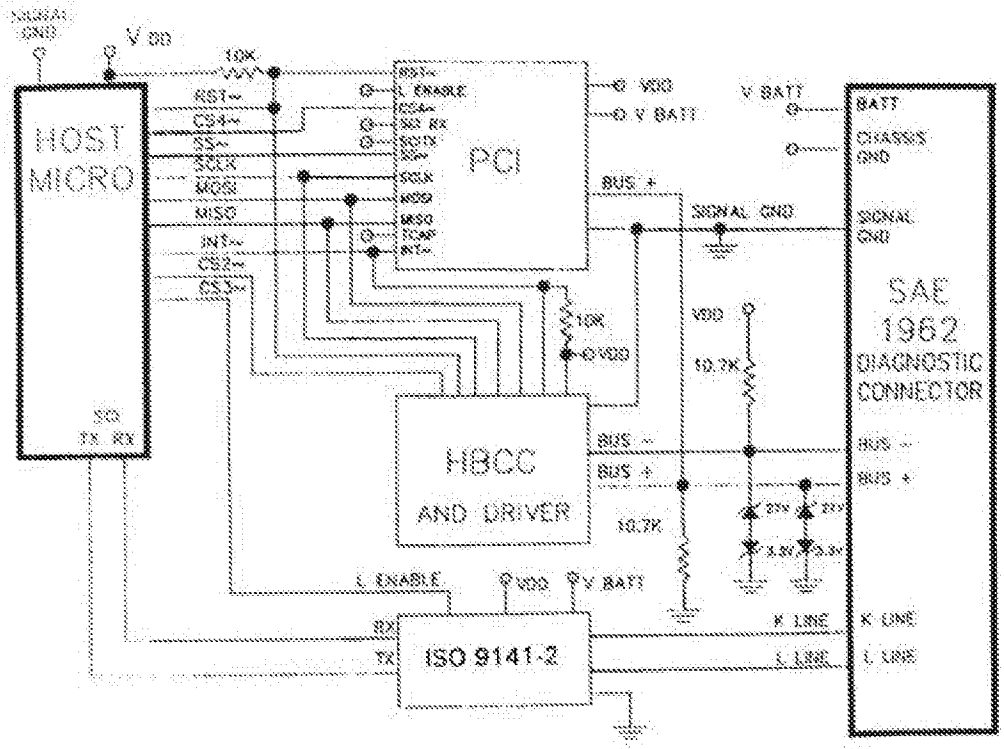

FIGURE A2a—PCI, HBCC, AND ISO 9141-2

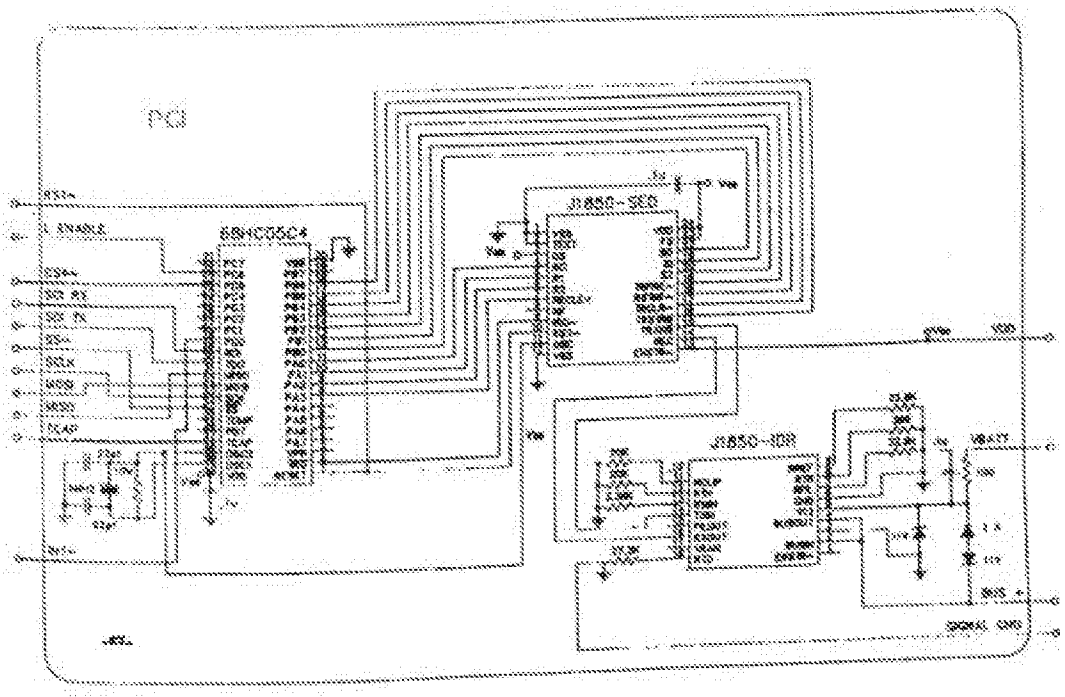

FIGURE A2b—PCI

A description of the HBCC interface is found in A.2.4.

A description of the ISO 9141-2 interface is found in A.1.4.

A description of the PCI is found in this section.

The host communicates with the PCI and the HBCC through the host's SPI interface. The host operates the SPI interface as the master and uses logic control lines to select either the PCI or the HBCC to communicate with. Control information sent from the host to the PCI and the HBCC cause the PCI and HBCC to be enabled or not. The ISO 9141-2 interface uses the SCI interface of the host and a logic line to enable the L line.

A.3.1 General Overview—The PCI operates at a 10.4 Kbps data rate using the symbols specified in SAE J1850.

The PCI is controlled by the coordinated interdependence of both hardware and software. The system consists of the interconnection of three devices:

a. A Control Microcomputer with custom software
b. A Symbol Encoder/Decoder (SED)
c. An Integrated Driver Receiver (IDR)

The control microprocessor controls the operation of the SED and interfaces with the host.

The SED is a digital gate array device which performs symbol encoding and decoding, timing and bus synchronization.

The IDR is an analog ASIC which performs as a 10.4 Kbps VPW bus transceiver for the PCI.

A.3.2 Control Microcomputer—The control microcomputer has overall control of the PCI's operation and interfaces with the host and the SED. The control microcomputer, under software control, interprets host commands and bus symbols.

A.3.2.1 Control Microcomputer Software Structure—The control microcomputer's most critical task is to service the IRQ interrupts generated by the SED. Less critical tasks are handled on an as-needed basis by the interruptable main program.

The IRQ interrupt processing task services the following:

a. Transmission of Frame Symbols
b. Reception of Frame Symbols
c. Bit-By-Bit Arbitration
d. Error Detection
e. Symbol encoding and decoding
f. In-frame response

The main program services the following:

a. Interface to the host
   (1) SPI (or Parallel) interface service
   (2) Chip selection of control microcomputer by the host
b. Bus calculations
   (1) Checksum or CRC
   (2) Transmit and receive message buffering
   (3) Error interpretation
c. Optional tasks when operating as host also
   (1) Keyboard inputs
   (2) Display drivers

A.3.2.2 Control Microcomputer Interface to the Host Microcomputer—The PCI supports both a SPI or a parallel interface with the host. The host functions as interface master for both types of interfaces.

A.3.2.3 Control Microcomputer Interface to the SED—The interface between the control microcomputer and the SED shall be as defined by A.3.3 and Table A4.

TABLE A4—CONTROL MICROCOMPUTER AND SED INTERCONNECTION

Input Port	SED Output	Output Port	SED Input
PA0	R0	PB0	S0
PA1	R1	PB1	S1
PA2	R2	PB2	S2
PA3	RECLEV	PB3	TRPRE-
PA4	IN	PB4	RSTNF
IRQ-	IRQ-	PB5	TRCLR-
		PB6	TRSTRB

A.3.3 Symbol Encoder Decoder (SED)—The SED receives commands from the control microcomputer and converts these commands to SAE J1850 VPW symbols on a symbol-by-symbol bit-by-bit basis. Reception of messages is similarly accomplished, with the SED converting each received symbol into data that is fed to the control microcomputer for deciphering.

A.3.3.1 Symbol Encoder—The control microcomputer initiates the transmission of a frame by first strobing Transmit Preset TRPRE- to a logic "0" and strobing Transmit Strobe TRSTRB to a logic "1". The S0, S1, and S2 inputs are then set to the logic levels defined in Table A5 in order to activate the transmit symbol generator circuit. During each symbol, the Transmit Strobe TRSTRB is strobed. The transmit symbol generator produces the required symbol on the Transmit TRANS Output of the SED. When the symbol has completed transmission, the SED Receive Circuit generates an IRQ- interrupt to the control microcomputer to obtain the next symbol. This cycle is repeated until the entire frame is transmitted.

TABLE A5—TRANSMIT SYMBOL DEFINITION

Inputs S2	Inputs S1	Inputs S0	Output Description J1850 Xmit Symbol
0	0	1	Tx1 Short
0	1	0	Tx2 Long
0	1	1	Tx3 SOF or EOD
1	0	0	Tx4 EOF
1	0	1	Tx5 IFS
1	1	0	xTx6 BREAK

A.3.3.2 Symbol Decoder—Similarly to the operation of the symbol encoder, the completion of the reception of a symbol from the IDR by the SED causes the SED to interrupt the control microcomputer. The control microcomputer reads the SED's R0, R1, and R2 outputs to determine which symbol was received, as defined by Table A6.

The meaning of each received VPW symbol is dependent on whether the symbol level is dominant or passive. This level is read by the control microcomputer on the Receive Level RECLEV Output of the SED.

TABLE A6—RECEIVE SYMBOL DEFINITION

Outputs R2	Outputs R1	Outputs R0	Input Description J1850 Rec. Symbol
0	0	0	Invalid Symbol
0	0	1	Rx1 Short
0	1	0	Rx2 Long
0	1	1	Rx3 SOF or EOD
1	0	0	Rx4 EOF
1	0	1	Rx5 IFS
1	1	0	Rx6 BRK

A.3.3.3 Invalid Symbol—The reception of an Invalid Symbol (Refer to Table A6) sets a Noise Flag NF Output. This Output remains at a logic "1" level until cleared by Reset Noise Flag RSTNF Input.

A.3.3.4 SED Inputs and Outputs—All inputs and outputs from the SED are at standard CMOS voltage levels.

The following discusses some particular SED inputs and outputs.

A.3.3.4.1 Transmit Clear (TRCLR-) Input—The SED's TRCLR- Input can be used by the control microcomputer to terminate the transmission of a IBS or Break symbol. IBS may be terminated after the minimum Tx5 period has been generated and a Break symbol may be terminated after a period greater than the maximum Tx5 has been generated.

A.3.3.4.2 Reset (RST) Input—The RST Input to the SED is used to initialize the SED.

A.3.3.4.3 Oscillator (OSC) Input—The OSC Input to the SED is the Time Base Clock Signal. When the DS Input is connected to VCC, a 4.0 MHz clock is required. When DS Input is grounded, an 8.0 MHz clock is required.

A.3.3.4.4 Transmit Strobe (TRSTRB) Input—The TRSTRB Input to the SED operates as a watchdog circuit to insure that the control microcomputer is functioning correctly. The TRSTRB Circuit requires that each transmit symbol must be strobed into the SED or the SED will transmit an Idle Output. The TRSTRB Input is active when ENTRSTRB Input is grounded and disabled when the ENTRSTRB Input is connected to VCC.

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A.3.4 Integrated Driver/Receiver (IDR)—The IDR is the interface between the vehicle bus wiring and the SED. The IDR integrates and simultaneously performs both the bus driver and receiver functions. The bus output waveform is specifically shaped to conform to SAE J1850 requirements and to minimize EMI.

A.3.4.1 Bus Output Waveshaping—The IDR bus output is wave shaped to have symmetrical rise and fall voltage waveforms within the range of allowed bus loading tolerances and battery operating voltages and during message arbitration. The waveshaping consists of a set rise/fall and corner rounding times. The maximum rise/fall time is 16 µs with the corner rounding of 4 µs. The typical rise/fall time is set to 14 µs with corner rounding of 3 µs.

A.3.4.2 Transmitting Signals on the Bus—The IDR receives 1's and 0's from the SED on the CMOS compatible Transmit pin (Tx) and translates these to wave shaped high and low signals at the bus out pin (Bout). The propagation delay between the transition on the Tx pin and the corresponding transition on the Bout pin measured at 3.875 V is a maximum of 12 µs, with a typical value of 10 µs.

A.3.4.3 Processing Signals Received from the Bus—The IDR receives 1's and 0's on the bus input pin (Bin) and translates these to 1's and 0's at the CMOS compatible Receive pin (Rx). The propagation delay between the transition on the Rx pin and the corresponding transition on the Bin pin measured at 3.875 V is a maximum of 2 µs, with a typical value of 1 µs.

A.3.5 Additional Capabilities—The additional capabilities of the HBCC are shown in A.2.6.

The PCI is able to buffer both transmit and receive messages, send and receive Break, support both CRC and Checksum for message error checking, and comprehend IBS.

The MPU used in this example for the control microcomputer is a Motorola 68HC05C4. This particular version of the 68HC05 family is used for the designer's convenience. A much simpler 68HC05P7 microcomputer could also be used to perform the required PCI control tasks and in some cases the host tasks of a scan tool. The 68HC05C4's utilization during message transmission averages about 50% of the available CPU time. It is likely that with so much CPU time still available, the 68HC05C4 or the more powerful and faster 68HC11 could be used to perform both the control and host tasks.

A second example in this section (see Figure A3) shows the use of the control microprocessor associated with the PCI as the host also. As such the control microcomputer is connected to the HBCC and ISO 9141-2 interfaces. The external equipment manufacturer is left to design the interface to any required keyboard and display, which are not shown. Similarly to the case shown in Figure A2a, the control microcomputer externally selects the HBCC or the ISO 9141-2 interface when needed.

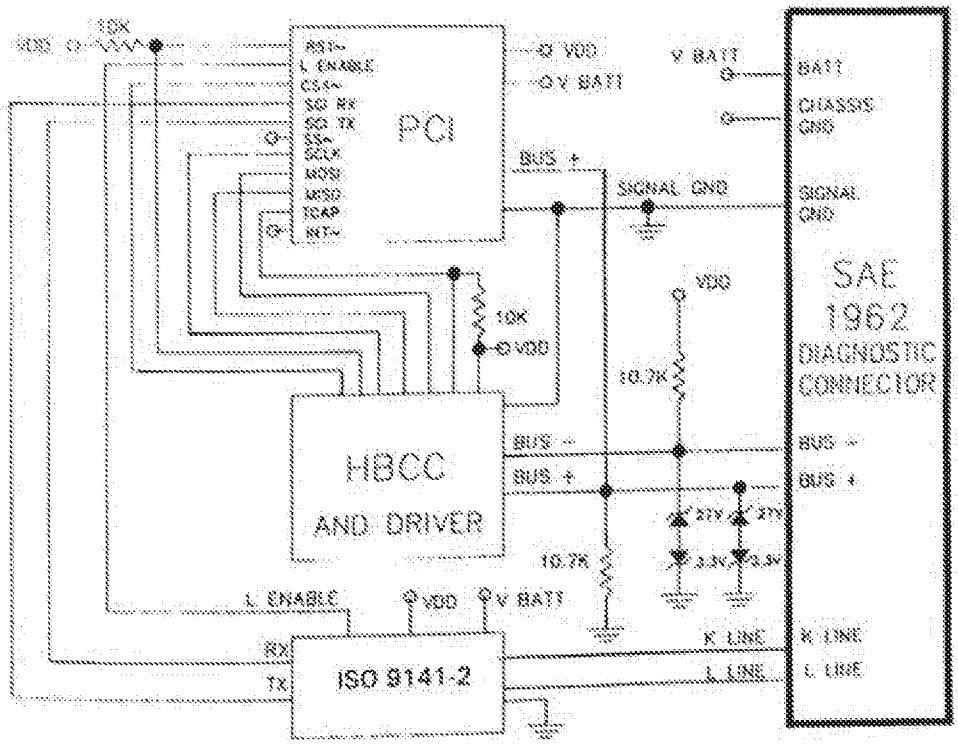

FIGURE A3—PCI, HBCC, AND ISO 9141-2 WITH PCI AS HOST ALSO

A.4 SGS-Thomson Protocol Engine Interface Example—This example (see Figure A4a) combines the use of an SGS-Thomson ST9 microprocessor as a control microcomputer, control microprocessor software, a GAL6001 programmable logic array device and discrete bus transceiver circuitry to provide the required interface support. Together these devices are identified as the SGS-Thomson Protocol Engine. (Figure A4b shows the detail of the ST9 and the GAL6001, Figure A4c shows the detail of the 10.4 Kbps Transceiver, Figure A4d shows the detail of the 41.6 Kbps Transceiver, and Figure A4e shows the detail of the ISO 9141 Transceiver.)

In this example the host microcomputer is connected to only one interface, the Protocol Engine. The Protocol Engine directly supports the required SAE J1850 and ISO 9141-2 interfaces and includes the ability to, on its own, determine the particular interface being used by a vehicle to support OBD II communication.

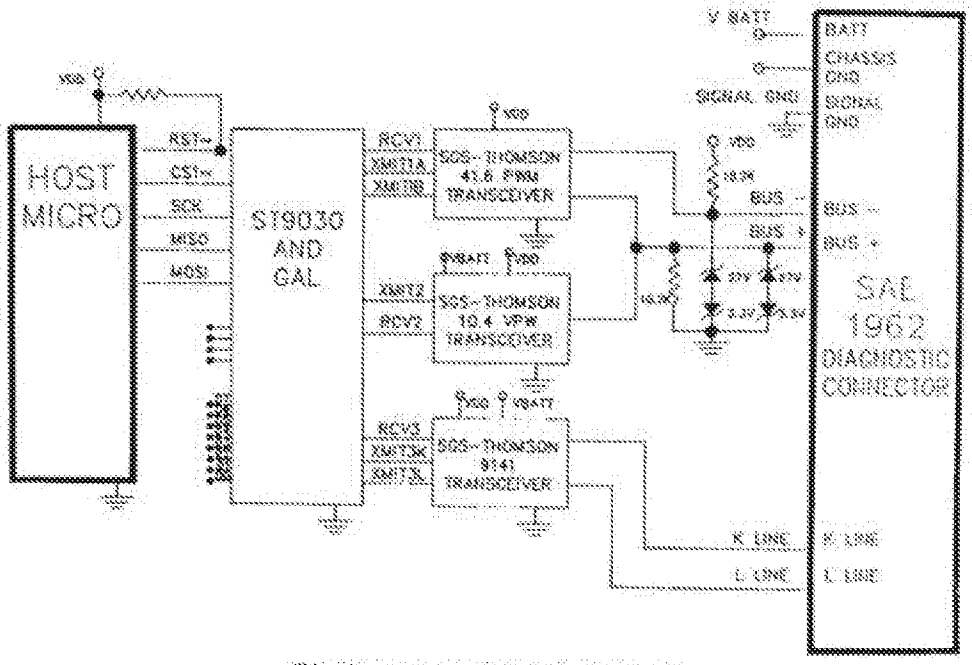

FIGURE A4a—SCS-THOMSON PROTOCOL ENGINE

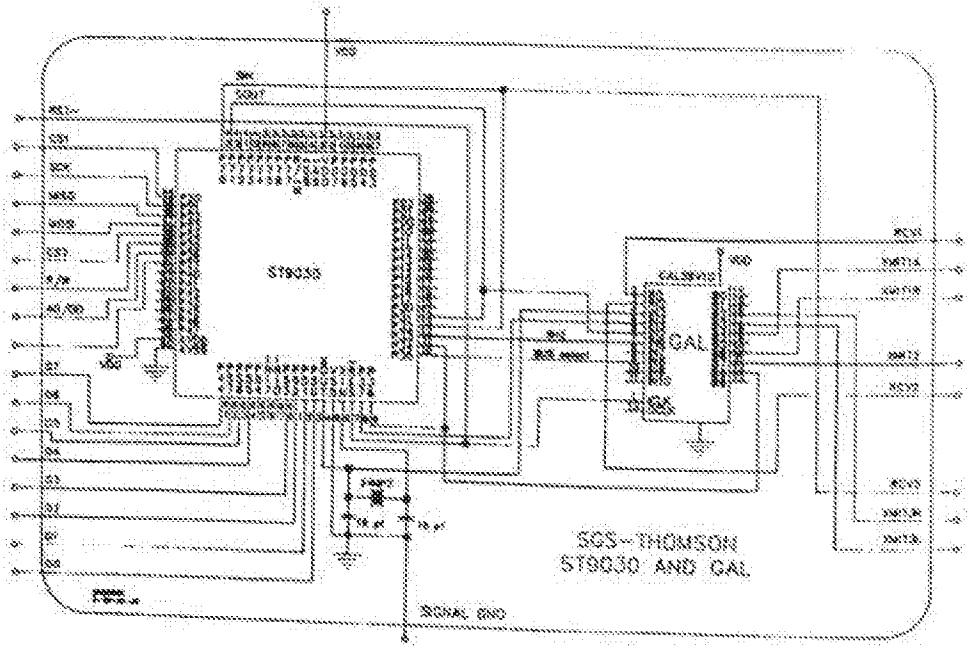

FIGURE A4b—SCS-THOMSON ST9030 AND GAL

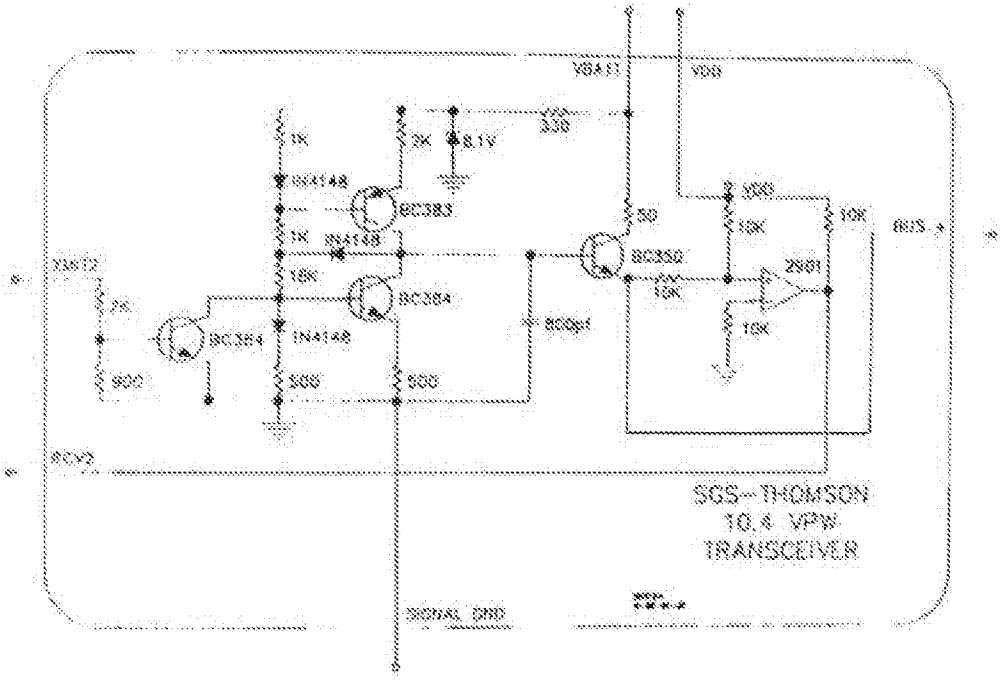

FIGURE A4c—SGS-THOMSON 10.4 VPW TRANSCEIVER

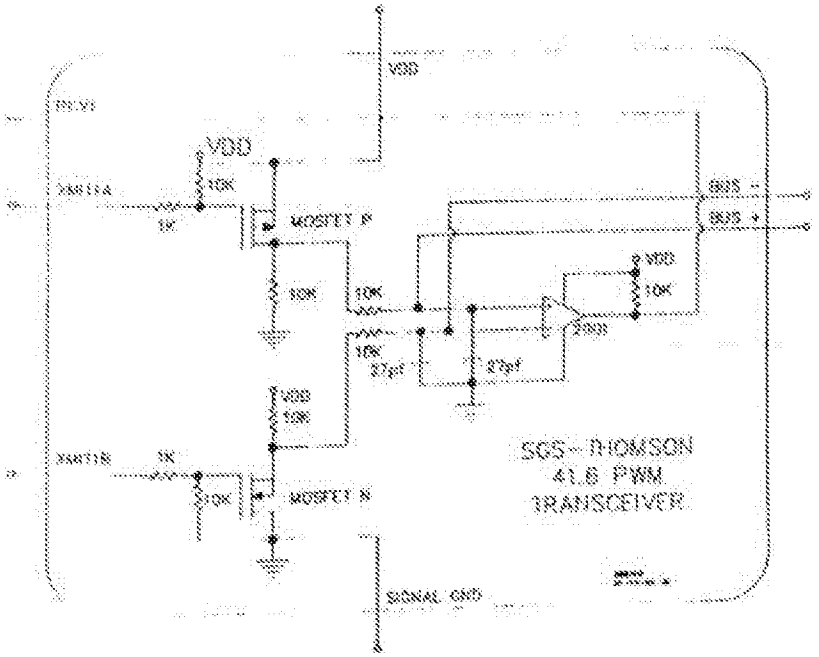

FIGURE A4d—SGS-THOMSON 41.6 PWM TRANSCEIVER

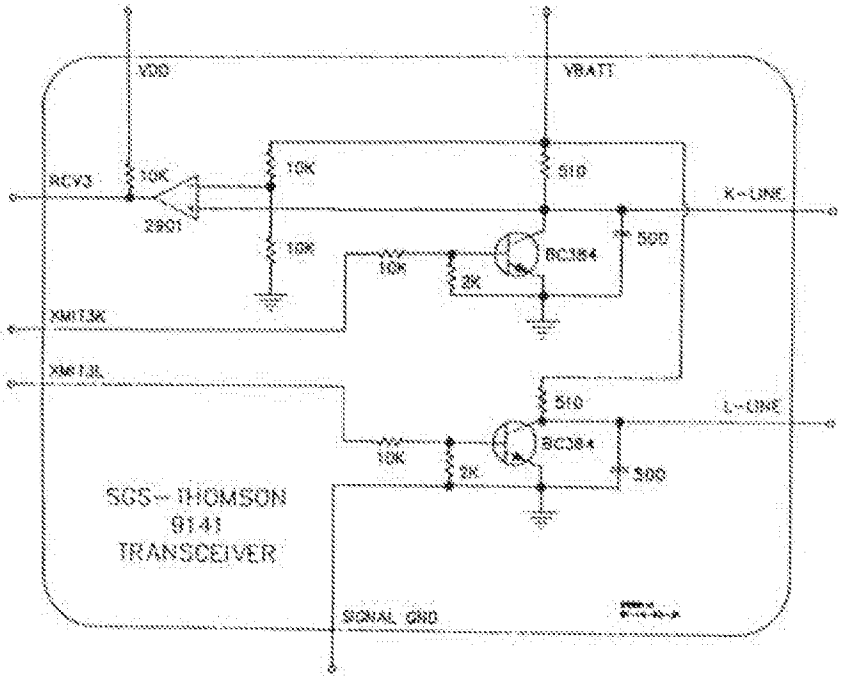

FIGURE A4—SGS-THOMSON 9141 TRANSCEIVER

A.4.1 General Overview—As mentioned in Section A.4, the Protocol Engine is comprised of four parts: the ST9 control microcomputer, control microcomputer software, the GAL6001 programmable logic array device, and several discrete transceivers.

A.4.2 Control Microcomputer—A SGS-Thomson ST9 family microcomputer is used as an interface control microcomputer. The ST9 microcomputer is a general purpose 8/16 bit microcomputer. Its timer facilities are used extensively to provide the control of transmitted waveforms and the detection of received signals.

Both SPI and parallel interfaces to host microcomputers are supported.

The host can request the Protocol Engine to either scan the possible OBD II interfaces and determine the type used in a given vehicle or use a selected interface type.

A.4.2.1 Control Microcomputer Software Structure—The highest priority tasks in the control microcomputer support the symbol-by-symbol processing of each transmitted and received message frame. The control microcomputer, and in particular the ST9's timers, directly controls the rise and fall of transmitted signals and directly follows the rise and fall of received signals. When transmitting a message, it performs both of these processes simultaneously. All other control microcomputer tasks are processed on a time available basis.

The following further identifies the control microcomputer's tasks:

a. Highest Priority Tasks:
   (1) Bus synchronization
   (2) Transmission and reception of frame symbols
   (3) Bit-by-bit arbitration
   (4) Comprehension of IRS
b. Background tasks:
   (1) CRC or checksum calculation
   (2) Symbol encoding and decoding
   (3) Message buffering
   (4) In-frame response processing
   (5) Error checking
   (6) Host interface

A.4.2.2 Control Microcomputer Interface to the Host—Communication between the control microcomputer and the host is based on the host reading from and writing to 64 bytes of memory in the control microcomputer. Sixteen bytes are reserved for status and control of SAE J1850 related operations, 13 bytes are reserved for status and control of ISO 9141-2 related operations, 3 bytes are reserved for general status and control, and 32 bytes are reserved for receive and transmit buffers and related pointers and counters.

Data transfers between the host and the control microcomputer are performed as 2 byte transfers, a control byte and a data byte, initiated by the host. The control byte from the host indicates whether the host wishes to read or write a byte in the control microcomputer and what the address of the byte is (see Figure A5). The second SPI byte transfer moves the byte read from the control microcomputer to the host or the byte to be written from the host to the control microcomputer.

The control microprocessor supports both an SPI and a parallel type of interface with the host. In order to properly service bus communications, the control microcomputer controls the actual data transfers between itself and the host.

A.4.2.3 Automatic OBD II Interface Scan—Upon host request, the Protocol Engine will, by itself, automatically scan all of the possible OBD II interfaces and determine the one supported by a given vehicle. The interface scan sequence used is as follows:

a. SAE J1850 41.6 Kbps PWM
b. SAE J1850 10.4 Kbps VPW
c. ISO 9141-2

A.4.3 GAL6001 Programmable Logic Array—The GAL6001 Programmable Logic Array performs primarily as a digital filter of the signal received from the vehicle bus. It is a standard high-performance field programmable EEPROM logic device and is available in a variety of packages. The device chosen has a 20-year data retention specification. It is organized as a 72 X 64 X 36 FPLA.

A.4.4 Discrete Transceiver—The discrete transceiver circuitry includes all the components necessary to create the required transmit signal waveforms on a bus and to receive bus signals. This includes support for 41.6 PWM, 10.4

VPW and ISO 9141-2. The transceiver is responsible for or controls the following:

a. Voltage on the bus
b. Current levels
c. Media impedance
d. Signal rise times and fall times

The overall signal transmitted by the transceiver is controlled by the control microcomputer. Signal transmission on a bus is created through the use of current sources/sinks. The 10.4 Kbps VPW driver is comprised of a current source of 1X magnitude and a current sink of 2X magnitude. By switching on and off the 2X current sink, the transceiver effectively causes the bus to make transitions from zero to one to zero. The current sinked or sourced into the bus capacitance controls the rise and fall times of the signals. The control microcomputer controls the "ON" and "OFF" timing of the 2X sink, thereby controlling the data and data rate on the bus.

7	6	5	4	3	2	1	0
R/W	IF	MSB	6 bits of address				LSB

R/W = Read/Write command bit. 0 = write to ST9
1 = read from ST9

IF = Reset. 0 = Resets the chip

6 bits of address = address to read/write

FIGURE A5—PROTOCOL ENGINE COMMAND BYTE

By using the controlled current sink and source approach this driver effectively becomes short-circuit proof.

A.4.5 Additional Capabilities—In addition to supporting the requirements of this document, the Protocol Engine also supports the following options of SAE J1850: Checksum, comprehend IBS, Single Byte Header, and Break.

Being software driven, the control microcomputer can be considered for supporting additional custom interfaces to test equipment host microcomputers.

Simulation has determined that the bus signal control and monitor tasks require less than 30% of the control microcomputer leaving at least 70% of a very fast microcomputer available for the other tasks such as performing as the host.

Other facilities that are available with various versions of ST9 microcomputers are:

a. Eight 8-bit analog-to-digital channels
b. Eight user readable input pins
c. Eight user writable output pins

The analog to digital support would allow the host to have the control microcomputer to do such things as determine if the diagnostic connector is plugged in, and look at the voltages on the bus and determine if communication is possible.

ST9 microcomputer models have support for up to 32K of ROM or up to 16 megabytes of external memory.

The ST9030 shown in this example is the lowest member in the ST9 family currently available, therefore all members of the ST9 family can support OBD II communication.

A.5 Silicon Systems F690/F691 Scan Tool Chipset Interface Example—This example (see Figure A6a) combines the use of the P690 Codec and F691 Transceiver scan tool chip set developed by Silicon Systems (SSI) to provide the required interface support. (Figure A6b shows the detail of the P690 Codec, and Figure A6c shows the details of the F691 transceiver.)

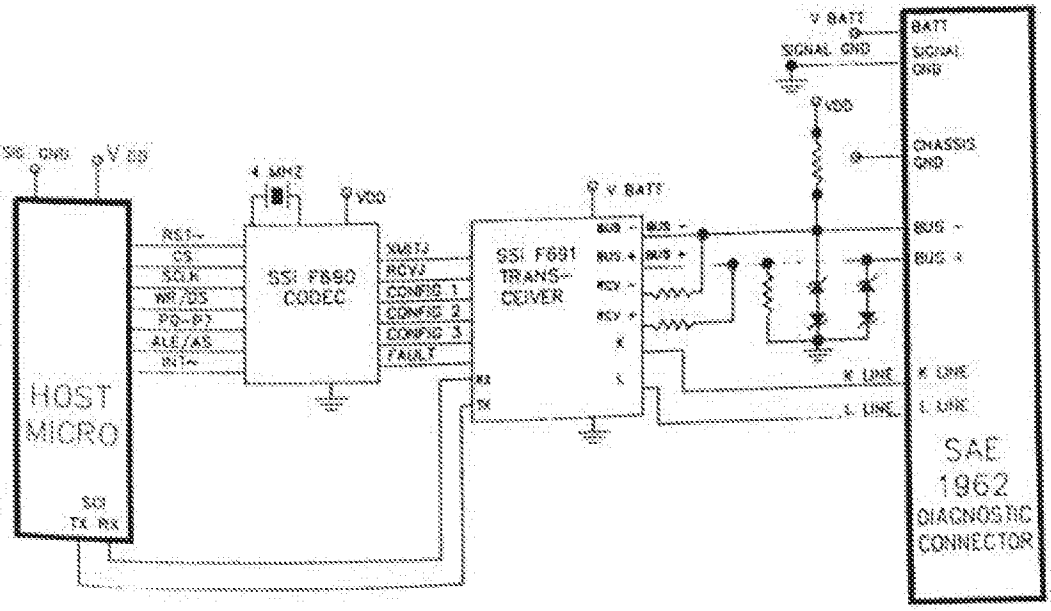

FIGURE A6a—SILICON SYSTEMS P690/F691 CHIPSET

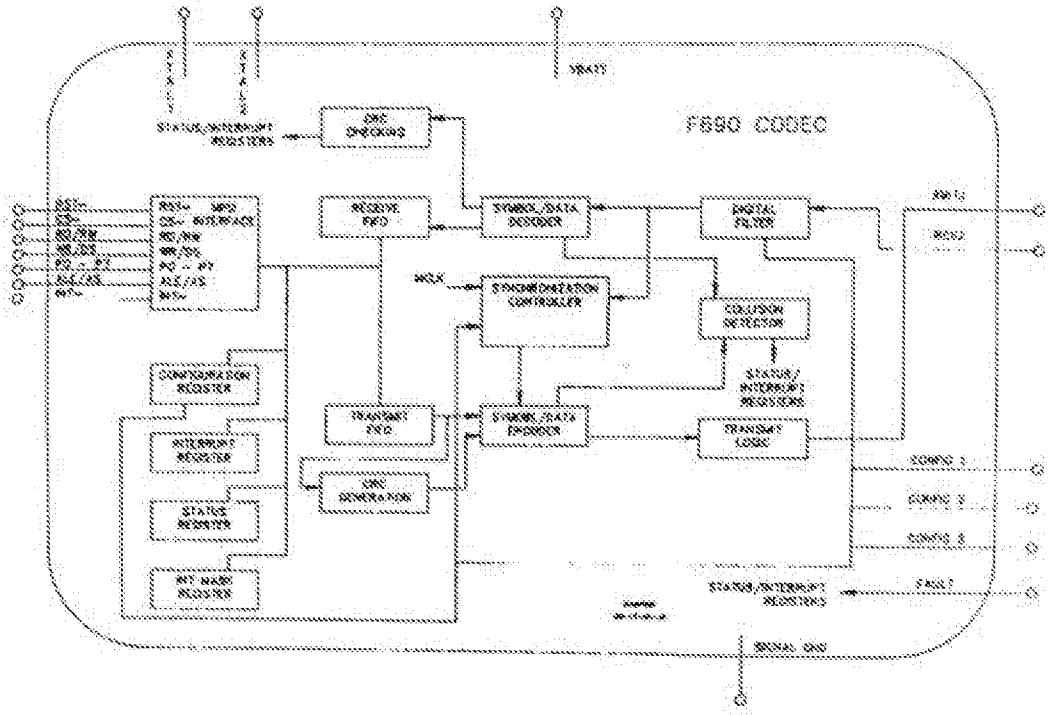

FIGURE A6—F690 CODEC

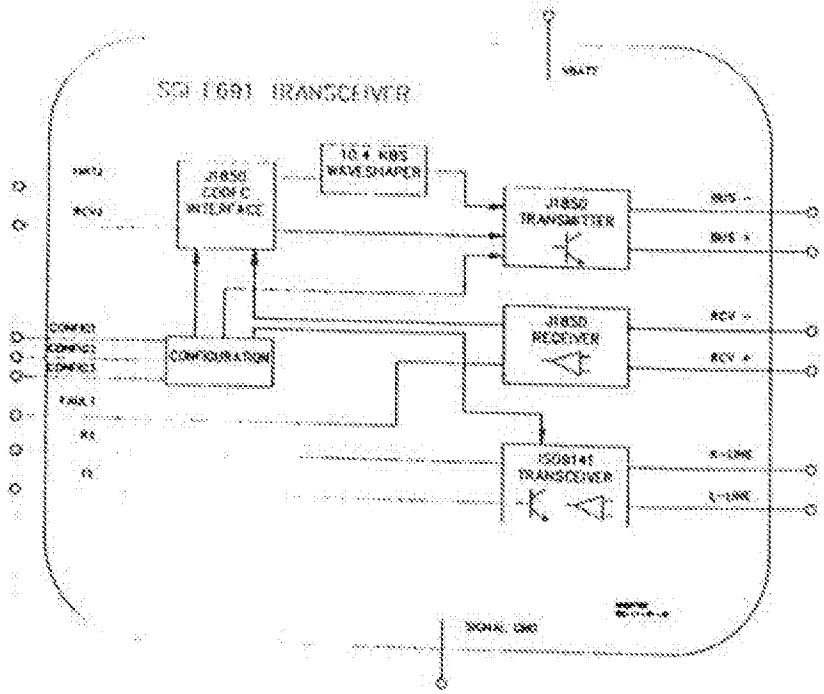

FIGURE A6—F691 TRANSCEIVER

A.5.1 General Overview—The SSI Scan Tool chipset consists of the P690 Codec and the P691 Transceiver. The P690 Codec performs the intersymbol level COder/DECoder operations for the SAE J1850 interfaces. This allows the host processor to communicate with the chipset at the byte level. A parallel type interface is used between the host and the Codec.

The P691 Transceiver performs the physical interface for the SAE J1850 41.6 Kbps PWM, SAE J1850 10.4 Kbps VPW, and ISO 9141-2 requirements.

The ISO 9141-2 interface support of the Transceiver is directly connected to the SCI interface of the host.

A.5.2 P690 Codec—A functional block diagram of the P690 Codec chip is shown in Figure A5b. The Codec interfaces with the host processor via an 8-bit parallel bus. The bus is multiplexed and both Motorola and Intel microcomputer parallel type interfaces are supported. Reset, chip select, and interrupt line connections are also used.

Transmit bytes are loaded from the host into the Transmit FIFO buffer of the Codec, which also performs a parallel to serial conversion. The bit serial output from the Transmit FIFO is input into the symbol encoder as well as into the CRC generation logic. The symbol encoder converts bits (1 or 0) into the appropriate PWM/VPW timing symbols. Transmitted symbols are synchronized to the received data. The transmit logic controls the output that drives the P691 Transceiver.

The framing symbols for SOF, IBS, EOD, NB, EOF, and IFS are also generated by the Codec. The host only needs to pass to the Codec the message byte, and checksum, when used.

The P690 Codec receives information from the P691 Transceiver chip via the RCVJ input pin. The receive input from the Transceiver is, in the Codec, digitally filtered and fed into the symbol decoder. Transitions at the digital filter output are also used to synchronize the transmitter. The collision detect logic compares the transmitted and received signals and performs the bus arbitration function.

The symbol decoder compares the digital filter output with known symbol templates. When a data bit match occurs, the proper bit (1 or 0) is shifted into the receive FIFO buffer. When framing symbols are detected, they are stripped from the received data and fed into the synchronization/controller logic. The data values from the symbol decoder output are also fed into the CRC checking logic. The receive FIFO buffer also performs a serial to parallel conversion such that the host processor can parallel read a received data byte.

Configuration data, transmit and receive status data, and interrupt mask registers are included on the P690 Codec. Interrupts can be enabled to indicate transmit buffer empty, receive buffer full, CRC error, lost arbitration, idle bus, fault detection, etc.

The P690 Codec chip is available in a 28 PLCC package. The part is fabricated in a CMOS technology, operates from a 5 V supply, and consumes less than 100 mW max.

A.5.3 P691 Transceiver—A functional block diagram of the P691 Transceiver is shown in Figure A6c. This chip performs the physical level interface functions. The Transceiver is capable of driving a single-ended, wavershaped, 10.4 Kbps VPW signal as well as the differential, 41.6 Kbps PWM signal onto SAE J1850 buses. Two configuration lines from the P690 Codec determine what send/receive mode is to be used by the Transceiver. The receiver consists of either single-ended or differential comparators. Hysteresis is added to improve noise immunity. The transmitter/receiver for the ISO 9141-2 interface is also included on the Transceiver.

Other than waveshaping for the SAE J1850 10.4 Kbps VPW interface, all timing is controlled by the P690 Codec chip. An on-chip bandgap reference and temperature trims are used to tightly control the SAE J1850 10.4 Kbps VPW waveshape parameters and comparator switching levels.

The P691 Transceiver chip is available in a 16-pin plastic DIP. The part is fabricated in a BIPOLAR technology, operates from a single 9 to 13 V supply, and dissipates 500 mW max.

A.5.4 Pin Descriptions—The pin numbers are not finalized. This section describes pin function only.

A.5.4.1 P690 CODEC PIN DESCRIPTION—The names and descriptions of the pins of the P690 Codec are shown in Table A7.

A.5.4.2 P691 TRANSCEIVER PINOUT—The names and descriptions of the pins of the P691 Transceiver are shown in Table A8.

TABLE A7—P690 CODEC PIN NAMES AND DESCRIPTIONS

Pin Number	Pin Name	Description
1	VDD	positive supply voltage, +5 V
2	GND	ground
3	XTAL1	4 MHz crystal connection; can be driven by an external clock
4	XTAL2	4 MHz crystal connection
5	CLKOUT	buffered output clock
6	CS	chip select, digital input, active low
7	RD/DS	digital input, Intel/MOTO processor interface control
8	WR/R/W	digital input, Intel/Moto processor interface control
9	ALE/AS	digital input, Intel/Moto address strobe
10	INT	digital output, interrupt, active low
11	RST	digital input, reset
12	XMTJ	digital output, SAE J1850 xmit signal
13	RCVJ	digital input, SAE J1850 receive signal
14	XMTJ	digital output, SAE J1850 xmit signal
15	BUSSEL	digital input, Intel/Moto bus select
16	CONFIG1	digital output, configuration bit for P691 Transceiver
17	CONFIG2	digital output, configuration bit for P691 Transceiver
18	CONFIG3	digital output, configuration bit for P691 Transceiver
19	N/A	
20	N/A	
21-28		digital I/O, bus interface P0-P7

TABLE A8—P691 TRANSCEIVER PIN NAMES AND DESCRIPTIONS

Pin Number	Pin Name	Description
1	VBAT	positive supply
2	GND	ground
3	BUSP	positive bus output drive
4	BUSN	negative bus output drive
5	RCVP	positive bus receiver input
6	RCVN	negative bus receiver input
7	K	ISO 9141-2 K line, input/output
8	L	ISO 9141-2 L line, output
9	ISO_RX	digital output, ISO 9141-2 receive signal
10	ISO_TX	digital input, ISO 9141-2 transmit signal
11	XMTJ	digital input, SAE J1850 xmit signal
12	RCVJ	digital output, SAE J1850 receive signal
13	CONFIG1	digital input, configuration bit
14	CONFIG2	digital input, configuration bit
15	CONFIG3	digital input, configuration bit
16	FAULT	digital output, fault detection

A.5.5 Additional Capabilities—The following is a list of additional SAE J1850 features supported by the P690 Codec/P691 Transceiver:

a. Checksum and CRC error checking
b. Comprehends IBS
c. Single Byte header support
d. generation of a Break signal

A.6 Motorola SCI and ISO 9141-2 Interface Example—This example (see Figure A7a) combines the use of the SAE J1850 Communications Interface (SCI) developed by Motorola, a discrete 41.6 Kbps transceiver, a discrete 10.4 Kbps transceiver, and the common ISO 9141-2 interface to provide the required interface support. Figure A7b shows the detail of the SCI.

This section contains a description of the SCI interface, which provides all of the required SAE J1850 interface support.

A description of the ISO 9141-2 interface is found in the section titled Common ISO 9141-2 Support.

The SCI communicates with the host through the host's SPI port, while the ISO 9141-2 interface communicates with the host via the host's SCI port. Separate logic interface lines from the host are used to enable either the SCI or the ISO 9141-2 interface.

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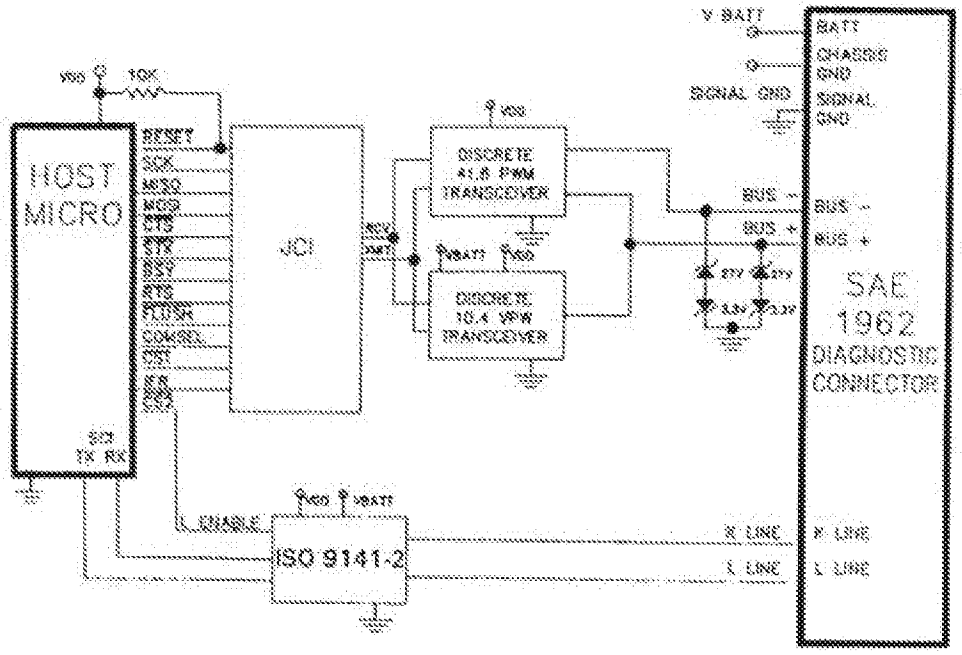

FIGURE A7a—JCI AND ISO 9141-2 EXAMPLE

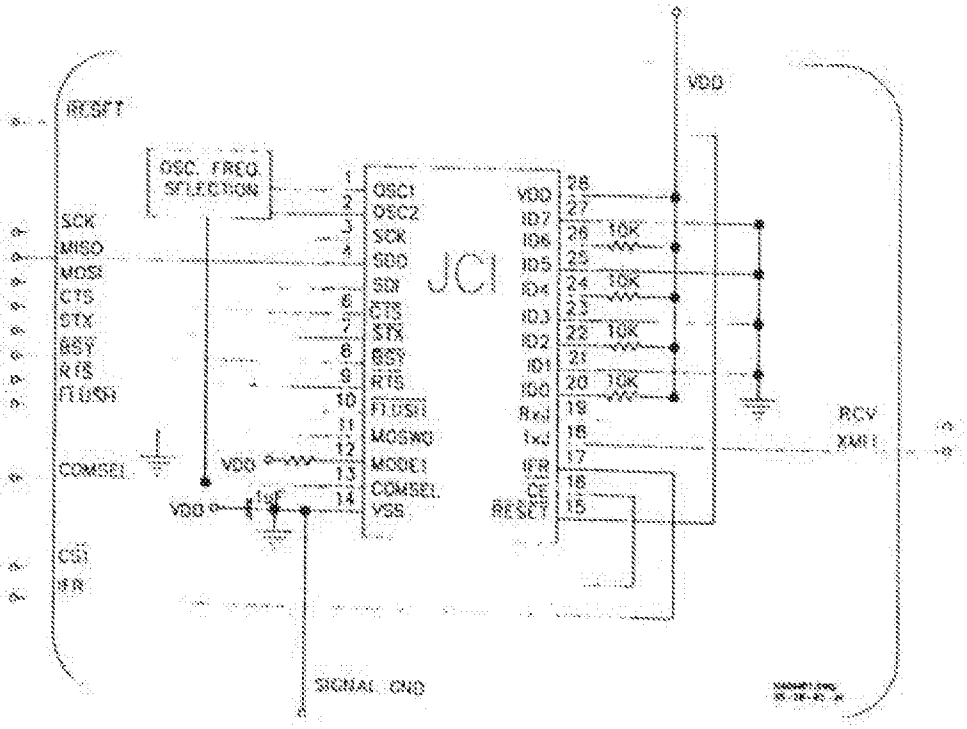

FIGURE A7b—MOTOROLA J1850 COMMUNICATIONS INTERFACE

A.6.1 General Overview—The JCI is an all-digital communications peripheral device which performs all of the required SAE J1850 communications tasks. This reduces the burden on the host to the loading of complete messages into the JCI for transmission onto the multiplex bus, and the unloading of complete messages which the JCI has received from the multiplex bus. The JCI can transmit messages using either modulation technique specified by SAE J1850 (10.4 Kbps VPW and 41.6 Kbps PWM). A separate network transceiver is required to perform all drive, wave-shaping, and input compare functions required for proper transmission and reception of each type. This example includes the use of the SGS-Thomson 41.6 Transceiver and 10.4 Transceiver. This example uses several logic lines from the host to enable the JCI interface, and to control the exchange of data between the host and the JCI, while the data exchange occurs via the host's SPI interface port. The ISO 9141-2 interface is as described in A.1.4. The host uses its SCI interface port to communicate with a vehicle through the ISO 9141-2 interface. A logic line is used by the host to enable the L line when necessary.

A.6.2 JCI Operation—The JCI is an all-digital integrated circuit which can support transmission of messages in both modulation formats specified in SAE J1850. The JCI also supports three different types of serial host interfaces, allowing the JCI to be used with a wide range of microcontrollers. This example utilizes the 'Handshake SPI' interface mode. The JCI contains a single transmit buffer, two receive buffers, bit timing and symbol encoding/decoding circuitry, and CRC generation and checking circuitry. All analog transmission functions must be performed by a separate physical interface transceiver circuit. This example uses two discrete transceiver circuits, one for 10.4Kbps VPW and one for 41.6 Kbps PWM.

A.6.2.1 HOST INTERFACE—The Handshake SPI interface used to communicate with the JCI uses eight signals to control the transfer of information in a serial format between the host and the JCI, three for data transmission, and the rest for data transfer control and error indication. The actual data transfer is in the standard Motorola SPI format. The five control lines include two outputs from the JCI and three inputs to the JCI. The function of these lines are as follows:

a. Output signals from the JCI to the host:
   (1) Request to Send (RTS)—Informs the host that the JCI has data to be transmitted to the host.
   (2) Busy (BSY)—Informs the host that the JCI has a message in its transmit buffer to be transmitted onto the multiplex bus.

b. Input signals to the JCI from the host:
   (1) Chip Enable (CE)—Enables the JCI for communication with the host.
   (2) Clear to Send (CTS)—Enables the JCI to transmit a byte of data to the host.
   (3) Start Transmit (STX)—Informs the JCI that the host has data to be transmitted to the JCI for transmission onto the multiplex bus. There are also other control inputs to the JCI which control the operating mode of the JCI, and allow clearing of either the receive or transmit buffers by the host if necessary.

A.6.2.2 COMMUNICATION MODE SELECTION—Since the JCI can transmit messages in either 10.4 Kbps VPW modulation or 41.6 Kbps PWM modulation type, it is necessary for the host to specify to the JCI which modulation type to use. The modulation type is determined through a combination of the input oscillator frequency and the logic level of the Communication Select input (COMSEL). Table A9 outlines the modulation format and transmission rate selection.

TABLE A9—COMMUNICATION MODE SELECTION

Note	COMSEL	Baud Rate	Modulation
8 MHz 4 MHz	Logic 1 Logic 0	41.6 Kbps 10.4 Kbps	PWM VPW

The different oscillator frequencies can be supplied to the JCI through a variety of techniques. If the host cannot supply 4 MHz and 8 MHz clock inputs to the JCI, then an oscillator selection must be devised which would allow the switching of the JCI's input oscillator frequency between 4 and 8 MHz, possibly using the logic level of the COMSEL line to determine the input frequency. The COMSEL input is level sensitive, and therefore switching between VPW and PWM can be performed simply by changing the logic level of the COMSEL input and the oscillator frequency. However, resetting the JCI when changing oscillator frequencies will ensure the JCI will begin communicating with the multiplex bus from a known state.

A.6.2.3 IN-FRAME RESPONSE AND I.D. BYTE—The JCI supports the optional transmission of an In-Frame Response. This option is selected by the logic level of the IFR input. If the IFR pin is at a logic one, a single byte In-Frame Response containing the I.D. byte will be transmitted at the appropriate time during the message frame. The I.D. byte of the JCI is the byte input on the I.D. pins (ID0-ID7). This byte is latched into the JCI upon reset, and should be hardwired in the application. In this example the I.D. byte of the JCI is hardwired to B5.

A.6.2.4 MESSAGE TRANSMISSION—The loading of a message for transmission by the JCI is begun by the host asserting the STX input, and then enabling the SPI interface and transferring a complete message (up to 11 bytes) to the JCI through a series of single byte SPI transfers. After the last byte has been transferred to the JCI, the host disables the SPI interface, and negates the STX input. Once the host has begun transmitting a message to the JCI, the JCI will assert the BSY output. This informs the host that the transmit buffer has data to be transmitted in it. The BSY output will stay asserted until the message is successfully transmitted onto the multiplex bus. Once the STX input is negated, the JCI will then attempt to transmit the message onto the multiplex bus. The JCI will handle all bus access functions, including idle bus detection, arbitration, and automatic retry (if necessary).

A.6.2.5 MESSAGE RECEPTION—The JCI will receive and buffer complete messages transmitted onto the multiplex bus. Once an entire message has been received with no errors, and the CRC byte verified as correct, the JCI will inform the host that a message is ready for delivery by asserting the RTS output. When the host is ready to receive the message, it enables the SPI interface, and asserts the CTS input. One byte is then transferred to the host, and the host then negates the CTS input to indicate to the JCI that the byte has been received. This is repeated for each byte until the entire message has been transferred to the host. When transmission of the last byte of the message begins, the JCI will negate the RTS output, informing the host that the last byte is being transmitted. After the last byte has been received by the host, the host negates the CTS input, and then disables the SPI interface. Since the JCI can buffer two complete messages received from the bus, the JCI may already have another message waiting for transmission to the host when one is finished. In this case, the JCI will still negate RTS to indicate the transmission of the last byte of the first message, and then reassert RTS as soon as the last byte of the first message is received by the host. If the host does not service the JCI before both receive buffers are filled, the JCI will then ignore any other messages transmitted onto the multiplex bus until one of the received buffers is emptied by the host.

A.6.3 JCI Pin Names and Descriptions—The names and descriptions of the pins of the JCI are shown in Table A10.

A.6.4 Additional Capabilities—The JCI supports automatic message retransmission after loss of arbitration, or detection of a transmission error. The JCI will attempt to retransmit a message up to two times if an error is detected in the message received. In the case of arbitration loss, the JCI will attempt to retransmit a message indefinitely. The JCI contains a digital filter to reject short noise pulses occurring on the multiplex bus, and can transmit and receive Break symbols, in either PWM or VPW format. The JCI also contains a mask/match optional message filter to reduce the number of messages passed to the host.

TABLE A10—JCI PIN NAMES AND DESCRIPTIONS

Pin Number	Pin Name	Description
1	OSC1	Oscillator 1
2	OSC2	Oscillator 2
3	SCK	SPI Serial Clock
4	SDO	SPI Serial Data Out
5	SDI	SPI Serial Data In
6	CTS	Clear To Send (Active Low)
7	STX	Start Transmit (Active Low)
8	BSY	Busy (Active Low)
9	RTS	Request To Send (Active Low)
10	FLUSH	Flush Message Buffer (Active Low)
11	MODE0	Mode Select 0
12	MODE1	Mode Select 1
13	COMSEL	Communications Select
14	VSS	Ground
15	RESET	Reset (Active Low)
16	CE	Chip Enable (Active Low)
17	IFR	In Frame Response Enable
18	TxJ	Bus Transmit Output
19	RxJ	Bus Receive Input
20	ID0	I.D. Byte - bit 0
21	ID1	I.D. Byte - bit 1
22	ID2	I.D. Byte - bit 2
23	ID3	I.D. Byte - bit 3
24	ID4	I.D. Byte - bit 4
25	ID5	I.D. Byte - bit 5
26	ID6	I.D. Byte - bit 6
27	ID7	I.D. Byte - bit 7
28	VDD	Power Supply

APPENDIX B
SUPPORTING DOCUMENTS

The following is a list of documents that may be useful to the reader for a further understanding of the examples shown in Appendix A:

Ford Hosted Bus Controller Chip User's Guide

Ford Hosted Bus Controller Circuit

Delco Introduction to GM Class 2 Serial Data Bus XDE - 3100

Delco DLCS/P IC User's Guide XDE - 3101

Delco DLCS/P IC Data Sheets XDE - 3102

Silicon Systems, F691 Transceiver Data Sheet - 67F686

SGS-Thomson, ST9 Family Technical Manual - DBST9TMST/1

SGS-Thomson, ST9 Family 8/16 Bit MCU Programming - DBST9PMST/1

SGS-Thomson, ST9XXX Databook - DBST9ST/1

SGS-Thomson, ST9 Brochure - BRST9/1190

Motorola, MC68HC05C4/C8, Technical Data 8-Bit Microcomputer - AD1991R2

Motorola, M68HC05 Applications Guide - M68HC05AG/AD

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EXPANDED DIAGNOSTIC PROTOCOL FOR OBD II SCAN TOOLS—SAE J2205 DEC95

SAE Recommended Practice

Report of the SAE Vehicle E/E System Diagnostic Standards Committee approved June 1994 and revised December 1995. Rationale statement available.

Foreword—Title 13, California Code of Regulations, Section 1968.1 "Malfunction and Diagnostic System Requirements 1994 and Subsequent Model Year Passenger Cars, Light Duty Trucks, and Medium Duty Vehicles With Feedback Control Systems," more commonly known as OBD II, includes the requirement that motor vehicle manufacturers provide information for the diagnosis and service of emissions-related powertrain components using the SAE J1978 OBD II Scan Tool and commonly available non-microprocessor tools (§ 2.1).

In order for motor vehicle manufacturers to use an SAE J1978 OBD II Scan Tool to diagnose and service emissions related powertrain components:

a. Vehicles must support a message protocol compatible with the facilities of the OBD II Scan Tool and capable of accessing the vehicle services required to diagnose and service vehicle emissions related powertrain components and systems.

b. The SAE J1978 OBD II Scan Tool must include facilities that allow the scan tool user to enter, edit, select, and transmit messages to a vehicle, identify the messages to be received from the vehicle, and receive them; and describe how to process the data in the received messages, and process them.

The vehicle communication interface used for this purpose is the one used by the vehicle to support SAE J1979 messages.

The messages to be transmitted or received and processed must conform to the requirements defined in SAE J1979, SAE J1850, and ISO 9141-2, with the exception that the message header and data fields may be vehicle specific.

The purpose of the Expanded Diagnostic Protocol is to define the encoding techniques to be used:

a. To describe to the SAE J1978 OBD II Scan Tool the messages to be transmitted to a vehicle and how they are to be transmitted.

b. To describe to the SAE J1978 OBD II Scan Tool the messages to be received and processed by the scan tool, and

c. To describe to the SAE J1978 OBD II Scan Tool how to process the data in the received messages.

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1. *Scope*—This SAE Recommended Practice defines the Expanded Diagnostic Protocol (EDP), the requirements for the SAE J1978 OBD II Scan Tool for supporting the EDP protocol, and associated requirements for diagnostic and service information to be provided by motor vehicle manufacturers.

Appendix A includes worked examples of the use of the protocol.

2. *References*

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1850—Class B Data Communication Network Interface

SAE J1930—Electrical/Electronic Systems Diagnostic Acronyms, Terms, and Definitions

SAE J1962—Diagnostic Connector

SAE J1978—OBD II Scan Tool

SAE J1979—Common Diagnostic Test Modes

SAE J2008—Recommended Organization of Vehicle Service Information

2.1.2 ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO 9141-2:1994(E)—Road vehicles—Diagnostic systems—CARB requirements for interchange of digital information

2.1.3 OTHER PUBLICATIONS

AIAG-B-1 1994—Automotive Industry Action Group—Bar Code Symbology Standard—3 of 9 Bar Code Symbols

Section 1968.1, Title 13, California Code of Regulations, "Malfunction and Diagnostic System Requirements 1994 and Subsequent Model Year Passenger Cars, Light Duty Trucks, and Medium Duty Vehicles With Feedback Control Systems"

Environmental Protection Agency 40 CFR Part 86 Control of Air Pollution From New Motor Vehicles and New Motor Vehicle Engines; Regulations Requiring On-Board Diagnostic Systems on 1994 and Later Model Year Light-Duty Vehicles and Light-Duty Trucks

2.2 Diagnostic Terms, Definitions, and Acronyms—SAE J1930 is hereby referenced as the basis for all such terms in this document, with the following additions:

CRC—Cyclic Redundancy Check—A byte of data appended to message data transmitted on SAE J1850 to ensure detection of corrupted data. CRC is defined in SAE J1850.

DSV—Data Security Verification—A byte of data appended to Extended Diagnostic Protocol definitions to ensure detection of corrupted data in EDP definitions, especially when they are entered and/or edited.

EDP—Extended Diagnostic Protocol—A method of encoding: messages to be transmitted, the selection of messages to be received, and how the data in the received messages are to be processed so that these messages can be processed by the SAE J1978 OBD II Scan Tool.

OBD II—A term commonly used to refer to Section 1968.1, Title 13, California Code of Regulations, "Malfunction and Diagnostic System Requirements 1994 and Subsequent Model Year Passenger Cars, Light Duty Trucks, and Medium Duty Vehicles With Feedback Control Systems."

RDPI—Received Data Processing Information—The information that describes how to process the data in received messages. This information includes a Received Data Processing Type and may include other type specific information.

RDPT—Received Data Processing Type—A code that indicates which data in the received message is to be processed, how the data is encoded, and how it is to be processed.

2.3 Codes Used in This Document—Unless otherwise specified, all codes shown in this document are hexadecimal. All codes shown preceded by a "$" (e.g., $1F) are also hexadecimal.

2.4 Tolerance for Timing Values—Unless otherwise specified, all timing values will have a ±10% tolerance (e.g., 10ms = 10 ms ± 1 ms).

2.5 User Manual and/or Help Facility—References to "user manual" and/or "help facility" in this document refer to the user manual and/or help facility requirement of SAE J1978 OBD II Scan Tool.

2.6 Significance of Bytes in a Multiple Byte Field of a Received Message—With respect to Received Data Processing Type definitions, a multiple byte field in a received message is interpreted first received byte, second received byte, third received byte, etc., and last received byte of the field as the most significant byte, less significant byte(s), and finally, the least significant byte, respectively.

3. *Introduction*—EDP provides a way of describing to the SAE J1978 OBD II Scan Tool:

a. Messages to be transmitted to the vehicle, and associated operating information (i.e., message repetition rate, etc.).
b. The messages to be received from the vehicle and processed.
c. How to process the data contained in the received messages.
d. Miscellaneous ISO 9141-2 related information (e.g., stop communication message, idle message, when to use the stop message, idle message parameters, etc.).

EDP is intended as an open-ended means for allowing motor vehicle manufacturers to communicate, through the OBD II supported communication interface, with vehicle modules using vehicle and module specific messages. EDP, as a minimum, is available to support diagnosing and servicing emissions-related components and systems.

Motor vehicle manufacturers may include and reference EDP definitions within diagnostic and service procedures for emissions-related components and systems.

4. *Communication Interfaces and Messages Supported*—The purpose of the functionality defined in this document is to support the use of the SAE J1978 OBD II Scan Tool for communicating with vehicles for the purpose of diagnosing and servicing vehicle emissions-related components and systems. This communication uses messages transmitted to and received from a vehicle that may be unique to a given vehicle manufacturer, model year, vehicle body type, powertrain module, etc. These messages will support functions unknown at the time this document is developed. Compared to the SAE J1979 messages, these messages may have different message headers and different data fields.

In order to support the communication requirements unique to ISO 9141-2, EDP must support:

a. The user's selection of an address.
b. The transmission of a message that terminates the communication link with the currently addressed module(s), and
c. The definition of an idle message and the characteristics of its transmission.

The other parameters defined by ISO 9141-2 and unmodified by SAE J1978 remain in effect.

EDP messages will use the same vehicle interface that supports the SAE J1979 messages.

Response messages received from an ISO 9141-2 interface must be no longer than 256 bytes.

5. *SAE J1978 OBD II Scan Tool EDP Support Requirements*—The SAE J1978 OBD II Scan Tool must allow users to enter, edit, and delete EDP definitions, and to select EDP definitions for processing (i.e., execution) and termination.

The SAE J1978 OBD II Scan Tool must be able to repeatedly transmit at least two messages, and monitor for, receive, and process the data in at least four receive message definitions and their associated processing information, simultaneously. A total of at least 256 bytes must be available to retain message bytes received due to active definitions.

The OBD II Scan Tool must allow the entry and retention of a combined total of at least 15 EDP definitions, where each definition may require up to 256 characters. One byte in a definition consists of two characters (e.g., 3C). One field separator (i.e., ",") is one character. One ";" is one character.

The determination of the retention time of EDP definitions after external power is disconnected from the scan tool is left to the discretion of the scan tool manufacturer.

The format of all definitions will include input data security verification (DSV) information and definition length information to minimize data input errors. The scan tool shall indicate to the user the presence of data entry errors in any definition. The scan tool shall allow the user to enter and save definitions that include errors and edit them. The scan tool shall not allow the user to process definitions with errors.

The user's manual/help facility of an SAE J1978 OBD II Scan Tool must document how to enter, edit, delete, select for processing, and select for termination EDP definitions.

The scan tool must support the entry of all the characters used in message definitions, such as hexadecimal data (i.e., 0-9, A-F), a "don't care nibble" identifier character, shown in this document as a "/" (slash), and a field separator character, shown in this document as a "," (comma).

The actual means of performing these actions is left to the scan tool manufacturer. The scan tool user's manual/help facility must describe how to perform these actions.

The processing of EDP definitions shall have no effect on other functions of the SAE J1978 Scan Tool (e.g., automatic determination of OBD II interface, processing of SAE J1979 messages, etc.).

6. *EDP Definitions*

(R) **6.1 Introduction**—There are four general types of EDP definitions:

a. Control type
b. Transmit type
c. Receive only type
d. Miscellaneous type

Each definition type includes a variable set of individual fields (e.g., id field (see 6.3), length field (see 6.4), type field (see 6.5), transmit message information (tx msg) field (see 6.6), receive filter information (rx filter) field (see 6.7), received data processing information (rx data processing info) field (see 6.8), and data security verification information (DSV) field (see 6.9)), each of which are further described in sections below.

The general forms of the four general EDP definition types are:

For control type definitions:
<id>,<length>,<type>,<DSV>
For transmit type definitions:
<id>,<length>,<type>,<tx msg>,<rx filter>,<rx data processing info>,<DSV>
For receive only type definitions:
<id>,<length>,<type>,,<rx filter>,<rx data processing info>,<DSV>
For miscellaneous type definitions:
<id>,<length>,<type and additional information>,<DSV>

6.2 Validation of Definition Data—The SAE J1978 OBD II Scan Tool will check for the correctness of all values entered for a given definition. Correct values for all fields, including the length of the overall definition, the codes used, the lengths of subfields, and the DSV value are required in order for the definition to be allowed to be processed.

6.3 Id Field—The id of a definition is the identification tag that allows a user to select a given definition for editing, deletion, execution, and termination. Some id values (see 6.3.1) imply automatic execution. Id values are assigned by the vehicle manufacturer. Diagnostic and service information shall reference definitions by their id. The id is available for users to indicate definitions to be edited, deleted, executed, and terminated.

The actual method used by a given SAE J1978 OBD II Scan Tool to enable the user to indicate which definition(s) the user wishes the scan tool to process must be described in the scan tool user's manual/help facility.

If a given definition id is already associated with an EDP definition when another message definition using the same id is successfully entered then the previous definition shall be replaced by the new definition.

Relative to vehicle diagnostic or service procedure documentation, where it would be useful, it is recommended that some meaningful identification (i.e., test name - EGR TEST, procedure name - INITIALIZATION, etc.) be associated in vehicle repair procedures with one or a set of definitions that perform an identifiable diagnostic or service procedure. This associated name could be used to directly access effectively similar facilities in scan tools that support them.

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§3.1 Automatic Execution for Definition Ids 0 to 9—If a message definition with an id in the range of 0 to 9 is successfully entered into the scan tool then the scan tool shall, in addition to recording that message definition, process it immediately as if it had been entered and selected for processing by the scan tool user. Any currently executing definition having the same definition id shall be terminated and replaced by the new definition.

6.4 Definition Length Field—The length field specifies the length or size of the definition in characters. Definition length is the number of characters in the definition, beginning with the definition id field and ending with the DSV field, inclusive. This includes any "don't care" symbols ("/") and field separators (","). The length field is one byte.

6.5 Definition Type Field—The type field indicates the type of definition.

Control type definitions (see 7.1.1 and 7.2) are used to define general operating parameters such as ones associated with the communication interface. When connected to a given vehicle, the SAE J1978 OBD II Scan Tool will automatically identify the communication interface used by the vehicle for CARB OBD II functions.

Transmit type definitions (see 7.1.2 and 7.2) define messages to be transmitted, how often they are to be transmitted when selected for processing, and optionally, an associated receive message filter and received data processing information.

Receive only type definitions (see 7.1.3 and 7.2) define only a receive message filter and associated received data processing information.

Miscellaneous type definitions are intended to define situations that fall out of the other definition types. Currently there are no miscellaneous definition types.

6.6 Transmit Message Field—The <type> and <tx msg> fields together describe what is to be transmitted and other miscellaneous transmit parameters such as how often the message will be transmitted.

The transmit message field, "<tx msg>", has the form:

aa bb cc ... zz

where:

aa bb cc ... zz are hexadecimal bytes that define the message to be transmitted.

The actual message transmitted by the scan tool is determined by the definition type, the interface being used, and the values of aa bb cc ... zz.

If the transmit type is SAE J1979, the transmit message field, "aa bb ... zz", will be interpreted as the SAE J1979 request message mode and mode data. The header for the transmit message and the receive filter information will automatically be as defined by SAE J1979.

As defined in SAE J1850, a CRC will automatically be appended to all messages transmitted on an SAE J1850 interface. As defined in ISO 9141-2, a checksum will automatically be appended to all messages transmitted on an ISO 9141-2 interface.

6.7 Receive Message Filter Field—Receive message filter information, or filters, is used by the scan tool to filter messages for processing from all the messages that may be received by the scan tool from the vehicle.

Specifying receive message filter information is optional but generally is a requirement for effective scan tool usage, particularly for SAE J1850 vehicle interfaces. If no receive message filter information is specified in a transmit or a receive only definition, default receive message filter information may be available in some cases. For example, if the transmit type is SAE J1979, then the associated SAE J1979 response message header definition will be used as the default receive message filter. If the vehicle OBD II interface is ISO 9141-2, then the default receive message filter information will be to use any message received.

Only one definition with a null receive message filter field (i.e., this field does not contain any filter information, such as ","), may be active at a time (i.e., all received messages will be processed by the received data processing instructions in this definition). All active non-null receive message filter fields shall take precedence over an active definition with a null receive message filter field. That is, any message detected by the scan tool should be processed against the active non-null received filters first, and processed against an active null receive filter last.

As defined in SAE J1850, a CRC will be expected for all messages received on a SAE J1850 interface. As defined in ISO 9141-2, a checksum will be expected for all messages received on an ISO 9141-2 interface.

The received message filters information has the form:

aa bb cc ... zz

where:

aa bb cc ... zz are nibble (i.e., 4 bits) by nibble indicators of whether to ignore or to match a supplied nibble value:

x or / to ignore a received nibble

<0 - F> to specify the value the received nibble must match

The comparison of received message data with all currently active receive message filters begins with the first byte of the received message and continues for the length of a given receive message filter. The received message must be at least as long as a given filter for that filter to be used. There is no implied meaning given to the data of the received message that are compared with received message filters. A particular vehicle's message protocol may interpret the data compared to received message filters as partial headers, full headers, headers and data, etc.

6.8 Received Data Processing Information (RDPI) Field—Associated with every receive message filter definition is default or specified sets of received data processing information.

Each set of received data processing information defines:

a. Which data in the received message the data processing information applies to
b. How that data is to be interpreted
c. How that data is to be formatted, if displayed
d. Other optional features, such as display constants
e. Other ways in which the data may be processed

If no received data processing information is specified with a given receive message filter, the following default received data processing information will be used:

All data of the received message will be displayed as hexadecimal values, beginning with the first byte of the received message through the last byte of the received message.

The display facilities of a given SAE J1978 OBD II Scan Tool implementation are subdivided into at least two display areas, in keeping with the SAE J1978 OBD II Scan Tool requirement to display simultaneously at least two data values. How a given scan tool actually implements display areas is left to the discretion of the scan tool manufacturer and must be described in the scan tool user's manual/help facility.

More than two display areas may be supported.

If data to be displayed from a given received message is larger than an available display area, the available display area is used as a window, displaying only a portion of the total data to be displayed, beginning with the first character of data to be displayed. The scan tool must allow the user to move the window back and forth over the entire data to be displayed.

The scan tool user's manual/help facility must specify how the display area window is moved back and forth over display data.

The complete set of received data processing information associated with a given received message filter is made up of one or more sets of Receive Data Processing Information <RDPI>:

<rx data processing info> = <RDPI><RDPI> ... <RDPI>

A set of Received Data Processing Instructions <RDPI> is of the form:

<RDPI> = <Received Data Processing Type><additional information>

Received Data Processing Types (RDPT) are further described in 7.3. Any "additional information" depends on the RDPT and is further explained in 7.4.3. The size of each received data processing information is defined by the type and any additional information.

6.9 Data Security Verification Field—The Data Security Verification Field <DSV> field is used with the length field to verify the correct entry of a definition into the scan tool. The value of DSV is the simple 1 byte sum without carry of all byte values in the message definition.

Where a "," is a part of a definition, the ASCII value for "," ($2C) will be included in the DSV calculation in place of the ",". Where an "/x" is a part of a definition, the ASCII value for "/" ($2F) and the value 0x will be included in the definition, the ASCII value for "/" ($2F) and the value 0x will be included in the DSV calculation in place of the "/x". Where an "x" is a part of a definition, the ASCII value for "x" ($2F) and the value x0 will be included in the DSV calculation in place of the "x".

7. Codes for EDP Definition Fields

7.1 Definition Type Codes—The following sections briefly identify the values for Control, Transmit, and Receive Only definition type codes. These codes are more fully explained in 7.2.

7.1.1 CONTROL DEFINITION TYPE CODES—Figure 1 shows the codes defined for Control Type definitions and a short description of the meaning of the codes.

7.1.2 TRANSMIT DEFINITION TYPES—Figure 2 shows the codes defined for Transmit Type definitions and their descriptions.

7.1.3 RECEIVE ONLY DEFINITION TYPES—Figure 3 shows the code defined for Receive Only Type definitions and its description.

7.1.4 VEHICLE MANUFACTURER RESERVED DEFINITION TYPES—Definition type codes $80 - $FF are reserved for use by vehicle manufacturers.

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Type	Description
12	Terminate the current ISO 9141-2 communication connection and begin the ISO 9141-2 addressing and initialization sequence with the given address
13	Define the idle message to be used for ISO 9141-2 communication
14	Define the stop 9141 communication message to be used to terminate ISO 9141-2 communication
17	Set the standard message retransmission interval
18	Use only two display areas
19	Delete all current definitions
1A	Delete a given definition by id
1B	Deactivate all active receive filters
1C	Deactivate a receive filter by definition id

FIGURE 1—CONTROL DEFINITION TYPE CODES

Type	Description
20	Transmit this message once per selection
21	Transmit this message repeatedly at the standard interval once selected, until selected again, at which time stop the repeated retransmission
22	Transmit message repeatedly at given interval once selected, until selected again, at which time stop the repeated retransmission
23	Transmit message repeatedly, once selected, at given interval for a given maximum interval, until selected again at which time stop the repeated retransmission
24	Process this message as an SAE J1979 request and transmit once per selection
25	Process this message as an SAE J1979 request and transmit repeatedly at the standard interval once selected, until selected again, at which time stop the repeated retransmission
26	Process this message as an SAE J1979 request and transmit repeatedly at the standard interval once selected, until selected again, at which time stop the repeated retransmission
27	Process this message as an SAE J1979 request and transmit message repeatedly, once selected, at given interval for a given maximum interval, until selected again at which time stop the repeated retransmission

FIGURE 2—TRANSMIT DEFINITION TYPES

Type	Description
30	Receive only definition

FIGURE 3—RECEIVE ONLY DEFINITION TYPES

7.2 **Definition Type Codes Defined**—For each message definition type, the form of the message type information field, the definition of any additional information, and the processing to be performed by the scan tool is shown.

12 Terminate the current ISO 9141-2 communication connection and begin the ISO 9141-2 addressing and initialization sequence with the given address
12 xx

where: xx = ISO 9141-2 address

When a message definition with this message type is processed by a scan tool and ISO 9141-2 is the OBD II communication interface, the scan tool will terminate the current ISO 9141-2 communication link using a stop 9141 message, if one has been defined, or if one is not defined, will terminate all communication for 5 s to force all active communication to terminate. After active communication has been terminated, a minimum of 300 (decimal) ms of bus idle will be allowed before the scan tool will begin the ISO 9141-2 addressing and initialization process, using the address given in the definition.

It is recommended that the scan tool indicate to the user what is going on whenever a 5 s delay is in progress.

13 Define the idle message to be used for ISO 9141-2 communication
13 aa bb ... zz

where: aa bb ... zz defines the idle message to be used to keep the ISO 9141-2 interface from reverting into address mode

This message definition defines the message to be used to keep the ISO 9141-2 communication link with the currently addressed module active.

14 Define the stop message to be used to terminate ISO 9141-2 communication
14 aa bb ... zz

where: aa bb ... zz defines the message to be used to terminate communication on the ISO 9141-2 interface

Subsequent redefinitions of the stop message replace previous definitions. If no aa bb ... zz data follows the 14, any previously defined stop message is deleted and the stop message facility is not available.

17 Set the standard retransmission interval
17 xx

where: xx becomes the standard retransmission interval, in 10 (decimal) ms increments

When a message definition with this message type is processed by a scan tool, the scan tool will begin to use the value specified for current and subsequent messages that are to be retransmitted at the standard rate.

Until a definition of this type specifies a message retransmission interval, an interval of 120 (decimal) ms shall be used. The retransmission interval is the time between the start of one message transmission and the start of the next transmission of the same message.

18 Use only two display areas
18

When a message definition with this message type is processed by a scan tool, the scan tool will use only two display areas, even if the scan tool is able to support more than two.

19 Delete all current message definitions
19

When this message type is processed by a scan tool, the scan tool will delete all current definitions.

1A Delete a given definition
1A xx

where: xx is a definition id

When this message type is processed by a scan tool, the scan tool will delete the message definition associated with the given id.

1B Deactivate all receive filters
1B

When a message definition with this message type is processed by the scan tool, the scan tool will deactivate all currently active receive message filters.

1C Deactivate a given receive filter
1C xx

where: xx is a definition id

When a message definition with this message type is processed by the scan tool, the scan tool will deactivate the receive filter associated with the given definition id.

20 Transmit given message once
20

When a message definition with this message type is processed by a scan tool, the scan tool will transmit the message contained in this definition, and enable any receive filter information contained in this definition. If the processing of this definition causes the limit of a given scan tool for simultaneously active transmit messages or simultaneously active receive filters to be exceeded, the oldest active transmit message will be terminated or the oldest active receive filter will be deactivated.

21 Transmit given message repeatedly at the standard interval
21

When a message definition with this message type is processed by a scan tool, the scan tool will begin to repeatedly transmit at the standard interval the message defined in this definition. The next time this definition is selected, message retransmission will be terminated. When selected again, the message will again begin to be repeatedly retransmitted, and so on.

The receive filter information associated with the definition selected will be added to the set of simultaneously active receive filters when the transmit message begins to be transmitted and will be deleted from the set of simultaneously active receive filters when message transmission is terminated.

22 Transmit a given message repeatedly at a given interval
22 xx

where: xx is the given interval in 10 (decimal) ms

Same processing as for type 21 except that the retransmission interval is specified in the definition.

23 Transmit a given message repeatedly at a given interval for a given maximum interval
23 xx yy yy

where: xx is the given retransmission interval in 10 (decimal) ms, and yy yy is the maximum transmission interval in seconds

Same processing as for type 22 except that the retransmissions will be terminated at the end of the maximum transmission interval or if this definition is selected again.

24 Process as a SAE J1979 request message and transmit it once per selection
24

When a message definition with this message type is processed by a scan tool, the scan tool will process the message as a SAE J1979 message. The transmit information supplied in this definition begins with the SAE J1979

mode value followed by any additional mode specific information. The header for the SAE J1979 message will be according to the OBD II interface type as defined in SAE J1979. The resultant transmit message will be transmitted once per selection. The default receive filter and received data processing information will be as defined for the selected SAE J1979 message.

25 Process this message as an SAE J1979 request and transmit it repeatedly at the standard interval

25

Process the transmit information as is defined for type 24 and transmit this message as is defined for type 21.

26 Process this message as an SAE J1979 request and transmit message repeatedly at given interval

26 xx

where: xx is the given interval in 10 (decimal) ms.

Process the transmit information as is defined for type 24 and transmit this message as is defined for type 22.

27 Process this message as an SAE J1979 request and transmit message repeatedly at given interval for a given maximum interval

27 xx yy yy

where: xx is the given retransmission interval in 10 (decimal) ms, and yy yy is the maximum transmission interval in seconds

Process this message as is defined for type 24 and transmit this message as is defined for type 23.

30 Receive only definition

The transmit information field of this definition should be null. Use the receive message filter field of the definition to filter received messages, and process the received messages as defined in the received data processing information field.

7.3 Received Data Processing Type (RDPT) Codes—The following is a list of Received Data Processing Types and a short description of the processing type.

7.3.1 TEXT DISPLAY DATA AS A DEFINITION—Text to be displayed as a part of processing of the data from a received message may be defined in a definition. The text may be displayed before and/or after the processed data. RDPTs within the range $00 to $7F are interpreted as standard ASCII codes. Some of these codes are for non-displayable characters (e.g., $0D for carriage return may cause the scan tool to move to the next line or may cause the scan tool to not do anything) and generally should not be used. Character codes for "A" to "Z" and "a" to "z" may be displayed in the same way, if not supported uniquely.

7.3.2 DATA CONVERSION—Figure 4 shows RDPT codes that identify which data in the received message is to be processed, how the data is to be interpreted, and how the data is to be displayed.

RDPT	Description
00	Display byte(s) as hexadecimal
01	Display byte(s) as hexadecimal
02	Display byte(s) as byte
03	Display byte(s) as byte with display mask
04	Display byte(s) as bits
05	Display byte(s) as bits with display mask
06	Display byte(s) as unsigned decimal
07	Display byte(s) as signed decimal
08	Display byte(s) as signed decimal with signed offset
09	Display byte(s) as (xx + kF + b, F = signed decimal
0A	Display byte(s) as decimal with binary point
0B	Display byte(s) as DTC 2 byte pairs
0C	Display byte(s) as ASCII packed data
0D	Display standard string followed by byte(s)
0E	Display byte(s) as a percentage with given denominator (xx x 100 (decimal) / denominator)
0F	Display byte(s) with a given signed offset as a percentage with a given denominator ((xx + b, b = offset) * 100 (decimal) / denominator)
10	Display byte(s) using given scaling data
11	Display byte(s) as BCD data
12	Display one of supplied text not based on logic value of received data AnDed with given bit mask
13	Display one of supplied text not based on inverse logic value of received data AnDed with given bit mask

FIGURE 4—DATA CONVERSION

7.3.3 MISCELLANEOUS DISPLAY FUNCTIONS—Figure 5 shows RDPT codes that allow the scan tool to display standard text information, clear parts or all of the display, and control the location of the next information to be displayed.

RDPT	Description
20	Display given supplied string
21	Clear entire display
22	Clear given display area
23	Position to beginning of display
24	Position to beginning of next display area
25	Position to beginning of given display area
26	Clear a given display area and position to the beginning of the display area
27	Display byte(s) as y = aX + b, X = unsigned decimal
28	Display 3 blanks
29	Display 4 blanks
2A	Move right 1 position
2B	Move right 2 positions
2C	Move right 4 positions
2D	Move right a given number of positions

FIGURE 5—MISCELLANEOUS DISPLAY FUNCTIONS

7.3.4 RDPT CODES FOR ALTERING DEFINITION EXECUTION—Figure 6 shows RDPT codes that cause the scan tool to alter the execution of definitions based on the data received. They describe what received data is to be processed, what data is to be compared to the received data, what type of data comparison must be found to cause a change in definition execution, and what change to definition execution is to be made if the comparison is true.

RDPT	Description
A0	If byte(s) equal terminate processing of this definition
A1	If byte(s) equal terminate processing of this definition and start processing of a given definition
A2	If byte(s) equal terminate processing of the given definition
A3	If byte(s) not equal terminate processing of this definition
A4	If byte(s) not equal terminate processing of this definition and start processing of a given definition
A5	If byte(s) not equal terminate processing of the given definition

FIGURE 6—RDPT CODES FOR ALTERING DEFINITION EXECUTION

7.3.5 RDPT CODE FOR UNIQUE PROCESSING OF MULTIPLE RECEIVED MESSAGES—Normally, when multiple messages are received due to the same definition, each received message is processed as the latest version of the same message. The last message received is the last one processed and last one displayed. Any previous messages have been processed and replaced by the next received message. In some cases, however, multiple messages received due to the same definition each convey unique information that must be displayed separately. Examples are the response messages to a SAE J1979 mode 3 - Request DTC's message.

Figure 7 shows the RDPT code that causes the scan tool to separately process multiple messages, received due to the same definition, as unique data. The results of the received message processing of each message are to be concatenated, one after another, from the first received message to the last, within the limits of the scan tool to retain all the received data.

When used, this RDPT code must be the first one in a Received Data Processing Information field. When a scan tool cannot retain any more received messages due to a definition that includes this RDPT code, the scan tool shall indicate such an error to the user, and document this error type in the user/help facility. The scan tool will allow the user to scan the processed data as described in SAE J1978 for displaying any data that cannot all be displayed because of the size of the data is greater than the size of the display.

RDPT	Description
C0	Multiple messages received as the result of this definition are to be processed as unique information and displayed, one after the other in the order received, to the limit of the scan tool to retain them. Each selection of the definition that includes this RDPT, or retransmission of any command message if included, will restart the collection and processing of received messages.

FIGURE 7—RDPT CODE FOR UNIQUE PROCESSING OF MULTIPLE RECEIVED MESSAGES

7.4 Received Data Processing Type Codes Defined

7.4.1 SYMBOLS USED IN DESCRIBING RECEIVED DATA PROCESSING TYPES—The following defines symbols used in 7.4.3 to describe RDPTs:

xx Indicates an offset, in bytes, to the beginning of a data field in the received message ($00 = first byte in received message, $01 =

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second byte in received message, $FF = last byte in received message, $FE = second last byte in received message, etc. Note that the last byte of a received message is the message error detection byte. Some hardware may not make this byte available for processing. If the last message byte is referenced in a RDPT, but is not available, the RDPT will be ignored.)

yy Indicates the length of a data field, in bytes

xy Indicates a combination of an offset, in bytes, to the beginning of a data field and the length of a data field, in bytes, where the "x" and "y" are individual nibbles in one definition byte

where: x = offset, in bytes, to the beginning of a data field in the received message ($0 = first byte in received message, $1 = second byte in received message, $F = 16th (decimal) byte in received message, $E = 15th (decimal) byte in received message, etc.)
y = length of data field, in bytes ($1 = one byte, $2 = two bytes, etc.)
xy = $32 defines a 2 byte data field that begins with the 6th byte of the received message

aa Indicates an offset, in nibbles, to beginning of a data field in the received message ($00 = first nibble in received message, $01 = second nibble, etc.). The first nibble of the message is the most significant nibble of the first byte of the message, the second nibble is the least significant nibble of the first byte of the received message.

bb Indicates the length of a data field, in nibbles ($01 = one nibble, $02 = two nibbles, etc.)

cc ... cc Is a given byte field that is compared with the received data. The length of this field is the same as the received data field, i.e., yy or y. A "F" is used in the given data field to indicate a "don't care" compare of a nibble in the received data field.

dd ... dd Indicates a display mask. The size of the display mask is the same as the size of the data field the mask is to be applied to, i.e., yy or bb. For every bit in the mask whose value is 1, the value of the corresponding bit in the data field is to be displayed. For every bit in the mask whose value is 0, the value of the corresponding bit in the data field is NOT to be displayed. The value of a data bit is displayed as a "1" or a "0".

ee or ee ee Indicates a one or two byte index, typically into a list of string constants ($00 or $0000 is index to first entry, $01 or $0001 is index to second entry, etc.)

ff ... ff Is a bit mask for offset to an indexed standard string. One and only one bit in this bit mask must be a "1".

gg ... gg Is a signed offset value. The length of the signed offset gg ... gg is the same as the received data field, i.e., yy.

7.4.2 DEFAULT DATA DISPLAY POSITION—The description of some received data processing type codes refer to display areas. Unless otherwise specified, the first data to be displayed in a given display area will be displayed at the left most position in the display area. All subsequent data to be displayed will follow this data to the right.

Display areas can be top to bottom, left to right, or both. Unless otherwise specified, the first display area will be the top left one. Subsequent display areas will follow left to right, first on the top line, and then from top to bottom for subsequent lines.

7.4.3 RECEIVED DATA PROCESSING TYPES WITH PARAMETERS—The following show received data processing types with any associated additional information. The following use the symbols shown in 7.4.1.

80 Display byte(s) as hexadecimal
80 xy

81 Display nibble(s) as hexadecimal
81 aa bb

82 Display byte(s) as bits
82 xy

83 Display byte(s) as bits with display mask
83 xy dd ... dd

84 Display nibble(s) as bits
84 aa bb

85 Display nibble(s) as bits with display mask
85 aa bb dd ... dd

86 Display byte(s) as unsigned decimal, with a maximum field size in the received data of 4 bytes
86 xy

87 Display byte(s) as signed decimal data, with a maximum field size in the received data of 4 bytes
87 xy

88 Display byte(s) as signed decimal with signed offset with a maximum field size in the received data of 4 bytes
E = N + offset
where: E = value to be displayed
N = value of field in received message
offset = gg ... gg

89 Display byte(s) as y = aX + b, where X = signed decimal received bytes
89 xy jj kk ... kk
where: jj = one byte signed multiplier (a)
kk = signed offset (b) with same length as data byte(s)

8A Display byte(s) as decimal with binary point, with a maximum field size in the received data of 4 bytes
8A xy pp
where: pp = location of binary point in bits from the right end of the data field, $00 = to the right of the right most bit

8B Display byte(s) as DTC(s) if not zero
8B xy
The data length (y) must be a multiple of the DTC data length (i.e., 3 bytes). A DTC code of 0000 is not displayed.

8C Display byte(s) as ASCII codes
8C xy

8D Display standard text indexed by unsigned message byte
8D xy
The index value in the message must be within range of the standard text table (see 7.4.4). If index value is out of range then the tool shall indicate a "data out of range error" and this error shall be explained in the tool user manual/help facility. The maximum field size of the received data is 1 byte.

8E Display byte(s) as percentage with given denominator, with a maximum field size in the received data of 4 bytes
E = N * (100 (decimal)/denominator)
where: E = value to be displayed
N = value of field in received message
8E xy zz ... zz
where: zz ... zz is the denominator, and has the same length as the data field

8F Display byte(s) with given signed offset as a percentage with given denominator, with a maximum field size in the received data of 4 bytes
E = (N + offset) * (100 (decimal)/denominator)
where: E = value to be displayed
N = value of field in received message
8F xy gg ... gg zz ... zz
where: zz ... zz is the signed decimal denominator, and has the same length as the data field

90 Display byte(s) using given scaling data, with a maximum field size in the received data of 4 bytes
90 xy ss
where: ss is scaling value:
bit 7 = scaling type:
0 = binary scaling
1 = decimal scaling
bit 6 - 0 = signed scaling power
If P = absolute value of bits 6 - 0
for bit 7,6 = 00 then E = N * 2**P
= 01 then E = N / 2**P
= 10 then E = N * 10**P
= 11 then E = N / 10**P
where: E = value to be displayed
N = value of field in received message

91 Display byte(s) as BCD data. If any of received data is out of range then the tool shall indicate a "data out of range error" and this error shall be explained in the tool user manual/help facility.
91 xy

92 Display one of a set of two indexed logic texts (see 7.4.5). The index "ee" determines which text set in 7.4.5 to use. The selection of which of the two texts of the indexed set to display is based on ANDing the given bit mask "ff" with the received message byte at location "xx".
92 xx ff ee

93 Same as for 92, except that the result of the ANDing is inverted before selecting which text to display (see 7.4.5)

99 zz ff zz
- zz (Display given standard text (see 7.4.4))
  ff zz
  where: zz = index into standard text table
- 9E (Clear entire display)
  9E
- 9F (Clear given area)
  9F bb
  where: bb = display area id, $00 = top left display area, $01 = next display area
- A0 (Position to beginning of top left display area)
  A0
- AC (Position to beginning of next display area)
  AC
- B0 (Position to beginning of given display area)
  B0 bb
  where: bb = display area id, $00 = top left display area, $01 = next display area
- BE (Clear given display area and position to beginning of the display area)
  BE bb
  where: bb = display area id, $00 = top left display area, $01 = next display area
- BF (Display byte(s) as $y = aX + b$, where X = unsigned decimal received byte(s) with a maximum field size in the received data of 4 bytes)
  BF xy jj kk ... kk
  where: jj = one byte signed multiplier (a)
  kk = signed offset (b) with same length as data byte(s)
- C0 (If received byte(s) equal given value then terminate this definition)
  C0 xy zz ... zz
- C1 (If received byte(s) equal given value then terminate this definition and start the given definition)
  C1 xy zz ... zz ww
  where: ww = definition id
- C2 (If received byte(s) equal given value then terminate the given definition)
  C2 xy zz ... zz ww
  where: ww = definition id
- C3 (If received byte(s) do not equal given value then terminate this definition)
  C3 xy zz ... zz
- C4 (If received byte(s) do not equal given value then terminate this definition and start the given definition)
  C4 xy zz ... zz ww
  where: ww = definition id
- C5 (If received byte(s) do not equal given value then terminate the given definition)
  C5 xy zz ... zz ww
  where: ww = definition id
- C6 (Move right given positions)
  C6 pp
  where: pp = number of positions to move
- C8 (Process multiple received messages uniquely)
  C8

The RDPT must be the first RDPT in the received data processing information field.

7.4.4 STANDARD TEXT FOR USE WITH RECEIVED DATA PROCESSING TYPES—Figure 8 shows the standard text associated with RDPT's 8D and 9E. Scan tool manufacturers may use alternate text that conveys the same meaning as the standard text, if the alternative text is documented in the user manual/help facility associated with a given scan tool. Abbreviations found in SAE J1930 or the following pages may also be used. Other abbreviations may be used if they are documented in the scan tool user's guide/help facility.

7.4.5 LOGIC TEXT USED WITH RECEIVED DATA PROCESSING TYPES—Figure 9 shows the logic text associated with RDPT's 92 and 93.

Scan tool manufacturers may also use standard abbreviations. Scan tool manufacturers may use alternate text or alternate abbreviations if such are documented in the user manual/help facility associated with a given scan tool.

Each of the following indexed sets consists of two values. Based on the RDPT type, if the resultant logic value after processing the message data and the specified data is "0," then the text shown under the "0" column, for the index specified in the RDPI, is to be displayed. In a similar way, if the resultant logic value is "1," then the text shown under the "1" column is to be displayed.

Index	Standard Text	Index	Standard Text
00	Degrees Centigrade or Centigrade	02	Degrees Fahrenheit or Fahrenheit
03	% Calculated Load	04	% Full
05	% Full Deep	06	% Full Extended
07	% Full Off	08	% Full On
09	% Full Up	0A	% Maximum Torque
0B	% Mechanical	0C	% Open
0D	% Remaining Life	0E	% Rich
0F	Counts	10	Idle Period Absolute
11	Idle Period Gauge	12	Grams per second
13	Revolutions	14	Revolutions Per Minute
15	Kilometers Per Hour	16	Miles Per Hour
17	Liter	18	Lb
19	Degrees CW	1A	Degrees CCW
1B	Liters per 100 Km	1C	Milliamps
1D	Volts	1E	Hertz
1F	seconds	20	minutes
21	Pulses	22	Diagnostic Trouble Code
23	pulses	24	pulses per minute
25	Amperes	26	Counts
27	Cycles	28	Cyl.
29	Inches	2A	Feet
2B	Rich	2C	Lean
2D	Pints	2E	Feet
2F	Calculated Load Values	30	Stalled Catalyst
31	Evaporative	32	Secondary Air
33	Oxygen Sensor	34	Oxygen Sensor Heater
35	Coolant Temperature	36	Ambient Temperature
37	seconds	38	Short Term Fuel Trim
39	Long Term Fuel Trim	3A	Fuel Pressure
3B	MAP	3C	MAFS
3D	Spark Advance	3E	Intake Air Temperature
3F	Absolute Throttle Position	40	Air Status
41	Baro	42	Sensor
43	OBD Support	44	Freeze Points

FIGURE 8—STANDARD TEXT FOR USE WITH RECEIVED DATA PROCESSING TYPES

8. Optional Ways of Entering EDP Information—Some form of user input interface, such as a keyboard, must be available to the scan tool user to enter EDP definition information into the scan tool. However, other means may optionally be used to enter EDP definitions.

8.1 Use of Bar Codes for Entry of EDP Information—Optionally, the OBD II Scan Tool may also support the use of a bar code for entering EDP information.

Optionally, motor vehicle manufacturer diagnostic and service information may include EDP definitions in bar coded form.

Index	"0"	"1"
00	OFF	ON
01	FALSE	TRUE
02	DISABLE	ENABLE
03	CLOSED	OPEN
04	WITHIN	EXPANSION
05	USA OCR	LOCK
06	UNSECURED	SECURE
07	SPEED DENSITY	MASS AIR FLOW
08	DECREASE	INCREASE
09	DECREMENT	INCREMENT
0A	DOWN	UP
0B	OUT	IN
0C	BACKWARD	FORWARD
0D	NOT SUPPORTED	SUPPORTED
0E	MINUS	PLUS
0F	LEFT	RIGHT
10	DOWNSTREAM	UPSTREAM
11	BACK/PORT	FRONT
12	Open Loop	Closed Loop

FIGURE 9—LOGIC TEXT USED WITH RECEIVED DATA PROCESSING TYPES

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In both of these cases the bar code type to be used is defined in AIAG B-1 1984 AUTOMOTIVE INDUSTRY ACTION GROUP—BAR CODE SYMBOLOGY STANDARD—3 OF 9 BAR CODE SYMBOLS.

8.2 Other Ways of Entering EDP Information—Optionally, the OBD II Scan Tool may receive EDP information through a RS-232 interface, an allowed vehicle communication interface, or a cartridge.

The RS-232 interface or the vehicle communication interface, including the SAE J1962 connector, may be used to receive EDP information from sources such as a terminal connected to a SAE J2008 data base.

9. *Guidelines for Showing EDP Definitions to Print and by the Scan Tool*—It can be difficult to read EDP definitions, especially long ones, in documents. However, some printing techniques can be used to make it easier for users to read and keep track of their place in a definition.

Printed definitions can be broken down into small groups with extra white space, alternating background shading, alternating fonts (e.g., bold non-italic), etc. Alternating EDP fields could have alternating backgrounds.

The scan tool could display the fields of a definition with blank separators, alternating colors, or alternating shading.

White space could, at the discretion of the scan tool manufacturer, be saved and displayed as a part of the definition. The white space would be considered as a part of a definition as far as any checking and processing of a definition was concerned. Any scan tool memory required for white space entry and display would be over and above the requirement for user defined definition data. The scan tool user manual/help facility would list any such features.

APPENDIX A
WORKED EXAMPLES

A.1 SAE J1979 Messages as SAE J2186 Definitions

Mode 1 PID 00

00,16,24,0100,,8094,17 or 00,16,24,0100,,82A8,6D

Mode 1 PID 01

00,2E,24,0101,,20865198342082612082712082B1,48

Mode 1 PID 03

00,20,24,0103,,8101F208361IF,68

Mode 1 PID 04 Calculated Load Value

00,1E,24,0104,,208E81FF9803,E8

Mode 1 PID 05 Engine Coolant Temperature

00,20,24,0105,,208851D8209801,DC

Mode 1 PID 06 Short Term Fuel Trim—Bank 1

00,1C,24,0106,,208F51D9881,A7

Mode 1 PID 0A Fuel Pressure (gage)

00,1C,24,010A,,20895103O0,80

Mode 1 PID 0B Intake Manifold Absolute Pressure

00,18,24,010B,,208651,47

Mode 1 PID 0C Engine RPM

00,18,24,010C,,965202,35

Mode 1 PID 0D Vehicle Speed

00,16,24,0100,,8651,27

Mode 1 PID 0F Intake Air Temperature

00,18,24,010F,,8851D8,05

Mode 1 PID 10 Air Flow Rate—MAF Sensor

00,18,24,0110,,965252,89

A.2 Expanded SAE J1979 Worked Example

Mode 1 PID 01

00,2E,24,0101,,20865198242082612082712082B1,48

id = 00

The id of this definition is 00. Because the id is in the range of 00 to 09, the scan tool will execute this definition immediately once entered successfully.

length = 2E

The length ($2E = 46 decimal) indicates the number of characters in definition, including the length field and the DSV field. It is used to check entry accuracy.

type = 24

This is an SAE J1979 type definition. The first byte of the positive response field will just be the SAE J1979 mode value. The rest of the transmit header will be defined by the mode value. The header for the transmit message will be the interface currently being used. The receive filter is defined by the transmit message header.

transmit field = 0101

This is a mode 01 SAE J1979 request message. A second byte of 00 is defined for mode 01 request messages. The PID value is 01.

Receive filter field = <null>

The receive filter will be the default defined by the definition type and actual transmit message header.

Received data processing field = 20865198242082612082712082B1

20	ASCII code for 1 blank.
8651	Display bytes as unsigned decimal, field starts at byte 1 and is 1 byte in size. Byte 5 of the received response message is SAE J1979 response data byte 3, which is the number of emission related powertrain diagnostic trouble codes.
9824	Display standard text $24. This is "DTC."
20	Same as above.
8261	Display bytes as bits, field starts at byte 6 and is 1 byte in size. Byte 6 of the received response message is SAE J1979 response data byte 4, which is the evaluation/MIL status bits.
20	Same as above.
8271	Same as 8261 above, except this is for SAE J1979 response data byte 5, which is evaluation support bits.
20	Same as above.
8281	Same as above, except this is for SAE J1979 response data byte 6, which is the evaluation status bits.

DSV = 48 This is the DSV value for this definition.

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Report of the SAE Vehicle Network for Multiplexing and Data Communications Standards Committee approved November 1988, completely revised July 1995 and August 1995, and revised May 1994 and July 1995.

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1. Scope—This SAE Standard establishes the requirements for a Class B Data Communication Network Interface applicable to all On- and Off-Road Land-Based Vehicles. It defines a minimum set of data communication requirements such that the resulting network is cost effective for simple applications and flexible enough to use in complex applications. Taken in total, the requirements contained in this document specify a data communications network that satisfies the needs of automotive manufacturers.

This specification describes two specific implementations of the network, based on media/Physical Layer differences. One Physical Layer is optimized for

a data rate of 10.4 Kbps while the other Physical Layer is specified for a data rate of 41.6 Kbps (see Appendix A for a checklist of application-specific features). The Physical Layers parameters are specified as they would be detected on the network media, not within any particular module or integrated circuit implementation.

Although devices may be constructed that can be configured to operate in either of the two primary implementations defined herein, it is expected that most manufacturers will focus specifically on either the 10.4 Kbps implementation or the 41.6 Kbps implementation depending on their specific application and corporate philosophy toward network usage. However, low-volume users of network-interface devices are expected to find it more effective to use a generic interface capable of handling either of the primary implementations specified in this document.

This SAE document is under the control and maintenance of the Vehicle Networks for Multiplexing and Data Communications (Multiplex) Committee. This committee will periodically review and update this document as needs dictate.

1.1 Objectives—This document constitutes the requirements for a vehicle-data communications network. These requirements are related to the lowest two layers of the ISO Open System Interconnect (OSI) model (Ref. ISO 7498). These layers are the Data Link Layer and the Physical Layer. This network has been described using the ISO conventions in ISO/TC 22/SC 3/WG1 N429 E, dated October, 1990. Both documents are intended to describe the same network requirements but using different descriptive styles. If any technical differences are identified, the very latest revision of these documents should be used.

This document has been submitted as an American National Standard. As such, its format is somewhat different from the formal ISO description in that descriptions have been expanded, but are in no way less precise. A more textual format has been adopted herein to allow explanations to be included.

The vehicle application for this class of data communication (Class B) network is defined (Reference SAE J1213 APR88) to allow the sharing of vehicle parametric information. Also per the definition, this Class B network shall be capable of performing Class A functions.

2. *References*

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1113—Electromagnetic Susceptibility Measurements Procedures for Vehicle Components

SAE J1211—A Recommended Environmental Procedure for Electronic Equipment Design

SAE J1213/1—Glossary of Vehicle Networks for Multiplexing and Data Communications

SAE J1547—Electromagnetic Susceptibility Measurement Procedures for Common Mode Injection

SAE J1879—General Qualification and Production Acceptance Criteria for Integrated Circuits in Automotive Applications

SAE J1962—Diagnostic Connector

SAE J1979—E/E Diagnostic Test Modes

SAE J2012—Diagnostic Codes/Messages

SAE J2178—Class B Data Communication Network Messages

SAE J2178/1—Class B Data Communication Network Messages: Detailed Header Formats and Physical Address Assignment

SAE J2190—Enhanced E/E Diagnostic Test Modes

2.1.2 CISPR PUBLICATION—Available from Retsil Hansen, SAE, Troy Office, 3001 West Big Beaver Road, Suite 320, Troy, MI 48084-3174.

CISPR/D/WG2 (Secretariat) 19 Sept 1989 Radiated Emissions Antenna and Probe Test

2.1.3 ISO PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ISO/TC22/SC3/WG1 N606 DCT90—Road vehicles—Serial data communication for automotive applications, low speed (125 Kbps and below)

ISO 7498—Data processing systems—Open systems interconnection—Standard reference model

ISO 7637/3—Road vehicles—Electrical disturbance by conduction and coupling—Part 3: Passenger cars and light commercial vehicles with nominal 12 V supply voltage and commercial vehicles with 24 V supply voltage—Electrical transient transmission by capacitive and inductive coupling via lines other than supply lines

2.2 Related Publication—The following publication is provided for information purposes only and is not a required part of this document.

2.2.1 SAE PUBLICATION—Available from SAE, 400 Commonwealth Dr, Warrendale, PA 15096-0001.

SAE J1930—Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, & Acronyms

2.3 Definitions

2.3.1 ACTIVE STATE—The state of a bus wire which results when one or more nodes have "turned on" their physical layer circuitry. This is V_a volts for Bus + (PWM and VPW) and V_a volts for Bus - (PWM only). Refer to 7.3.1 (PWM DC Parameters) and 7.3.3.2 (VPW DC Parameters) for the values of V_a and V_a. The active state voltage level is determined by the source voltage of the node physical layer drive circuitry.

2.3.2 ARBITRATION—The process of resolving which frame, a Function Response data, continues to be transmitted when two or more nodes are transmitting frames, or In-Frame Response data, simultaneously.

2.3.3 CLASS A DATA COMMUNICATIONS—A system whereby vehicle data is reduced by the transmission and reception of multiple signals over a single signal bus between nodes that would have been accomplished by individual wires in a conventionally wired vehicle. The nodes used to accept multiplexed body wiring typically did not exist in the same or similar form in conventionally wired vehicle.

2.3.4 CLASS B DATA COMMUNICATIONS—A system whereby messages (or parametric data values) is transferred between nodes to eliminate redundant sensors and other system elements. The nodes in this form of a multiplex system would already existed as stand-alone modules in a conventionally wired vehicle. A Class B network shall also be capable of performing Class A functions.

2.3.5 CLASS C DATA COMMUNICATIONS—A system whereby high data rate signals typically associated with real-time control systems, such as engine controls and anti-lock brakes, are sent over the signal bus to facilitate distributed control and to further reduce vehicle wiring. A Class C network shall also be capable of performing Class A and Class B functions.

2.3.6 DOMINANT BIT—A bit which wins arbitration when contending for the bus. For SAE J1850, a logic "0" is the dominant bit.

2.3.7 DUAL WIRE—Two wires that are routed adjacently throughout a network and can be either a twisted or a parallel pair of wires.

2.3.8 FAULT TOLERANCE—The ability of a system to survive a certain number of failures with allowance for possible downgraded performance while maintaining message transmission capability at the specified data rate.

2.3.9 FRAME—One complete transmission of information, which may or may not include an "in-frame response." For this network, each frame contains one and only one message. A frame is delineated by the Start of Frame (SOF) and End of Frame (EOF) symbols.

2.3.10 FUNCTIONAL ADDRESSING—Labeling of messages based on the operation code or data content. See 5.1.2 for an example of the typical usage for functional addressing.

2.3.11 MESSAGE—All of the data bytes contained in a frame. The message is what is left after the frame symbols have been removed from the frame. As such, the message is the sequence of bytes contained in the frame.

2.3.12 PASSIVE STATE—The state of a bus wire which results when all nodes have "turned off" their physical layer circuitry. This is V_p volts for Bus + (PWM and VPW) and V_p volts for Bus - (PWM only). Refer to 7.3.2 (PWM DC Parameters) and 7.3.3.2 (VPW DC Parameters) for the values of V_p and V_p. The passive state voltage level is determined by the reference voltage of the bus wire termination resistor(s).

2.3.13 PHYSICAL ADDRESSING—Labeling of messages for the physical location of their source and/or destination(s). See 5.1.1 for an example of the typical usage for physical addressing.

2.3.14 PULSE WIDTH MODULATION (PWM)—A data bit format where the width of a pulse of constant voltage or current determines the value (logic one or zero) of the data transmitted.

2.3.15 RECESSIVE BIT—A bit which loses arbitration when contending for the bus with a dominant bit. For SAE J1850, a logic "1" is the recessive bit.

2.3.16 SLEEP MODE—Node behavior in a low power consumption and inactive state waiting to be switched on by a frame or other activity. This is distinct from an off-mode where the node is disconnected from the power supply.

2.3.17 VARIABLE PULSE WIDTH (VPW) MODULATION—A method of encoding both the state of the bus and the width of the pulse to encode bit information. This encoding technique is used to reduce the number of bus transitions for a given bit rate. One embodiment would define a "ONE" (1) as a short active pulse or a long passive pulse while a "ZERO" (0) would be defined as a long active pulse or a short passive pulse. Since a frame is comprised of random 1's and 0's, general byte or frame times cannot be predicted in advance.

2.4 Abbreviations/Acronyms

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BRK: Break
CRC: Cyclic Redundancy Check
E/E: Electrical and Electronic
EMC: Electromagnetic Compatibility
EMI: Electromagnetic Interference
EOD: End of Data
EOF: End of Frame
IFR: In-Frame Response (Byte/Bytes)
IFS: Inter-Frame Separation
ISO: International Standards Organization
Kbps: Kilo bits per second
NA: Not Applicable
NB: Normalization Bit
OSI: Open System Interconnect
SOF: Start of Frame

3. *Description of the Architecture*

3.1 General—It is the intent of this network to interconnect different electronic modules on the vehicle using an "Open Architecture" approach. An open architecture network is one in which the addition or deletion of one or more modules (data nodes) has minimal hardware and/or software impact on the remaining modules.

In order to support an open architecture approach, the Class B network utilizes the concept of Carrier Sense Multiple Access (CSMA) with nondestructive contention resolution. Additionally this network supports the prioritization of frames such that, in the case of contention, the higher priority frames will always win arbitration and be completed.

3.2 Network Topology

3.2.1 DATA BUS TOPOLOGY—Data bus topology is the map of physical connections of the data bus nodes to the data bus. It includes all nodes and data buses involved in the data bus integration of the vehicle. A single-level bus topology, the simplest bus topology, is currently being used in several automotive applications. In a single-level bus topology, all nodes are interconnected via the same data bus. The redundancy requirements of a particular application may require a single-level topology to be implemented using multiple interconnecting cables operating in various modes (active or passive). However, the requirement to use multiple buses for redundancy purposes does not change the single-level bus topology definition if the following criteria are maintained:

a. All nodes/devices transmit and receive from a single path.
b. All nodes/devices receive all frames at the same time.
c. Communication on each data bus is identical.

3.2.2 DATA BUS CONTROL—Although various methods of data bus control can be used, this Class B network is intended for "masterless" bus control. The principal advantage of the masterless bus control concept is its ability to provide the basis for an open-architecture data communications system. Since a master does not exist, each node has an equal opportunity to initiate a data transmission once an idle bus has been detected. However, not all nodes and/or data are of equal importance, prioritization of frames is allowed and the highest priority frame will always be completed. This also implies that frame/data contention will not result in lost data. Two disadvantages of the masterless bus concept are the data latency cannot be guaranteed, except for the single highest system priority frame, and bus utilization extremes are difficult to evaluate.

3.3 References to the OSI Model—Although this document focuses on the data link layer and the physical layer, references are included for the application layer since this needs to be included for emission-related, diagnostic communication legislation requirements. The Class B network maps into the OSI model as described in the following paragraphs. This "mapping" is illustrated in Figure 1.

3.3.1 APPLICATION LAYER—At the top of the OSI reference model is the Application Layer. This layer establishes the relationship between the various application input and output devices, including what is expected of human operators. This layer documents the high level description of the function including control algorithms if appropriate. An example of an Application Layer functional description might be: "Pressing the head lamp button shall cause the low beam head lamp, marker and tail lamp filaments to be energized." Legislated diagnostics is another area in which application layer requirements need to be specified.

3.3.2 DATA LINK LAYER—The primary function of the Data Link Layer is to receive bits and/or symbols to validated error free frames/data. Typical services provided are serialization (parallel to serial conversion) and clock recovery or bit synchronization. An important additional service provided by the Data Link Layer is error checking. When errors are detected, they may be corrected or higher layers may be notified.

3.3.3 PHYSICAL LAYER—The Physical Layer and its associated wiring form the interconnecting path for information transfer between Data Link Layers. Typical Physical Layer protocol elements include voltage/current levels, media impedance, and bit/symbol definition and timing.

3.4 Network Implementation—The network implementations based on this document have been reduced to commercial hardware, software, messages, and tools. The consolidation of messages has been documented in SAE J2178. The first byte or the first three bytes of these messages are called the "Header" byte(s). These header bytes fully define the associated requirements of this network interface, which previously had been optional. Figure 2 shows the general format for single byte header forms. Figure 3 shows the three byte header form. Figure 4 shows the specific bit assignments for priority, In-Frame Response, and Functional/Physical Address mapping in the three byte header format. For a complete description of the "KYZZ" bits shown in Figure 4 refer to SAE J2178/1.

4. *Application Layer Details*—The application of this communication network is the transfer of information from one node of the network to one or more other nodes. This transfer of information supports both operational and diagnostic needs. SAE has developed documents describing each of these types of applications, consistent with this document.

4.1 Normal Vehicle Operation (Down the Road) Messages—The messages sent during non-diagnostic operations are called normal vehicle operation messages. These normal vehicle operation messages are used for communication from a transmitter to one or more receivers across this network. The normal operation messages have been developed by the SAE for this communication network and are defined in SAE J2178. SAE defined messages and the "Reserved" messages of SAE J2178 shall remain specific to those definitions. In SAE J2178, there is also a set of "Reserved - Manufacturer" messages which, if used, will have meanings specific to a vehicle manufacturer but are likely to be different between manufacturers.

4.2 Diagnostic Messages—It is expected that this network will be used for diagnostics of the devices utilizing the network. These diagnostic procedures may include legislated diagnostics, industry standard diagnostics, or manufacturer-specific diagnostic procedures.

Legislated diagnostics, and some level of voluntary industry standard diagnostics that reference this document, should only specify procedures and frames that conform to this document. SAE J1979 and SAE J2190 define the set of recognized test modes that are available and have been reserved for diagnostic purposes.

Manufacturer-specific test procedures utilizing this network may specify procedures that do not conform to the requirements of this recommended practice.

4.2.1 DIAGNOSTIC PARAMETRIC DATA—SAE J1979 and SAE J2190 define test modes and frame formats for use by off-vehicle test equipment to obtain diagnostic data from the vehicle. SAE J1979 and SAE J2190 messages conform to the requirements and limitations of this document.

4.2.2 DIAGNOSTIC MALFUNCTION CODES—SAE J2012 defines trouble codes to be assigned to various vehicle system malfunctions, and also assigns ranges of codes to be used for manufacturer-specific codes. SAE J1979 and SAE J2190 include messages to be used to retrieve these codes from the on-vehicle systems. When trouble codes are to be assigned to system malfunctions, the code structure of SAE J2012 should be used.

4.3 Frame Filtering—The network interface device may be capable of filtering frames on the network to select those appropriate to a given node. Because this Class B protocol may use more than one type of frame addressing (e.g., functional and physical; see 5.1), the criteria for these filtering operations may include multiple byte comparisons occurring over the first several frame bytes. Regardless of the exact technique used for frame filtering, the objective is to reduce the software and processing burden associated with network operations by limiting the number of received frames to just those necessary for any given node.

5. *Data Link Layer Details*—This section defines the requirements on the following Data Link Layer attributes:

a. Addressing Strategy
b. Network Access and Data Synchronization
c. Frame Elements and Structure
d. Error Detection
e. Error Response

5.1 Addressing Strategy—Two types of addressing strategies are defined and can co-exist on this network. The two strategies serve different types of tasks and the flexibility to use both types on the same network provides a major benefit.

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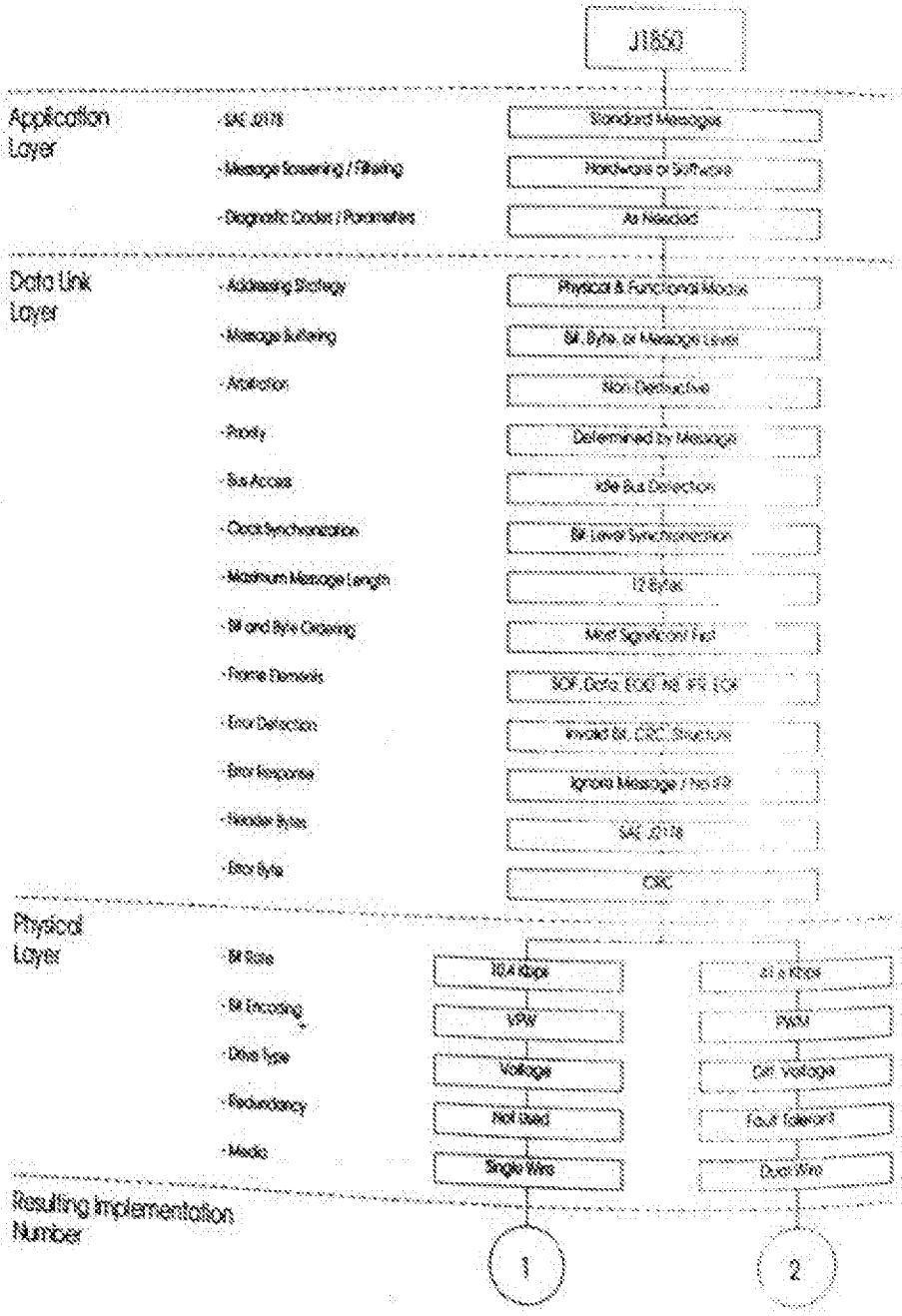

FIGURE 1—MAP OF SAE J1850 TO THE ISO OSI MODEL

5.1.1 PHYSICAL ADDRESSING—Frames are exchanged only between two devices based on their "Physical" address within the network. Each node must be assigned a unique physical address within the network. This type of addressing strategy is used when the communications involve specific nodes and not the others that may be on the network. Diagnostic access would be one case where identification of a specific module is important.

5.1.2 FUNCTIONAL ADDRESSING—Frames can be transmitted between devices based on the function of that frame on the network. Each node is assigned the set of functions that it cares about, either as transmitter or receiver, and can be located anywhere in the network. This type of addressing strategy is used when the physical location of the function is not important but only the account from one module to another. In the case of functional addressing, the function of the message is important and not the physical addresses of the nodes

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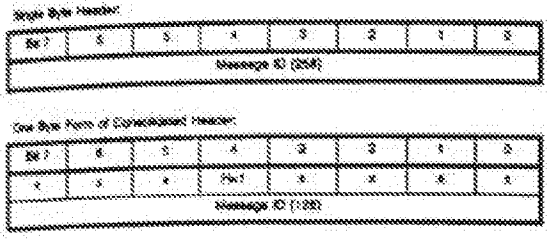

FIGURE 2—SINGLE BYTE HEADER AND ONE BYTE FORM OF CONSOLIDATED HEADER

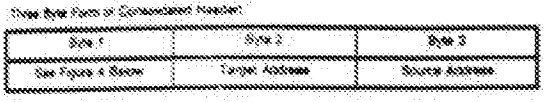

FIGURE 3—THREE BYTE FORM OF CONSOLIDATED HEADER

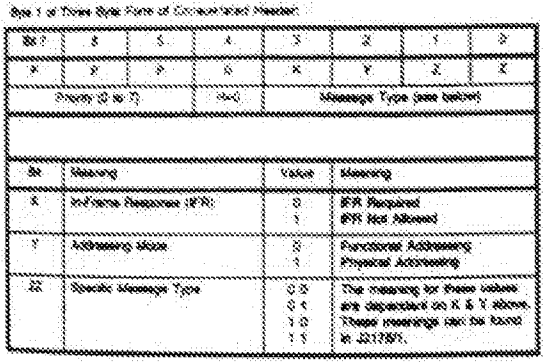

FIGURE 4—FIRST BYTE OF THREE BYTE FORM OF CONSOLIDATED HEADER

5.2 Network Access and Data Synchronization—The network interface shall implement a multiple access arbitration-based protocol using nondestructive bit-by-bit arbitration to transparently resolve simultaneous access to the bus. Network access is allowed after detection of an idle bus. The definition of an idle bus is contained in 6.6.1.7.

Since a discrete clock wire is not used with this network, node synchronization can be derived from bit/symbol transitions on the bus.

5.2.1 FULL MESSAGE BUFFERING—One or more messages exist in their entirety in the interface device. This approach reduces software burden at the expense of hardware costs. Message filtering (or screening) is possible in such a device which reduces software burden even further.

5.2.2 BYTE BUFFERING—Each byte of a received message (or transmit message) is stored individually in the interface device. The controlling device is responsible for the timely servicing of the interface device to keep up with frame traffic.

5.3 Network Elements and Structure

The general format is:

idle, SOF, DATA_0, ..., DATA_N, CRC, EOD, NB, IFR_1, ..., IFR_N, EOF, IFS, idle

The preceding acronyms are defined as follows:

idle: Idle Bus (occurs before SOF and after IFS)
SOF: Start of Frame
DATA: Data bytes (each 8 bits long)
EOD: End of Data (only when IFR is used)
CRC: CRC Error Detection Byte (may occur in IFR as well)
NB: Normalization Bit (10.4 Kbps only)
IFR: In-Frame Response Byte(s)
EOF: End of Frame
IFS: Inter-Frame Separation

NOTE—Break (BRK) can occur (be sent) on a network at any time.

5.3.1 FRAME ELEMENTS—The frame elements other than the symbols SOF, EOD, NB, EOF, IFS, and BRK will be byte oriented and must end on byte boundaries. Each byte will be 8 bits in length.

5.3.2 BIT ORDERING—The first bit of each byte transmitted on the network shall be the most significant bit (i.e., MSB first).

5.3.3 MAXIMUM FRAME LENGTH—The maximum number of continuous bit times that a single node is able to control the bus shall not exceed the value specified in 7.2.

5.3.4 FUNCTION OF SOF, EOD, EOF, IFS, NB, AND BRK—In addition to actual data bytes (i.e., data, CRC, IFR) frame delimiter symbols are defined to allow the data bus to function properly in a multitude of different applications. An overview of these symbols is provided here. Detailed timing requirements on each symbol can be found in 7.3.

5.3.4.1 Start of Frame (SOF)—The SOF mark is used to uniquely identify the start of a frame. The SOF mark shall not be used in the calculation of the CRC error detection code.

5.3.4.2 End of Data (EOD)—End of Data (EOD) is used to signal the end of transmission by the originator of a frame. The in-frame response (IFR) section of the frame, if used, begins after the EOD time but before the EOF. If the IFR feature (see 5.3.7) is not used, then the bus would remain in the passive state thereby resulting in an End of Frame (EOF). If a frame includes an IFR, the originator of the frame will expect the recipient(s) of the frame to drive the network with one or more in-frame response bytes immediately following EOD.

5.3.4.3 End of Frame (EOF)—The completion of the EOF defines the end of a frame. After the last transmission byte (including in-frame response bytes where applicable), the bus will be left in a passive state. When EOF has expired, all receivers will consider the transmission complete.

5.3.4.4 Inter-Frame Separation (IFS)—Inter-Frame Separation is used to allow proper synchronization of various nodes during back-to-back frame transmissions. A transmitter must not initiate transmission on the bus before the completion of the IFS minimum period. However, receivers must synchronize to any other SOF occurring after the EOF minimum period in order to accommodate individual clock tolerances.

A transmitter that desires bus access must wait for either of two conditions before transmitting a SOF:

a. IFS minimum has expired.

b. EOF minimum has expired and another rising edge has been detected.

5.3.4.5 Normalization Bit (NB)—Only applicable to 10.4 Kbps implementation. For Variable Pulse Width Modulation, the first bit of In-Frame Response data is also passive and, therefore it is necessary to generate a Normalization Bit to follow the EOD symbol. This Normalization Bit shall define the start of the in-frame response. The Normalization Bit is defined in 6.6.2.5.

5.3.4.6 Break (BRK)—BRK is allowed to accommodate those situations in which bus communication is to be terminated and all nodes react to a "ready-to-receive" state. If BRK is used, it must adhere to the requirements as specified in 6.6.

5.3.5 IDLE BUS (IDLE)—Idle bus is defined as any period of passive bus state occurring after IFS. During an idle bus, any node may transmit immediately. Contention may still occur when two or more nodes transmit nearly simultaneously; therefore, resynchronization to rising edges must continue to occur.

5.3.6 DATA BYTE(S)—A number of data bytes, each eight (8) bits in length, can be transmitted at the discretion of the system designer. However, the total message length (from SOF to EOF) shall not exceed the limit defined in 7.2.

5.3.7 IN-FRAME RESPONSE (IFR)—For In-Frame Response, the response byte(s) are transmitted by the responders and begin after EOD. If the first bit of the in-frame response byte does not occur at this point and the bus remains passive for a period of time defined as EOF, then the originator and all receivers must consider the frame complete. In-frame response bytes may take one of the following forms (refer to Figure 5).

a. None

b. A single byte transmitted from a single recipient, typically a unique identifier (ID) or address.

c. Multiple bytes, a single byte transmitted from each recipient. The effect is to concatenate the individual response bytes into a response "stream." The response byte from each recipient must be unique, typically a physical address (ID #). Arbitration takes place during the response process so that each recipient, if arbitration is lost during its response byte, will retransmit the single byte until the recipient observes its unique byte in the response stream. Once a given recipient observes its own unique response byte, it discontinues the transmission process to allow any remaining responders to transmit their byte.

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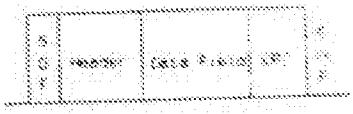
d. One or more data bytes, all from a single recipient. A CRC byte may be appended to the data byte(s). The CRC byte is calculated as described in 5.4.1, except only the data in the response is used for the CRC calculations.

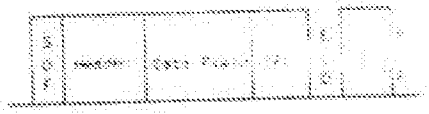
Refer to SAE J2178/3 for a detailed discussion of the different IFR types and for determination of which message types utilize which IFR types.

If in-frame response bytes are used, the overall frame/message length limit remains in effect. The sum total of data bytes, CRC bytes, and in-frame response bytes shall not exceed the frame length as specified in 7.2.

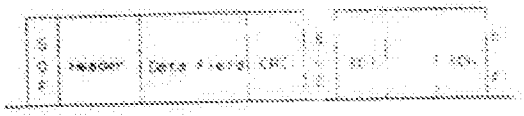
3.3.7.1 Normalization Bit—If the In-Frame Response is employed in the 10.4 Kbps implementation then a "Normalization Bit" is required. The Normalization Bit is described in 8.6.2.5.



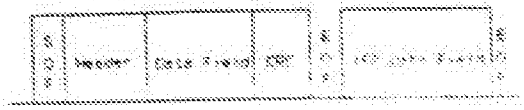
Type 0 – None



Type 1 – Single Byte From a Single Recipient



Type 2 – Single Byte From Multiple (Up to Four) Nodes



Type 3 – Multiple Bytes From a Single Node (Up to 255)

FIGURE 5—TYPES OF IN-FRAME RESPONSE

5.4 Error Detection—The error descriptions in this document are loosely defined and classified. In general, the action taken after an error condition has been detected is manufacturer-specific unless it has been specified in this document.

5.4.1 CYCLIC REDUNDANCY CHECK (CRC)—The CRC is required with either of the header byte systems used. The method of calculating and checking the CRC byte is defined as follows. An invalid CRC byte may constitute a detected error.

a. The CRC calculation and the CRC checker shift registers (or memory locations) will be located in the sender and receiver nodes, respectively, and shall be initially set to the "all ones" state during SOF. (The setting to "ones" prevents an "all zeros" CRC byte with an all zero-data stream.)

b. All frame bits that occur after SOF and before the CRC field are used to form the Data Segment Polynomial which is designated as D(X). For any given frame, this number can be interpreted as an "n-bit" binary constant, where n is equal to the frame length, counted in bits.

c. The CRC division polynomial is $X^8 + X^4 + X^3 + X^2 + 1$. This polynomial is designated as P(X).

d. The Remainder Polynomial R(X) is determined from the following Modulo 2 division equation:

$$\frac{X^8 * D(X) + X^n + X^{n-1} + \ldots + X^{n-7}}{P(X)} = Q(X) + \frac{R(X)}{P(X)} \qquad \text{(Eq.1)}$$

NOTE—Q(X) is the quotient resulting from the division process.

e. The CRC byte is made equal to $\overline{R(X)}$, where $\overline{R(X)}$ is the ones complement of R(X).

f. The Frame Polynomial M(X) that is transmitted is shown in Equation 2:

$$M(X) = X^8 * D(X) + \overline{R(X)} \qquad \text{(Eq.2)}$$

g. The receiver checking process shifts the entire received frame, including the transmitted CRC byte, through the CRC checker circuit. An error-free frame will always result in the unique constant polynomial of $X^7 + X^6 + X^3$ (C4 hex) in the checker shift register regardless of the frame content.

h. Examples of frames with the appropriate CRC bytes are listed in Table 1.

TABLE 1—EXAMPLES OF FRAMES AND APPROPRIATE CRC BYTES

Data Bytes (hex)								CRC (hex)
00	00	00	00					39
F2	53	83						37
06	AA	00	55					78
06	FF	55	11					66
33	22	55	AA	88	CC	00	EE	FF	C8
92	6B	33							8C
FF	FF	FF	FF						73

i. A status flag may be used to indicate the occurrence of a received CRC error.

j. When In-Frame Response data is protected by a CRC field, the previous rules are used to define the CRC, except that the sender and receiver nodes are interchanged. The CRC calculation only includes the in-frame response bytes. (Note that the SOF, EOD, EOF, and NB are not used in the CRC calculation and serve as data delimiters.)

NOTE—Figure 6 illustrates a typical CRC generator and Figure 7 illustrates a typical CRC checker. With appropriate gating, the two circuits may be combined to use only a single shift register for both CRC generation and CRC checking.

5.4.2 FRAME/MESSAGE LENGTH—A frame exceeding its defined length limit may constitute a detected error.

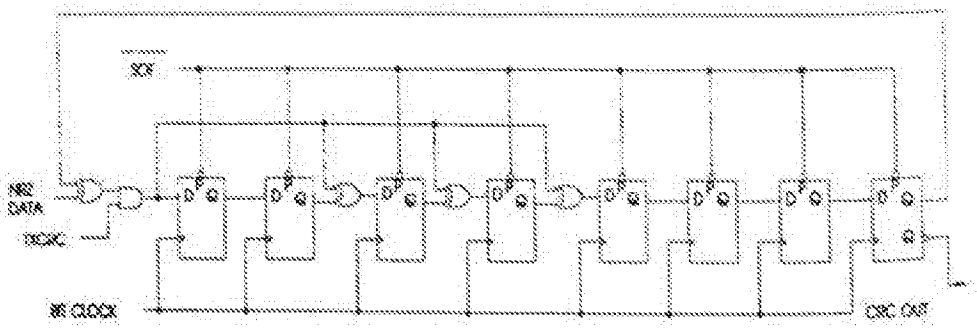


FIGURE 6—CRC GENERATOR

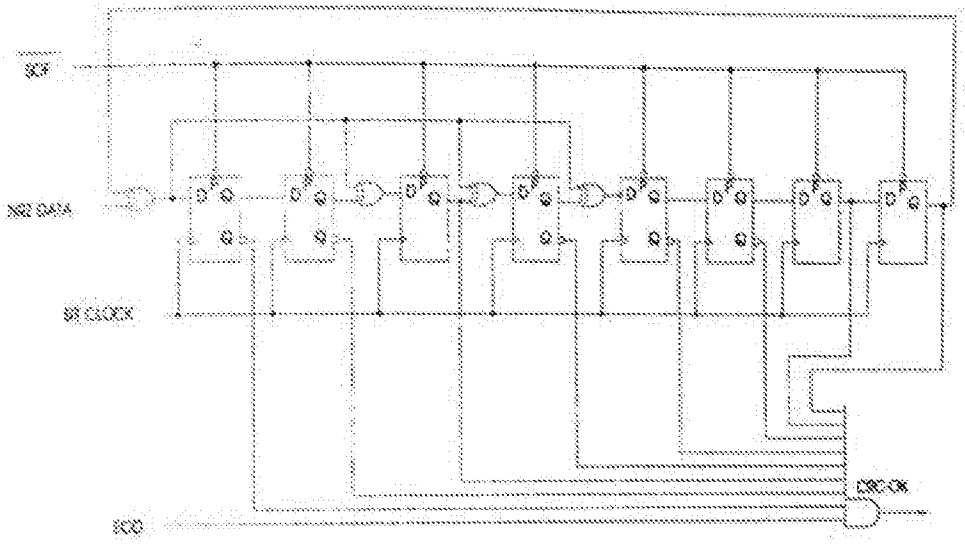


FIGURE 7—CRC CHECKER

5.4.3 OUT-OF-RANGE—Data is corrupted in a vehicle network when transient interference is large enough to drive the receiver out of its dynamic range of operation. This out-of-range condition, where the receiver can no longer accurately decode the data, may be detected by an out-of-range detector. The following defines the operation of an out-of-range detector:

a. Data is recovered by holding the receiver output in the state it was prior to the out-of-range condition for the duration of the interference.
b. If the interfering transient is long enough to corrupt a desired bus symbol, accurate data recovery may not occur. This may constitute a detected error.

5.4.4 CONCEPT OF VALID/INVALID BIT/SYMBOL DETECTION

5.4.4.1 Invalid Bit Detection—In some cases, data integrity may be increased by detecting the condition in the data stream where the received data bit does not match the specifications for either a "one" or a "zero" bit.

5.4.4.2 Invalid Frame Structure Detection—Regardless of data encoding, data integrity may be increased by detecting the condition when an EOD or EOF occurs on a non-byte boundary within the data stream, or the frame exceeds the maximum frame length.

5.5 Error Response

5.5.1 TRANSMIT—When an originator of a frame detects an error condition on the network (i.e., one of the error conditions defined in 5.4), the originator must discontinue the transmit operation prior to the start of the next bit. After the specified period of IFS or reception of an edge after EOF, the originator is allowed to retransmit the frame.

5.5.2 RECEIVE—If a frame is received and the frame contains an error (i.e., one of the error conditions defined in 5.4), the frame is to be ignored. If "In-Frame Response" is being used, the receiver must not respond to a received frame containing an error. This lack of response serves as a signal to the originator that an error was detected by the receiver.

6. *Physical Layer Details*—This section defines the requirements on the following physical layer attributes.

a. Media
b. Unit Load Specifications
c. Maximum Number of Nodes
d. Maximum Network Length
e. Media Characteristics
f. Data Bit/Symbol Definitions/Detection
g. Network Wake-Up Via Physical Layer
h. Physical Layer Fault Considerations
i. EMC Requirements

Specific parametric values associated with the physical layer are contained in Section 7.

6.1 Physical Layer Media—Although this specification focuses on the bus carrying media, it is assumed that each node shall be supplied with switched power and ground.

6.1.1 SINGLE WIRE—The network medium for the single wire voltage drive shall be a single random lay wire.

6.1.2 DUAL WIRES—The network medium for the dual wire voltage drive shall be either a parallel wire pair separated by a constant distance, or a twisted pair of wires.

6.1.3 ROUTING—No Restrictions

6.2 Unit Load Specifications—The electrical loading effect of each device connected to this network will be measured in terms of unit loads. A unit load is a nominal value which, if all nodes correspond to one unit load, will allow the maximum specified number of nodes to be connected to the network. There is no requirement that a given node must be equal to a standard unit load, but the combination of all load values must not exceed the limits for any given system.

6.3 Maximum Number of Nodes—The maximum number of nodes, assuming each node is the equivalent of a standard unit load, is specified in Section 7.

6.4 Maximum Network Length—The maximum medium length between any two nodes shall not exceed the value specified in Section 7.

6.4.1 ON-VEHICLE/OFF-VEHICLE—The maximum network length, maximum capacitance value and minimum load/termination resistance values for any off-vehicle equipment have been specified in 7.3. Because all applications must allow for such off-vehicle equipment, the allowed maximum on-vehicle loads shall be limited to account for this level of off-vehicle loading.

6.5 Media Characteristics—The characteristics of the media are as specified in Section 7.

6.6 Data Bit/Symbol Definition/Detection—The data bus can be in one of two valid states % active or passive. For clarity in the following sections, a rising edge is a transition from the passive to active state and a falling edge is a transition from the active to the passive state.

There are two methods of bit encoding specified in this document, Pulse Width Modulation (PWM) and Variable Pulse Width (VPW) modulation. The timing diagrams that follow represent the requirements for the logical waveforms. It is the transmitter's responsibility to transmit bits/symbols which are valid (i.e., it is the transmitter's responsibility to insure that its bits/symbols which are valid (i.e., meets these specifications). In some contention situations, the transmitter will have to re-synchronize to ensure that the falling edge is within specification. The requirements associated with the reception of these bits and symbols are not stated explicitly in this specification, but are to be derived from transmitter specifications by the module or circuit designer. It is expected that the receiver will employ a simple clock-driven digital filter and digital integrator or majority vote sampling circuit for decoding data and maintaining "clock" synchronization. All timing requirements are specified in Section 7.

The following bits/symbols are defined for both PWM and VPW:

a. One "1" bit
b. Zero "0" bit

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c. Start of Frame (SOF)
d. End of Data (EOD)
e. End of Frame (EOF)
f. Inter-Frame Separation (IFS)

The Normalization Bit (NB) is only applicable for VPW implementations and is therefore only defined for VPW.

6.6.1 PULSE WIDTH MODULATION (PWM)—The following values represent nominal timing, detailed timing requirements for each bit/symbol can be found in Section 7.

6.6.1.1 The One "1" and Zero "0" Bits (see Figures 8 and 9)

a. "1" Bit - A "1" bit is characterized by:
   (1) A rising edge that follows the previous rising edge by at least Tp3. Two rising edges shall never be closer than Tp3.
   (2) A falling edge that occurs Tp1 after the rising edge.
b. "0" Bit - A "0" bit is characterized by:
   (1) A rising edge that follows the previous rising edge by at least Tp3. Two rising edges shall never be closer than Tp3.
   (2) A falling edge that occurs Tp2 after the rising edge.
   (3) A next data bit rising edge that occurs Tp11 after the previous falling edge (if applicable).

6.6.1.2 Start of Frame (SOF)—The Start of Frame (SOF) mark has the distinct purpose of uniquely determining the start of a frame (see Figure 10). The SOF is characterized by:

a. A reference rising edge that follows the previous rising edge by at least Tp5.
b. A falling edge that occurs Tp7 after the reference rising edge.
c. The rising edge of the first data bit will occur at Tp10 after the reference rising edge.

NOTE—Last bit of a frame may be the last data bit, last CRC bit, or last In-Frame Response bit.

6.6.1.3 End of Data (EOD)—End of Data is used to signal the end of transmission by the originator of a frame. The In-Frame Response (IFR) section of the frame, if used, begins immediately after the EOD bit (see Figure 11). If the In-Frame Response feature is not used, then the bus would remain in the passive state for an additional bit time, thereby signifying an End of Frame (EOF).

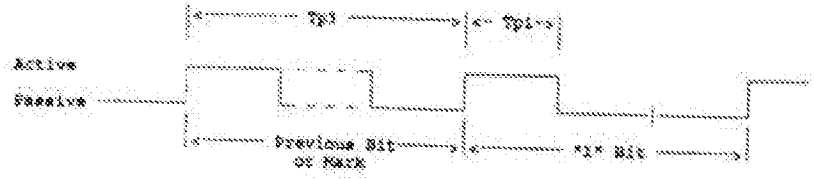

FIGURE 8—"1" BIT DEFINITION

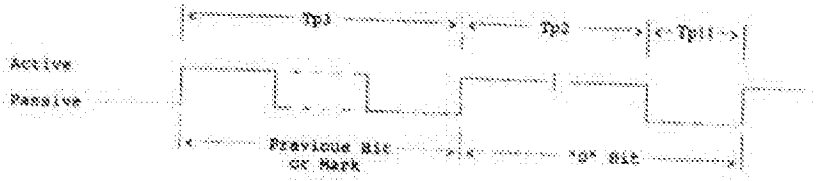

FIGURE 9—"0" BIT DEFINITION

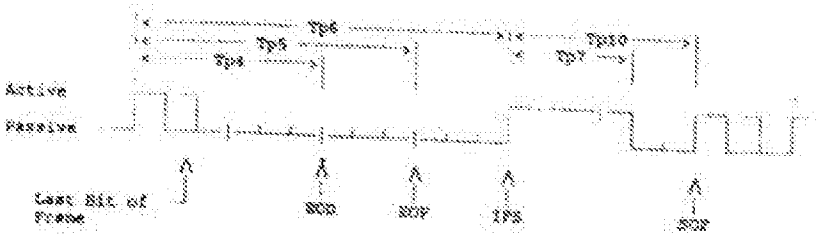

FIGURE 10—FRAME SYMBOLS

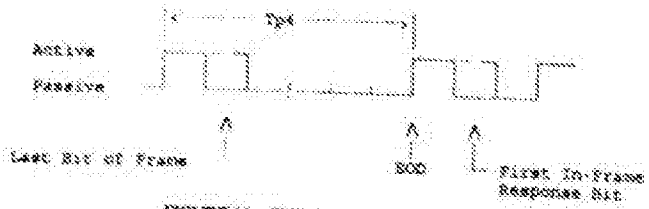

FIGURE 11—END OF DATA SYMBOL

For In-Frame Response, the response byte(s) are driven by the responder and begin with the rising edge of the first bit of the response, Tp4 after the rising edge of the last bit sent from the originator of the frame.

If the first bit of the response byte does not occur at Tp4, and the bus remains passive for one additional bit time (total time Tp5) then the originator and all receivers must consider the frame complete (i.e., EOD has been transformed into an EOF).

NOTE—Last bit of a frame may be the last data bit, last CRC bit, or last In-Frame Response bit.

6.6.1.4 End of Frame (EOF)—The completion of the EOF defines the end of a frame (by definition, an EOD forms the first part of the EOF - see Figure

3). After the last transmission byte (including in-frame response bytes where applicable), the bus will be left in a passive state. When EOF has expired (Tp5 after the rising edge of the last bit), all receivers will consider the transmission complete.

6.6.1.5 Inter-Frame Separation (IFS)—Inter-Frame Separation allows proper synchronization of various nodes during back-to-back frame operation.

A transmitter that desires bus access must wait for either of two conditions before transmitting a SOF:

a. IFS minimum has expired (Tp6 after the rising edge of the last bit).

b. EOF minimum and another rising edge has been detected (Tp5 after the rising edge of the last bit).

6.6.1.6 Break (BRK)—BRK is allowed to accommodate those situations in which bus communication is to be terminated and all nodes reset to a "ready-to-receive" state (see Figure 12). The PWM Break symbol is an extended SOF symbol and will be detected as an "invalid" symbol to some devices, which will then ignore the current frame, if any. Following the break symbol, an IFS following BRK period (Tp9 after the rising edge of the break) is needed to synchronize the receivers. If the "Breaking" device wishes to obtain guaranteed access to the bus, the highest priority frame must then be sent, otherwise, other frames may gain access under the normal rules of arbitration.

6.6.1.7 Idle Bus (Idle)—Idle bus is defined as any period of passive bus state occurring after IFS minimum (see Figure 13). A node may begin transmission at any time during idle bus.

During an idle bus, any node may transmit immediately. Contention may still occur when two or more nodes transmit nearly simultaneously; therefore, synchronization to rising edges must continue to occur.

NOTE—Last bit of a frame may be the last data bit, last CRC bit, or last In-Frame Response bit.

6.6.1.8 PWM Symbol Timing Requirements—The symbol timing reference for PWM encoding is based on transitions from the passive state to the active state. The SOF and each data bit in PWM has a "leading edge" from which all subsequent timing is derived. The transition from active to passive (which occurs within the SOF or data bits) is not used as a timing reference. The leading edge is used as the only reference because the transition from passive to active appears on the bus wires as a fast clean edge while the transition from active to passive is slow and ambiguous due to variations in network capacitance.

Paragraph 7.3.2.1 defines the timing values for PWM at 41.6 Kbps. Values are provided for the transmitter and receiver (based on the suggested bit decoder implementation).

6.6.2 VARIABLE PULSE WIDTH MODULATION—The SOF symbol, "0" bit, and "1" bit are defined by the time between two consecutive transitions and the level of the bus, active or passive. The EOD, EOF, IFS, and Break symbols are defined simply by the amount of time that has expired since the last transition. EOD, EOF, and IFS are all passive symbols and the Break is an active symbol. Therefore, there is one symbol per transition and one transition per symbol. The end of the previous symbol starts the current symbol. The following values represent nominal timing, detailed timing requirements for each bit/symbol can be found in Section 7.

6.6.2.1 The One "1" and Zero "0" Bits—A "1" bit is either a Tv2 passive pulse or a Tv1 active pulse. Conversely, a "0" bit is either a Tv1 passive pulse or a Tv2 active pulse (see Figure 14). The pulse widths change between passive and active bus states in order to accommodate the arbitration and priority requirements as specified in 6.7.

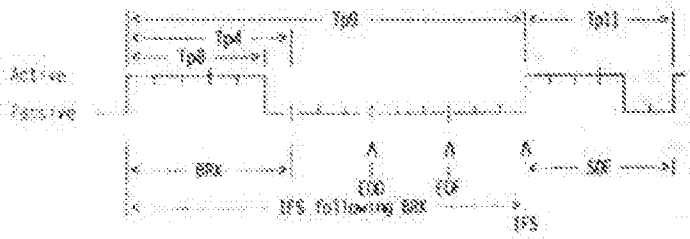

FIGURE 13—PWM BREAK SEQUENCE

FIGURE 13—EOF AND IDLE BUS DEFINITION

6.6.2.2 Start Of Frame (SOF)—SOF is an active pulse, Tv3 in duration (see Figure 15).

FIGURE 14—ONE AND ZERO BIT DEFINITIONS

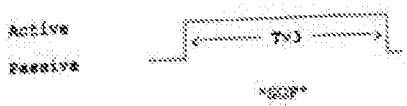

FIGURE 15—START OF FRAME (SOF) SYMBOL

6.6.2.3 End Of Data (EOD)—EOD is a passive pulse, Tv3 in duration (see Figure 16).

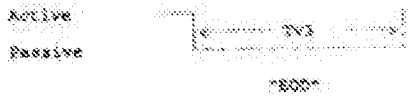

FIGURE 16—END OF DATA (EOD) SYMBOL

6.6.2.4 End of Frame (EOF)—EOF is a passive pulse, Tv4 in duration (see Figure 17).

FIGURE 17—END OF FRAME (EOF) SYMBOL

6.6.2.5 In-Frame Response Byte(s)/Normalization Bit—The "In-Frame Response" (IFR) is transmitted by the responder and begins after the passive EOD symbol. For Variable Pulse Width Modulation, the first bit of the IFR data is also passive. Therefore, it is necessary to generate a normalization bit to follow the EOD symbol. The responding device generates the normalization bit prior to sending the IFR data. This normalization bit defines the start of the IFR and can take two forms. The first form is an active short period (Tv1) and the second form is an active long period (Tv2). Figure 18 illustrates the IFR using the normalization bit. The normalization bit can also be used to indicate what type of response is expected during the IFR portion of the frame. The preferred method is to use an active short bit (Tv1) to indicate that the IFR DOES NOT contain a CRC (i.e., IFR types 1 or 2). An active long bit (Tv2) would therefore indicate that the IFR DOES contain a CRC (i.e., IFR type 3). This is only a preferred method, and individual manufacturers are allowed to implement the normalization bit per their requirements. However, all future SAE J1850 applications are urged to implement the normalization bit using the preferred method described above.

If in-frame response bytes are used, the overall frame/message length limit remains in effect. The sum total of data bytes, CRC byte, and in-frame response bytes shall not exceed the value specified in Section 7.

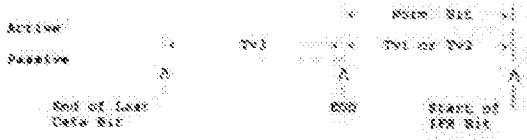

FIGURE 18—NORMALIZATION BIT

6.6.2.6 Inter-Frame Separation (IFS)—Inter-Frame Separation is used to allow proper synchronization of various nodes during back-to-back frame operations.

A transmitter that desires bus access must wait for either of two conditions before transmitting a SOF (see Figure 19):

a. IFS minimum has expired (Tv6).

b. EOF minimum and another rising edge has been detected (Tv4).

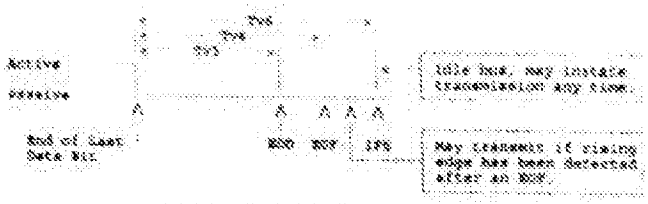

FIGURE 19—INTER-FRAME SEPARATION

6.6.2.7 Break (BRK)—BRK is allowed to accommodate those situations in which bus communication is to be terminated and all nodes reset to a "ready-to-receive" state (see Figure 20). The VPW Break symbol will be detected as an "invalid" symbol to some devices, which will then ignore the current frame, if any. The VPW Break symbol is a long active period (> Tv5). Following the break symbol, an IFS period (Tv6) is needed to resynchronize the receivers and the normal IFS rules for transmitting a SOF during back-to-back operation apply. If the "Breaking" device wishes to obtain guaranteed access to the bus, the highest priority frame must then be sent, otherwise, other busses may gain access under the normal rules of arbitration.

FIGURE 20—BREAK SIGNAL

6.6.2.8 Idle Bus (Idle)—Idle bus is defined as any period of passive bus state occurring after IFS. A node may begin transmission at any time during idle bus.

An idle bus will exist after IFS (Tv6). Contention may still occur when two or more nodes transmit nearly simultaneously; therefore, resynchronization to rising edges must continue to occur.

6.6.2.9 VPW Symbol Timing Requirements—The most important factor in symbol timing uncertainty is the edge position uncertainty due to the time taken to make a transition between $V_{d,max}$ and $V_{d,min}$ (in either direction). The maximum allowable transition time, $T_{t,max}$ (the area between $V_{d,max}$ and $V_{d,min}$), bounds the time span between the earliest and latest node to recognize a transition and is a key design parameter. As $T_{t,max}$ is reduced it becomes more and more difficult to design a driver which also meets the necessary EMI requirements. In this manner, the corners of the waveform, which are a major contributor to the radiated contents of the signal, do not fall within the limits imposed by $T_{t,max}$ as found in Section 7.

Other factors that affect the transmitted pulse width are oscillator tolerance and variations in delay through the receiver, noise filter, and driver. For a fixed oscillator and a well-designed digital filter, most of the variation is in the time it takes the driver to leave the current state and start the transition. The various factors (plus some guard band and allowance for alternative implementations) can be lumped into a single set of limits, $T_{x,min}$ and $T_{x,max}$, for each symbol. Each is measured from the trip point of the previous transition as seen by the transmitting node (assuming a step input) to the beginning or end of the transition at $V_{d,max}$ or $V_{d,min}$.

The pulse width as seen by another node, which may perceive the leading edge either sooner or later than the transmitting node, can range from $T_{x,min} - T_{t,max}$ to $T_{x,max} + T_{t,max}$ in absolute terms. This range represents a receiver's required acceptance range for a given symbol. The actual acceptance range must be wider to allow for receiver oscillator tolerance and any implementation-dependent uncertainties or constraints. The necessary guard band limits how close together symbols can be defined. To keep the symbols short, there is no space allocated for an unambiguous (with normal tolerances) forbidden zone between symbols.

The time windows are not affected by multiple nodes trying to transmit at the same time during arbitration. This is because a single node effectively dominates each transition. It is either the first node to leave the passive state or the last node to leave the active state. Although the fastest or slowest node dominates a particular transition, the contention scheme assures that the highest priority frame always wins regardless of which node started transmitting first.

The purpose of the noise filter is to eliminate impulse noise which may exceed the steady-state noise margin and to minimize the need for hysteresis at the receiver input. The delay through the filter is compensated for in the timing logic. A specific implementation of the filter is not required for compatibility so long as the delay is properly compensated and the uncertainty bounds are not exceeded. In the presence of arbitrary noise during the transition period, the filter should respond as though a single step input had occurred at some point within that period.

The symbol limits defined in Section 7 are consistent with $T_{t,max}$ and the specified oscillator tolerance. T_{nom} is the nominal symbol time with no oscillator error and the receiver detecting the transition at V_t (see analysis in Appendix D).

6.7 Contention/Arbitration/Priority—A contention situation arises when more than one node attempts to access the bus at essentially the same time.

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6.7.1 CONTENTION DETECTION—Contention detection is the recognition of conflicting symbols or bits. The process of bit-by-bit arbitration allows conflicting frame transmissions to be detected. A node that detects a difference between the symbol or bit it receives and the symbol or bit it is currently transmitting has detected contention to the transmission of its frame. Only the one frame that wins all conflicts of different symbols and bits with all the other nodes that began transmitting during that frame will not detect contention.

6.7.2 BIT-BY-BIT ARBITRATION—The bit-by-bit arbitration scheme described as follows settles the conflicts that occur when multiple nodes attempt to transmit frames simultaneously. This scheme is applied to each symbol/bit of the frame, starting with the SOF symbol and continuing until the end of the frame. Bit-by-bit arbitration is based on the use, at the physical layer, of two states of the bus called the active state and the passive state. All symbols and bits are encoded on the bus by the physical layer as combinations of active and passive state signals. During simultaneous transmissions of active state and passive state signals on the bus, the resultant state on the bus is always active (active state dominates). If the transmitting node detects a signal state on the bus that is different from the state being transmitted by the node during the header portion of the frame, the node must discontinue the transmit operation prior to the start of the next bit. If the transmitting node detects a signal state on the bus that is different from the state being transmitted by the node during the data portion of the frame (following the header), the process used to cause termination is implementation specific. Some possible options are:

a. Discontinue the transmit operation prior to the start of the next bit (similar to the action taken if contention is detected during the header phase). If termination of a message is prematurely terminated on a byte boundary due to unexpected contention detection following the header, care must be taken by receiving nodes not to accept the message as a valid one. There is a 1 in 256 chance that the last byte received is the CRC of the previous bytes and would therefore appear to be a valid message. In this case, a node may need to validate the received message to ensure it is of the correct length.

b. Transmit additional bits (e.g. 8) when contention is detected on a byte boundary. This ensures that a framing error will be received by all other receivers in the case of unexpected contention detection possibly due to noise.

Bus access is granted to nodes sending an active state signal over nodes using a passive state signal. Figure 21 shows this operation on the physical layer, based on the two forms of modulation allowed (PWM and VPW).

The arbitration process begins with the SOF and continues through all the bits of the frames being sent. As each symbol or bit of all the simultaneous frames is transmitted, all of the nodes still transmitting after the last symbol or bit will detect whether any contention is taking place. Nodes that detect contention have, by definition, lost arbitration and will discontinue sending any further symbols or bits. Any remaining nodes will continue to send their symbols/bits until the next contention is detected. The node which obtains sole access to the medium is that which sends its symbols and bits without detecting any contention.

6.7.3 ARBITRATION AREA—The arbitration resolution described previously concerns all the symbols and bits between the SOF and the EOF including, in the case of an in-frame response, all the symbols and bits of the in-frame response. In other words, arbitration acts throughout the frame.

6.7.4 FRAME PRIORITY—The bit-by-bit arbitration mechanism allows the implementation of a frame priority system. When unique frames or, more particularly, when arbitration is resolved down to a single transmitter prior to any data values within the frame, a structure of relative frame priority is inherent.

Should two or more nodes attempt to access the bus within the same frame synchronization window (see IFS in 6.6.1.5 and 6.6.2.7), nondestructive arbitration will occur based on the bit value within each frame. The bus allows two states - active and passive. If an active state bit and a passive state bit are transmitted on the bus simultaneously, then the active state bit will override the passive state bit. Hence, frame arbitration occurs in a bit-wise manner. The result of the arbitration is that the node(s) sending lower priority frame(s) will recognize that they have lost arbitration and will discontinue transmitting before the next bit time. The node transmitting the highest priority frame will continue transmitting uninterrupted.

Based on the bit definitions contained in Section 6.6, the lowest value bytes immediately following the SOF will have the highest priority. Therefore, regardless of the number of bits allocated for "frame prioritization," the numerical value of zero will have the absolutely highest priority (that is, 000 is higher priority than 001 or 111).

6.8 Node Wake-Up Via Physical Layer—The transition to a functional/operating network from an unpowered or standby state is a common occurrence in vehicle multiplex systems. In the context of this document the Session Layer controls the transitions between the operating and the standby states.

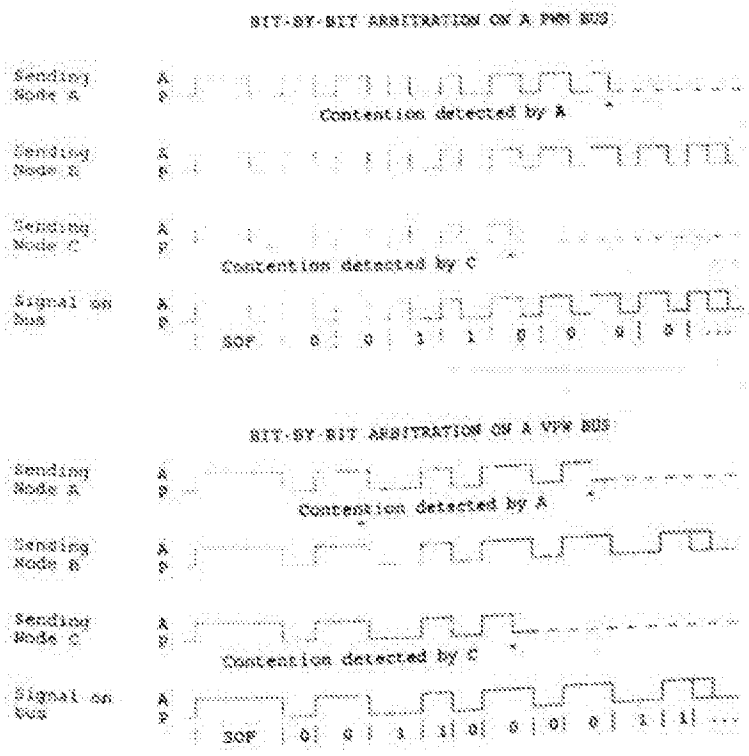

FIGURE 21—ARBITRATION

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Two perspectives are used to define the session layer:

a. The view of the media itself, without regard to the individual nodes on the network.

b. The view from an individual node.

Both are required for a complete definition of the possible states of network operation.

It is expected that a typical vehicle multiplex system may contain a mixture of unpowered and powered nodes, and that the individual nodes may themselves have both powered and standby states.

6.8.1 NETWORK MEDIA

6.8.1.1 Unbiased Network—An unbiased network is all conductors at ground voltage and the impedance of the conductors not controlled. No communication is possible on an unbiased network. The media must first be brought to the biased state before communication can take place. The transition of the network from the unbiased to the biased state may serve as a node wake-up signal for certain applications, but this is not a requirement (i.e., it is possible for individual nodes to be in the sleep state on a fully biased network or in the awake state on an unbiased network).

6.8.1.2 Biased Network—A biased network is all conductors at the "passive" voltage level (with no communication occurring) and with appropriate impedances capable of supporting communication. Individual nodes on the network may exist in any of the three states described as follows. Note that nodes which use the optional sleep state are required to wake up from the appropriate network signal within a defined wake-up period. In other words, all nodes which are capable of wake-up from network signals must do so; otherwise these nodes are considered "unpowered." This requirement assures a finite and limited delay to establish communication with nodes which may be in the sleep state.

The time required for the media to make the transition from the unbiased to the biased state is not defined in this document, since this parameter is largely application dependent and, in fact, may not even occur (e.g., media always biased). For the same reason, the time required for a node to make the transition between the unpowered state and the sleep or awake state is also not defined.

6.8.2 INDIVIDUAL NODES

6.8.2.1 Unpowered Node—An unpowered node is not capable of network communication, nor wake-up from network signal transitions.

6.8.2.2 Sleeping Node—A sleeping node may have an optional low-power standby mode capable of detecting network signal transitions for the purpose of wake-up. Any interface device in the sleep state can be awakened by any other interface device via network activity or awakened by its host via its interface to the host. There is no specified requirement for the transition from the awake state to the sleep state, since this is an implementation-specific issue.

6.8.2.3 Awake/Operational—An awake/operational node is fully capable of receiving and transmitting frames on the network. The maximum amount of time from the wake-up stimulus until the node is capable of communicating is implementation specific. A transition of the bus from the passive state to the active state shall be considered a "wake-up" signal to a sleeping node. Proper bus bias must be supplied by all nodes designated to supply bias when the network is powered.

6.9 Physical Layer Fault Considerations

6.9.1 REQUIRED FAULT TOLERANT MODES—The network must meet the requirements as defined per the following failure modes:

a. Node Power Loss—All nodes must continue to meet the network leakage current requirements during a loss of power (or low voltage) condition.

b. Bus Short to Ground—Network data communications may be interrupted but there shall be no damage to any node when the bus is shorted to ground.

c. Bus Short to Battery—Network data communications may be interrupted but there shall be no damage to any node when the bus is shorted to battery power.

d. Loss of Node Connection to Ground—When a node loses its ground connection, the remaining nodes shall remain capable of communications.

6.9.2 OPTIONAL FAULT TOLERANT MODES—The network may optionally meet the requirements as defined per the following failure modes:

a. Loss of Termination/Bias—Biasing and termination resistors shall be redundant such that no single point failure will cause the network to become inoperative.

b. Loss of Connection to Network—When a node becomes disconnected from the network the remaining nodes shall remain capable of communications.

c. Dual Wire Fault Tolerant Operation—Nodes on a dual wire bus may be capable of full communication (sending and receiving frames) at the specified bit rate in the presence of any one of the following faults occurring anywhere on the network:

(1) Bus "+" wire Open Circuit

(2) Bus "–" wire Open Circuit

(3) Bus "+" wire Shorted to Ground

(4) Bus "–" wire Shorted to Ground

(5) Bus "+" wire Shorted to Battery + (V_{bat})

(6) Bus "–" wire Shorted to Battery + (V_{bat})

(7) Bus "+" wire Shorted to any voltage between Ground and Battery

(8) Bus "–" wire Shorted to any voltage between Ground and Battery

Noise immunity and emissions may be somewhat degraded during the fault period but shall return to normal after the fault is removed.

All nodes shall be protected from damage during the presence of any fault such that recovery to normal operation occurs automatically upon removal of fault (i.e., faults shall not propagate through the network).

Continued communication is not required for the "Double Fault" mode: the Bus "+" wire shorted to the Bus "B" wire.

6.10 EMC Requirements—The vehicle manufacturer shall specify minimum EMC level of operation for a module that utilizes the data interface device. A philosophical method for classification of functional performance can be found in SAE J1113 Part 1 Appendix B (formerly SAE J1113 Appendix B). A component manufacturer that designs the interface device to conform to the most severe classification of Class C (type) is, for example, could be assured of adequate performance for all modules.

The modules that communicate with each other via this interface device shall not generate levels of noise emissions (EMI) large enough to interfere with each other. For reference, the levels defined by CISPR/AWG1 (Geneva, Sept 1989) may be used. In general, the specifications on rise and fall times control the EMI levels.

The vehicle manufacturers may find SAE J1211 helpful in applying to multiplex systems. SAE J1879 may also be utilized for specifying compliance.

This document recommends the vehicle manufacturers use the listed documents and the outlined EMC test plan defined in Appendix B. The actual voltage "level" requirements specified by the Test Plan are given for reference and the vehicle manufacturer specifications shall be used for compliance testing.

a. Radiated Emissions Antenna & Probe Test (CISPR/AWG1 Geneva 19 Sept 1989)

b. Transfer Function, Current probe monitoring (SAE J1113 Part 3)

c. Transfer Function, Antenna monitoring (SAE J1113 Part 3)

d. RF Susceptibility (SAE J1113 Part 13)

e. Transient Susceptibility (SAE J1113 Part 10)

7. Parameters

7.1 Application Layer—The following Application Layer requirements shall exist whenever the network is used.

Bit Dominance - A "0" bit dominates over a "1" bit.

7.2 Data Link Layer

7.2.1 PULSE WIDTH MODULATION (PWM) AT 41.6 Kbps—The maximum frame length from SOF to EOF inclusive is 101 bit times. The maximum number of message bytes (i.e., excluding frame delimiters SOF, EOD, EOF, and IFS) is 12 bytes.

7.2.2 VARIABLE PULSE WIDTH (VPW) AT 10.4 Kbps—The maximum number of message bytes (i.e., excluding frame delimiters SOF, EOD, EOF, and IFS) is 12 bytes.

7.3 Physical Layer

7.3.1 GENERAL NETWORK REQUIREMENTS (see Table 2)

TABLE 2—GENERAL NETWORK PARAMETERS

Parameter Description	Applicable Spec
On-Vehicle Network Length	35 meters
Off-Vehicle Network Length	5 meters
Total Vehicle Network Length	40 meters
Maximum number of standard size nodes (including off-vehicle equipment)	32 nodes
Off-vehicle load resistance	10.4 kohms ± 500 ohms
Off-vehicle capacitance (each bus wire to signal or chassis ground, as measured at the SAE J1962 connector)	

7.3.2 PULSE WIDTH MODULATION (PWM)

7.3.2.1 PWM Timing Requirements—The following requirements, Table 3, are for a nominal bit time of 24 us or 41.6 Kbps as seen at the source media.

Transmit tolerances include oscillator tolerances, physical layer skew(s) (turn-on and turn-off delays), and other miscellaneous tolerances. Receive tolerances include considerations for voltage offsets between transmitter and receiver and other miscellaneous tolerances.

Symbols received in the "gray" areas previously can be decoded as either the symbol before or after that of the "gray" area. For example, an active

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of 12.5 ms can be decoded as either an active phase "1" (Tp1) or an active phase "0" (Tp2). An incorrect decision will be detected in the CRC error detection byte. Figure 22 gives an example of how a signal should be decoded based on the received pulse width.

TABLE 5—PWM PULSE WIDTH TIMES (MS)

Symbol	Tx min	Tx nom	Tx max	Rx min	Rx max
Tp1: active phase "1"	≥ 7	8	≤ 9	≥ 6	≤ 11
Tp2: active phase "0"	≥ 15	16	≤ 17	≥ 14	≤ 19
Tp3: IFS time	≥ 23	24	≤ 25.5	≥ 20	≤ 27
Tp4: SOF/EOD time	≥ 47	48	≤ 51	≥ 45	≤ 53
Tp5: EOF time	≥ 76	72	78.5	≥ 70	80[1]
Tp6: IFS time	≥ 84	96	102[1]	N/A	N/A[2]
Tp7: Active SOF	≥ 30	32	≤ 33	≥ 30	≤ 35
Tp8: Active EOD	≥ 30	32	≤ 41	≥ 28	≤ 45
Tp9: BRK to IFS time	≥ 119	120	102[1]	N/A	N/A[2]
Tp10: SOF to Data rising edge	≥ 47	48	≤ 51	≥ 45	≤ 52
Tp11: Passive to next rising edge	≥ 0	N/A	N/A	≥ 0	N/A

SOF transitions into IFS and is not actually a "transmitted" symbol.
[1] Maximum IFS ends at next SOF.

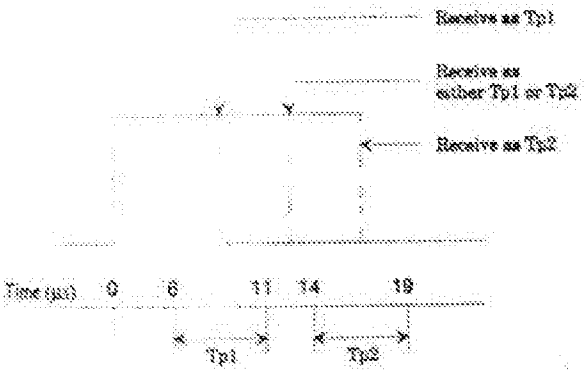

FIGURE 22—EXAMPLE OF RECEIVING A Tp1 OR Tp2 SYMBOL

Note that a pulse width detected between Tp1(min) and Tp1(max) must be decoded as an active phase "1" and a pulse width detected between Tp2(min) and Tp2(max) must be decoded as an active phase "0." However, a pulse width detected between Tp1(max) and Tp2(min) can be decoded as either an active phase "1" or active phase "0."

7.3.2.2 PWM DC Parameters (see Table 4)

7.3.3 VARIABLE PULSE WIDTH MODULATION (VPW)

7.3.3.1 VPW Timing Requirements—The following requirements, Table 5, show the VPW timing values.

7.3.3.2 VPW DC Parameters (see Table 6)

TABLE 4—PWM DC PARAMETERS[1]

Parameter	Symbol	Min	Typ	Max	Units
Input High Voltage	V_{IH}	3.50	–	5.25	V
Input Low Voltage	V_{IL}	-1.00	–	2.20	V
Output High Voltage	V_{OH}	3.50	–	5.25	V
Output Low Voltage	V_{OL}	0.00	–	1.00	V
Absolute Ground Offset Voltage	V_{AGO}	0.00	–	1.00	V
Bus (+) Driver & Bus (M) Termination Supply Voltage	V_{BUS}	4.75	5.00	5.25	V
Receiver Input Common Mode Operating Range	V_{CM}	1.96	–	4.75	V
Receiver Hysteresis & Crossover	V_{HYS}	0.98	–	1.80	mV
Network Resistance (each wire)	R_{NET}	0.00	–	378	Ohms
Network Capacitance (each wire)	C_{NET}	0.00	–	6,000	pF
Network Time Constant[2]	T_{NET}	–	–	1.50	µs
Signal Transition Time	T_{TRAN}	–	–	1.79	µs
Node Resistance (unit load, each wire)	R_{NODE}	–	2,000	–	Ohms
Node Capacitance (unit load, each wire to ground)	C_{NODE}	–	200	–	pF
Node Capacitance (unit load, wire-to-wire)	C_{NODE}	–	10	–	pF
Node Leakage Current (each wire - active state)	I_{LEAK}	–	–	100	µA
Node Leakage Current (each wire - passive state, unpowered node)	I_{LEAK}	–	–	100	µA
Node Leakage Current (each wire - passive state, powered node)	I_{LEAK}	–	–	20	µA

[1] Refer to Appendix D for an analysis of the PWM parameters.
[2] The network time constant (T_{NET}) is the product of R_{NET} and C_{NET}. Therefore, some combinations of network resistance and network capacitance are not allowed. The product of R_{NET} and C_{NET} must always be less than $T_{NET(max)}$.

TABLE 5—VPW PULSE WIDTH TIMES (MS)

Symbol	Tx min	Tx nom	Tx max	Rx min	Rx max
Tv1: Short Pulse	≥ 60	64	≤ 127	> 34	≤ 96
Tv2: Long Pulse	≥ 112	128	≤ 163	> 96	≤ 163
Tv3: SOF/EOD time	≥ 163	200	≤ 239	> 163	≤ 239
Tv4: EOF time	≥ 239	280	N/A[1]	> 239	N/A[1]
Tv5: BRK time	≥ 239	300	≤ 5 ms	> 239	≤ 1.0 s
Tv6: IFS time	≥ 239	300	N/A[1]	> 239	N/A[1]

[1] SOF transitions into IFS and is not actually a "transmitted" symbol.
[2] Maximum IFS ends at next SOF.

TABLE 6—VPW DC PARAMETERS[1]

Parameter	Symbol	Min	Typ	Max	Units
Input High Voltage[2]	V_{IH}	4.25	–	25.00	V
Input Low Voltage	V_{IL}	–	–	3.50	V
Output High Voltage	V_{OH}	6.50	–	8.00	V
Output Low Voltage	V_{OL}	0.00	–	1.00	V
Absolute Ground Offset Voltage	V_{AGO}	0.00	–	2.00	V
Network Resistance	R_{NET}	356	–	1,975	Ohms
Network Capacitance	C_{NET}	2,470	–	16,844	pF
Network Time Constant[3]	T_{NET}	–	–	5.2	µs
Signal Transition Time	T_{TRAN}	–	–	18.5	µs
Node Resistance (unit load)	R_{NODE}	–	10,600	–	Ohms
Node Capacitance (unit load)	C_{NODE}	–	470	–	pF
Node Leakage Current	I_{LEAK}	–	–	15	µA

[1] Refer to Appendix C for an analysis of the VPW parameters.
[2] Individual manufacturers may require a higher upper limit ($V_{IH(max)}$).
[3] The network time constant (T_{NET}) is the product of R_{NET} and C_{NET}. Therefore, some combinations of network resistance and network capacitance are not allowed. The product of R_{NET} and C_{NET} must always be less than $T_{NET(max)}$.

APPENDIX A
CHECKLIST OF APPLICATION-SPECIFIC FEATURES

A.1 Figure A1 is a checklist provided as an aid to highlight the communication features of J1850.

FEATURES	Tx	Rx	Comments
FRAME ELEMENTS			
Minimal Frame Elements : IFS, SOF, Data, CRC, EOF			
End of Data (EOD)			
Normalization Bit (NB) - Tx1/Tx2			
BUS ACCESS			
Idle Bus			

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FEATURES	Tx	Rx	Comments
Break (BRK)			
IN-FRAME RESPONSE			
Type 0 (None)			
Type 1 (Single Byte, Single Responder)			
Type 2 (Single Byte, Multiple Responder)			
Type 3 (Multiple Byte, Single Responder)			
ERROR DETECTION			
Cyclic Redundancy Check (CRC)			
Out of Range			
Invalid Bit			
Invalid Symbol			
Invalid Structure			
Invalid Message Length			
Number of Arbitration Bytes			
FAULT TOLERANCE			
Node Power Loss			
Bus Short to Ground			
Bus Short to Battery			
Loss of Node Ground Connection			
Loss of Termination Resistance			
Loss of Network Connection			
Dual Wire Fault Tolerance			
HEADER BYTES			
Single Byte			
One Byte Consolidated			
Three Byte Consolidated			
PHYSICAL ENCODING			
10.4 Kbps Variable Pulse Width Modulation (VPWM)			
41.6 Kbps Pulse Width Modulation (PWM)			
FEATURE ELEMENTS			
Maximum Frame Size			
Wake-Up Capability			

FIGURE A1 CHECKLIST OF APPLICATION-SPECIFIC FEATURES

APPENDIX B
I/O EMC TEST PLAN

B.1 Radio Disturbance From Vehicle Components—(CISPR/D/WG2 (Secretariat) 19 Sept 1989) - See Figure B1 for diagram.

B.1.1 Radiated Emissions Antenna Test

B.1.1.1 FREQUENCY RANGE—10 kHz to 1.8 GHz

B.1.1.2 BANDWIDTH SETTING

a. Frequency - 10 kHz to 149 kHz, Bandwidth - 1 kHz

b. Frequency - 150 kHz to 1 GHz, Bandwidth - 3 kHz

B.1.1.3 TEST DATA

B.1.1.3.1 Ambient Reference

a. 10 kHz modulation off

b. Both transmitter and receiver power off

c. Sweep signal off

B.1.1.3.2 Idle Bus State

a. 10 kHz modulation off

b. Both transmitter and receiver power on

c. Sweep signal off

B.1.1.3.3 Active Bus State

a. 10 kHz modulation on

b. Both transmitter and receiver power on

c. Sweep signal off

B.1.2 Radiated Emissions Probe Test

B.1.2.1 FREQUENCY RANGE—10 kHz to 200 MHz

B.1.2.2 BANDWIDTH SETTING

a. Frequency - 10 kHz to 149 kHz, Bandwidth - 1 kHz

b. Frequency - 150 kHz to 1 GHz, Bandwidth - 3 kHz

B.1.2.3 PROBE TYPE—As required to make measurements

a. Recommended probe type - Tektronix A6302 (0 - 29 MHz)

b. Recommended probe type - Allanch 94111-1 (30 - 200 MHz)

B.1.2.4 PROBE DISTANCE—5 cm from part

B.1.2.5 TEST DATA

B.1.2.5.1 Ambient Reference

a. 10 KHz modulation off

b. Both transmitter and receiver power off

c. Sweep signal off

B.1.2.5.2 Idle State

a. 10 kHz modulation off

b. Both transmitter and receiver power on

c. Sweep signal off

B.1.2.5.3 Active Bus

a. 10 kHz modulation on

b. Both transmitter and receiver power on

c. Sweep signal off

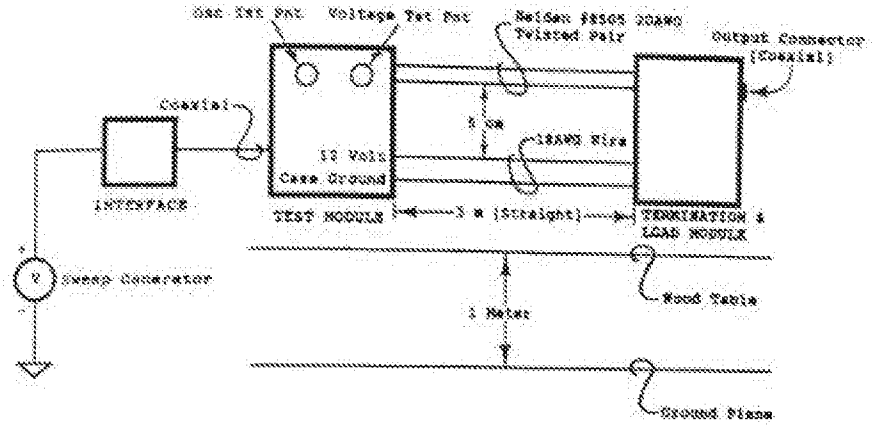


FIGURE B1—EMC TEST SETUP

B.2 Transfer Function—Electromagnetic Susceptibility Measurement Procedure for Vehicle Components

B.2.1 Current Probe Monitoring—Adapted from SAE J1113 Part 2 (formerly SAE J1113 (Aug 87) Section 2).

a. Frequency - 50 Hz to 250 kHz
b. Amplitude - 1 V peak-to-peak at test point
B.2.2 Antenna Monitoring—Adapted from SAE J1113 Part 3 (Formerly SAE J1113 (Aug 87) Section 3).
a. Frequency: 250 kHz to 200 MHz
b. Attenuator input power: = 25 mW to generate 1 V peak-to-peak at test point
B.2.3 Test Data
B.2.3.1 TRANSFER FUNCTION FROM VCC TO BUS
a. 10 kHz modulation on
b. Both transmitter and receiver power on
c. Sweep signal on
B.2.3.2 TRANSFER FUNCTION FROM GROUND TO BUS
a. 10 kHz modulation on
b. Both transmitter and receiver power on
c. Sweep signal on

B.3 RF Susceptibility—Electromagnetic Susceptibility Measurement Procedures for Common Mode Injection for compliance, test per SAE J1113 Part 13 (formerly SAE J1547).

B.3.1 Frequency Range—1 MHz to 200 MHz.
B.3.2 Max Level—100 mA RMS.
B.3.3 Procedure—Injection and monitoring to be applied to Bus pair only.
B.3.4 Test Data—Record the nature of any interaction occurring below the max level along with the current and frequency.

B.4 Transient Susceptibility—Test per SAE J1113 Part 10 (Adapted from ISO 7637/3).

Test Pulse Amplitude
a. Test Pulse 1: -30 V (Reference)
b. Test Pulse 2: +30 V (Reference)
c. Test Pulse 3a: -60 V (Reference)
d. Test Pulse 3b: +40 Vs (Reference)

APPENDIX C
VPW WAVEFORM ANALYSIS

C.1 VPW Waveform Analysis—Figure C1 shows a drawing of a bus waveform with various voltage levels and trip points. The voltage levels and trip points are defined as follows:

C.2 Voltage Levels and Trip Points

C.2.1 V_{min}—Minimum guaranteed output high voltage. This is also the highest trip point, with the source having no ground offset noise, and the receiver having 2 V of noise.

C.2.2 V_{max}—Maximum guaranteed output low voltage. This is also the highest trip point, with the receiver having no ground offset noise, and the source having 2 V of noise.

C.2.3 V_i—Ideal receiver trip point.

C.2.4 V_{inmin}—Minimum guaranteed input high voltage and is also the highest trip point with no offset noise.

C.2.5 V_{inmax}—Maximum guaranteed input low voltage and is also the lowest trip point with no offset noise.

C.3 VPW Pulse Width Analysis—Factors that affect the transmitted pulse width are oscillator tolerance and variations in delay through the source driver, bus, and the medium. These factors, along with some guard banding, are lumped into a single set of limits called T_{xmin} and T_{xmax} for each bus symbol.

Equations C1 and C2 are used to generate the transmitted pulse values shown in Table C1:

$$T_{xmin} = (T_{nom} - T_{xmin}/2) * 0.98 - T_{xmin} \quad \text{(Eq. C1)}$$

$$T_{xmax} = (T_{nom} + T_{xmax}/2) * 1.02 + T_{xmin} \quad \text{(Eq. C2)}$$

The $(T_{nom} \pm T_{xmin}/2) * 2\%$ factor covers the 2% oscillator tolerance. The T_{xmin} and T_{xmax} factors are given in Section 7. The T_{xmin} factor is assumed to be 5.0 which covers the rest of the factors (lumped variation in delay through the source driver and medium).

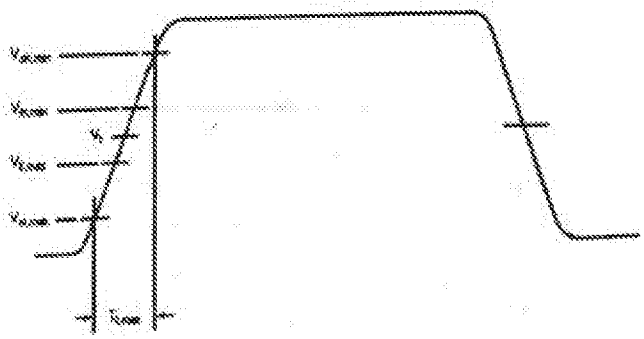


FIGURE C1—VOLTAGE LEVELS AND TRIP POINTS

TABLE C1—VPW PULSE WIDTH TIMES (µs)

Symbol	$T_{x,min}$	$T_{x,nom}$	$T_{x,max}$	$R_{x,min}$	$R_{x,max}$
Tx1: Short Pulse	49	64	79	34	96
Tx2: Long Pulse	112	128	145	96	163
Tx3: EOF/EOD time	190	200	218	184	237
Tx4: EOF time	251	280	N/A	241	N/A

(R) For VPW, node synchronization is an integral part of symbol timing. All transmitting nodes reference their transmit timing from their receiver's perception of the previous edge without regard to whether that edge was due to their own or another transmitter.

Figure C2 shows a plot of T_x, $T_{r,min}$ and $T_{r,max}$. Each is measured from the ideal trip point on the leading edge of the waveform. The fact that what is seen at the source's own receiver contributes to the transmitted pulse width and implies that the source device could be using echoed back information to shape what is transmitted.

(R) The pulse width seen by another node (receiver) can range from $T_{x,min} - T_{r,min}$ to $T_{x,max} + T_{r,max}$. This range comes from the variations in the transmitted pulse width combined with possible noise offset effects on the transmitted and receiving node. The $T_{x,min} - T_{r,min}$ situation occurs when a $T_{x,min}$ pulse width is transmitted by a source node with no ground offset noise, and received by a receiving node with a 2 V of ground offset noise. This sets up the possibility of the receiver tripping at $V_{dl,max}$ on the leading and trailing edge of the waveform. Therefore the pulse width seen by another node for the this $T_{x,min} - T_{r,min}$ situation including the oscillator tolerance and guard banding is given by Equation C4. Equation C5 is derived by including the effect of the real receiver trip point $T_{tp,max}$ in Equation C1 and substituting for $T_{x,min}$ in Equation C4. The $T_{r,min}$ /2 factor is equal to zero since an ideal trip point and no ground offset was assumed. The $T_{x,max} + T_{r,min}$ situation occurs with a $T_{x,max}$ pulse being transmitted, the source node having 2V of noise, and the receiver having no offset. This sets up the possibility of the receiving node tripping at $V_{dl,max}$. Again the actual acceptance range must be wider to allow for the receiving node's oscillator tolerance and any implementation-dependent uncertainties or constraints. Similarly Equations C7 and C8 are derived.

The receiving node may perceive the leading edge sooner or later than the transmitting node (source node). This range represents a receiver's required acceptance range for a given bus symbol. Figure C2 shows a drawing of this acceptance range.

The calculations for the received $T_{r,min}$ and $T_{r,max}$ are derived using the factors specified in section 7 for a 2 V ground offset range and a transition rise time of $T_{r,max}$. The transmitting node $T_{r,min}$ factor would be zero (0) if it was a perfect receiver and sensed a transition at the ideal trip point. However, for a real receiver the trip point $T_{tp,max}$ can be approximated by Equation C3 assuming a linear waveform rise time.

(R) $$T_{tp,max} = T_{r,max} * ((V_{hl,max} - V_{dl,max})/(V_{ah,max} - V_{dl,max})) \quad \text{(Eq. C3)}$$

The values for this range shown in Table C1 were arrived at using Equations C6 and C9. Note these values compare favorably with the values specified in Section 7, Table 5.

$$T_{x,min} = (T_{x,min} - T_{r,min}) * 0.98 - T_{r,min} \quad \text{(Eq. C4)}$$

(R) $$T_{x,min} = (((T_{x,min} - T_{tp,max}/2) * 0.98 - T_{r,min}) - T_{r,min}) * 0.98 - T_{r,min} \quad \text{(Eq. C5)}$$

$$T_{x,max} = (((T_{x,min} - T_{tp,max}/2) * 0.98 - T_{r,min}) - T_{r,min}) * 0.98 - T_{r,min} \quad \text{(Eq. C6)}$$

$$T_{x,max} = (T_{x,max} + T_{r,min}) * 1.02 + T_{r,min} \quad \text{(Eq. C7)}$$

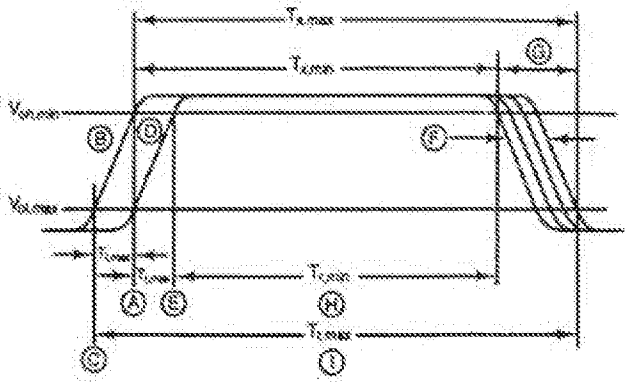
(R) $$T_{x,max} = (((T_{x,min} + T_{tp,max}/2) * 1.02 + T_{r,max}) + T_{r,max}) * 1.02 + T_{r,max} \quad \text{(Eq. C8)}$$

(R) $$T_{x,max} = (((T_{x,min} + T_{tp,max}/2) * 1.02 + T_{r,max}) + T_{r,max}) * 1.02 + T_{r,max} \quad \text{(Eq. C9)}$$

The 2% guard bands cover the oscillator tolerances of both transmitter and receiver and $T_{r,max} = 4.0$ covers the other uncertainties, including receiver delay and signal filter delay. VPW bus symbols allow no forbidden zones between symbols.

Table C1 shows the VPW Pulse Width Timing Requirements

Filter Compensation—The reason for choosing a synchronous data encoding technique is to synchronize at every valid state transition. If the delays through the filter, receiver, and output drivers can be characterized into a constant value, this delay can be compensated for by the timing logic. If variations in delay caused by this Filter and I/O Hardware cannot be easily compensated for, then the Source Interface device variations should be included in the ± 5.0 µs factor defined in $T_{x,min}$ and $T_{x,max}$. All further, variations in delay and including a safety factor for dead zones between symbols for the Receiving device should be included in the ± 4.0 µs factor defined in $T_{r,min}$ and $T_{r,max}$.



A - The trigger point on waveform "B" or "D" where the transmitting node sees the transition ending the previous symbol, and starts timing the current symbol. Take note that a node could trigger at any level of a transition between $V_{dl,max}$ and $V_{ah,min}$. The maximum and minimum trigger points of any given transition are illustrated by showing line A cutting through two different waveform transitions. This method of illustration allows separating the uncertainties of noises causing the beginning and ending of a symbol.

B - The earliest waveform that could trigger the transmitter at point A.

C - The earliest point on waveform "B" that could trigger any other node.

D - The latest waveform that could trigger the transmitter at point A.

E - The latest point on waveform "D" that could trigger any other node.

F - The waveform dispersion due to transmitter tolerances in oscillator, driver, etc.

G - The total transmitter spread when transition time limits are combined with the other tolerances in "F".

H - The shortest legitimate symbol time which can legitimately be seen under worst case conditions.

I - The longest legitimate symbol time which can legitimately be seen under worst case conditions.

Notes—$T_{x,min}$: Starts at $V_{dl,max}$ on wave "B"; $T_{x,max}$: Starts at $V_{ah,min}$ on wave "D"

FIGURE C2—WAVEFORM TIMING PARAMETERS

APPENDIX D
PWM WAVEFORM ANALYSIS

D.1 PWM Waveform Analysis—Figure D1 shows a drawing of a typical bus waveform with various voltage levels and trip points. Table D1 contains the DC parameter specifications.

D.2 Voltage Levels and Trip Points

D.2.1 V_{ih}—This is the input high voltage which a receiver must detect as an active state on bus (+) and as a passive state on bus (–).

D.2.2 V_{il}—This is the input low voltage which a transmitter must detect as an active state on bus (–) and as a passive state on bus (+).

D.2.3 V_{oh}—This is the output high voltage which a transmitter must drive bus (+) and the voltage which bus (–) must passively return to. Note that $V_{oh,min}$ is $V_{ah,min}$ plus the absolute maximum ground offset voltage ($V_{gs,max}$).

D.2.4 V_{ol}—This is the output low voltage which a transmitter must drive bus (–) and the voltage which bus (+) must passively return to. Note that $V_{ol,max}$ is $V_{dl,max}$ minus the absolute maximum ground offset voltage ($V_{gs,max}$).

D.2.5 V_{gs}—This is the absolute ground offset voltage that can exist between any two nodes on the network.

D.2.6 V_{sup}—This is the supply voltage which a transmitter must use to drive bus (+) and terminate bus (–).

D.2.7 V_{cm}—This is the receiver input common mode operating range. In order for the differential receiver to recognize a valid signal transition, the bus (+) and bus (–) signals must cross at a voltage within this range.

D.2.8 V_{hys}—This is the receiver hysteresis and overdrive voltage including any power supply reference tolerance.

D.2.9 R_{bus}—This is the equivalent network resistance from each bus wire to the corresponding passive voltage source.

D.2.10 C_{bus}—This is the equivalent network capacitance from each bus wire to ground.

D.2.11 T_{bus}—This is the network time constant for each bus wire. This is the product of R_{bus} and C_{bus} of each bus wire. The time constant determines the maximum active-to-passive transition time.

D.2.12 T_t—This is the signal transition time for each bus wire from either the active-to-passive state or passive-to-active state. The passive-to-active edge is driven by the transmitter and shall be no more than $T_{r,max}$. The active-to-passive edge is determined by the network time constant, bus voltage levels, and the passive state supply voltage level.

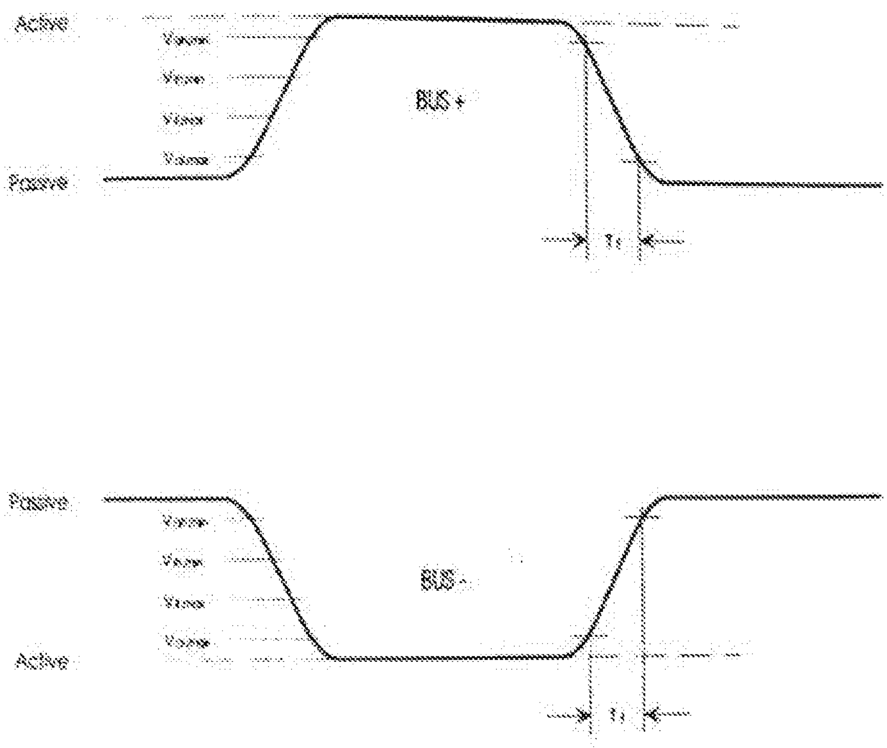


FIGURE D1—TYPICAL PWM WAVEFORM

TABLE D1—PWM DC PARAMETERS

Parameter	Symbol	Min	Typ	Max	Units
Input High Voltage	V_{IH}	2.80	—	6.25	V
Input Low Voltage	V_{IL}	-1.00	—	2.20	V
Output High Voltage	V_{OH}	3.80	—	6.25	V
Output Low Voltage	V_{OL}	0.00	—	1.20	V
Relative Ground Offset Voltage	V_{GO}	0.00	—	1.00	V
Bus (+) Driver & Bus (-) Termination Supply Voltage	V_{SUP}	4.75	5.00	5.25	V
Receiver Input Common Mode Operating Range	V_{CM}	1.80	—	2.75	V
Receiver Hysteresis & Overdrive	V_{HYS}	—	—	180	mV
Network Resistance (each wire)	R_{NET}	85	—	375	ohms
Network Capacitance (each wire)	C_{NET}	500	—	15,000	pF
Network Time Constant[1]	T_{NET}	—	—	1.35	μs
Signal Transition Time	T_T	—	—	1.75	μs
Node Resistance (unit load, each wire)	R_L	—	2,880	—	ohms
Node Capacitance (unit load, each wire to ground)	C_{LG}	—	250	—	pF
Node Capacitance (unit load, wire to wire)	C_{LW}	—	10	—	pF
Node Leakage Current (each wire - active state)	I_{LKA}	—	—	100	μA
Node Leakage Current (each wire - passive state, unpowered node)	I_{LKU}	—	—	100	μA
Node Leakage Current (each wire - passive state, powered node)	I_{LKP}	—	—	20	μA

[1] The network time constant (T_{NET}) is the product of R_{NET} and C_{NET}. Therefore, some combinations of network resistance and network capacitance are not allowed. The product of R_{NET} and C_{NET} must always be less than T_{NET}.

D.2.13 C_{LG}—This is the unit load node capacitance of each wire to ground. This capacitance, along with the unit load node capacitance wire-to-wire, results in the total network capacitance referred to in C.2.10.

D.2.14 C_{LW}—This is the unit load node capacitance wire-to-wire. This capacitance along with the node capacitance of each wire to ground results in the total network capacitance referred to in C.2.10.

D.2.15 I_{LKA}—This is the leakage current of each wire when the bus is in the active state.

D.2.16 I_{LKU}—This is the leakage current of each wire when the bus is in the passive state and the node is unpowered.

D.2.17 I_{LKP}—This is the leakage current of each wire when the bus is in the passive state and the node is powered.

D.3 Input Voltage Limits—Given the Bus (+) Driver & Bus (-) Termination Supply Voltage (V_{sup}) and the maximum Receiver Hysteresis & Overdrive Voltage (V_{hys}), V_{IH} and V_{IL} can be derived. (See Equations D1 through D4.)

$$V_{IL,min} = \text{(Ground Reference)} - V_{go} = 0.00 - 1.00 = -1.00 \text{ V} \quad \text{(Eq. D1)}$$

$$V_{IL,max} = ½ (V_{sup,min}) - V_{hys,max} = ½ (4.75) - 0.18 = 2.20 \text{ V} \quad \text{(Eq. D2)}$$

$$V_{IH,min} = ½ (V_{sup,max}) + V_{hys,max} = ½ (5.25) + 0.18 = 2.81 \text{ V} \quad \text{(Eq. D3)}$$

$$V_{IH,max} = V_{sup,max} + V_{go} = 5.25 + 1.00 = 6.25 \text{ V} \quad \text{(Eq. D4)}$$

where the ½ factor in $V_{IL,max}$ and $V_{IH,min}$ assumes a receive comparator voltage level of one-half of the supply voltage. It turns out this is a good tradeoff for voltage ground offset capability versus output drive requirements.

D.4 Output Voltage Limits—Output voltage limits can be derived directly from the input voltage limits. (See Equations D5 through D8.)

$$V_{OL,min} = V_{IL,min} + V_{go} = -1.00 + 1.00 = 0 \text{ V (Ground Reference)} \quad \text{(Eq. D5)}$$

$$V_{OL,max} = V_{IL,max} - V_{go} = 2.20 - 1.00 = 1.20 \text{ V} \quad \text{(Eq. D6)}$$

$$V_{OH,min} = V_{IH,min} + V_{go} = 2.80 + 1.00 = 3.80 \text{ V} \quad \text{(Eq. D7)}$$

$$V_{OH,max} = V_{IH,max} - V_{go} = 6.25 - 1.00 = 5.25 \text{ } (V_{sup,max}) \quad \text{(Eq. D8)}$$

D.5 Network Time Constant & Signal Transition Time—In order to guarantee signal cross over in the Receiver Input Common Mode Operating Range (V_{CM}) the signal transition time must be less than 2.20 μs. This is T_{LMAX} + the worst case transition time from $V_{OL,max}$ to $V_{IH,min}$ for Bus (-), or $V_{OH,min}$ to $V_{IL,max}$ for Bus (+). Therefore, given Δt = 2.20 μs, the following relationship for $V_{IH,min}$ for Bus (+) and $V_{IL,max}$ for Bus (+). (See Equations D9 through D12.)

$$V_{IH,min} = V_{sup,min} (1 - e^{-(\Delta t/T_{NET,max})}) \text{ for Bus (-)} \quad \text{(Eq. D9)}$$

$$V_{IL,max} = V_{OH,min} (e^{-(\Delta t/T_{NET,max})}) \text{ for Bus (+)} \quad \text{(Eq. D10)}$$

From this, the maximum network time constant ($T_{NET,max}$) can be derived.

$$T_{NET,max}\text{(Bus -)} = -\Delta t \div \ln(1 - (V_{IH,min}/V_{sup,min})) \quad \text{(Eq. D11)}$$

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(R) CLASS B DATA COMMUNICATION NETW
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$= -2.20 \times \ln(1-(3.80/4.75)) = 1.37$ ms

$T_{net,max}(\text{Bus}+) = -\Delta t \times \ln(V_{d,max}/V_{d,max})$ (Eq. D12)

$= -2.20 \times \ln(1.20/3.25) = 1.49$ ms

Choosing a $T_{net,max}$ of 1.35 µs satisfies both equations. Given a maximum network time constant of 1.35 µs, the signal transition time $T_{t,max}$ can be found by subtracting the time from $V_{d,max}$ to $V_{d,max}$ (for Bus –) or the time from $V_{d,max}$ to $V_{d,max}$ (for Bus +) from 2.20 µs. (See Equations D13 through D16.)

Bus (–):

$T(V_{d,max} \text{ to } V_{d,max}) = -T_{net,max} (\ln(1-(V_{d,max}/V_{sig,max}))$ (Eq. D13)

$= -1.35 (\ln(1-(1.20/4.75))) = 0.39$ µs

$T_{net,max} = 2.20 - T(V_{}$

$= 2.20 - 0.39$

Bus (+):

$T(V_{d,max} \text{ to } V_{d,max}) = -T_{net,max} (\ln$

$= -1.35 (\ln 3.$

$T_{net,max} = 2.20 - T(V_{}$

$= 2.20 - 0.44$

Therefore, choosing a network time const transition time $T_{t,max}$ of 1.75 µs ensures that the Common Mode Operating Range.

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V_{CC} to $V_{CC(min)}$ (0.1)

19 × 1.83 μs

$(1-V_{CC(min)}/V_{CC(min)})$ (0.2)

3.3(0.3.3333) = 0.45 μs

$V_{CC(min)}$ to $V_{CC(min)}$ (0.3)

18 × 1.36 μs

Where $T_{CC(min)}$ of 1.33 μs and a slight of the two bus signals will cross with

(R) CLASS B DATA COMMUNICATION NETWORK MESSAGES —DETAILED HEADER FORMATS AND PHYSICAL ADDRESS ASSIGNMENTS—SAE J2178/1 JAN95

SAE Recommended Practice

Report of the SAE Vehicle Network for Multiplexing and Data Communication Standards Committee approved June 1993. Completely revised by the SAE Message Strategy Task Force of the SAE Vehicle Network for Multiplex and Data Communication Standards Committee January 1995.

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APPENDIX A—NETWORK ARCHITECTURES AND HEADER SELECTION

1. *Scope*—This SAE Recommended Practice defines the information contained in the header and data fields of non-diagnostic messages for interactive serial communications based on SAE J1850 Class B networks. This document describes and specifies the header fields, data fields, field sizes, scaling, representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scope of frame fields defined by this document for non-diagnostic messages. Refer to SAE J1979 for specifications of emissions related diagnostic message header and data fields. Refer to SAE J2190 for the definitions of other diagnostic data fields. The descriptions of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC byte are given in SAE J1850.

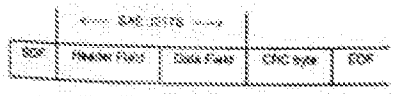


FIGURE 1—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE (IFR)

FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The Consolidated header format has two forms, a Single Byte form and a three byte form. This document covers all of these formats and forms to identify the meaning of messages which could be sent on a SAE J1850 network.

This document consists of four parts, each published separately.

SAE J2178/1 (Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats, Single Byte and Consolidated. It also contains the physical node address range assignments for the typical sub-systems of an automobile.

SAE J1962 (Titled: Data Parameter Definitions) defines the standard parameter data which may be exchanged on SAE J1850 (Class B) networks. The parameter scaling, ranges, and transfer functions are specified. Messages which refer to these parametric definitions shall always adhere to these parametric definitions. It is intended that at least one of the definitions for each parameter in this part matches the SAE J1979 definition.

SAE J2178/3 (Titled: Frame IDs for Single Byte Forms of Headers) defines the message assignments for the single byte header formats and the one byte form of the consolidated header format.

SAE J2178/4 (Titled: Message Definition for Three byte Headers) defines the message assignments for the three byte form of the consolidated header format.

2. *References*

2.1 Applicable Documents—The following publications form a part of this specification to the extent specified herein. Unless otherwise specified, the latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1931/1—Glossary of Vehicle Networks for Multiplex and Data Communication

SAE J1850—Class B Data Communication Network Interface

SAE J1930—Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms

SAE J1979—E/E Diagnostic Test Modes

SAE J2190—Enhanced E/E Diagnostic Test Modes

2.1.2 ANSI/IEEE PUBLICATION—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI/IEEE 754-1985—IEEE Standard for Binary Floating-Point Arithmetic

3. *Terms, Definitions, Abbreviations, and Acronyms*

3.1 Terms and Definitions

3.1.1 DATA (DATA FIELD)—Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or user modes which further defines a particular message content being exchanged over the network.

3.1.2 EXTENDED ADDRESS—The extended address is a means to allow a message to be addressed to a geographical location (such as geographic) or zone of the vehicle, independent of any node's physical address.

3.1.3 FRAME—A frame is one complete transmission of information which may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" definition below).

3.1.4 FRAME ID—The Frame ID is the header byte for the Single Byte Header format and the one byte form of the consolidated header format. The definition of the frame ID is found in SAE J2178/3. This header byte defines the target and source and content of the frame.

3.1.5 FUNCTIONAL ADDRESSING—Functional addressing allows a message to be addressed or sent to one or more nodes on the network interested in that function. Functional addressing is intended for messages that may be of interest to more than a single node. For example, an exterior lamp "off" message could be sent to all nodes controlling the vehicle exterior lamps by using a functional address. The functional address consists of a primary ID and may include a secondary ID and may also include an extended address.

3.1.6 HEADER (HEADER FIELD)—The header (or header field, used interchangeably) is a one or three byte field within a frame which contains information about the message priority, message source and target addressing, message type, and in-frame response type.

3.1.7 IN-FRAME RESPONSE (IFR) TYPE—The IFR type identifies the form of the in-frame response which is expected within that message.

3.1.8 LOAD—The load command indicates the operation of directly replacing the current/existing value of a parameter with the parameter value(s) contained in the message.

3.1.9 MESSAGE—A message consists of all of the bytes of a frame excluding the delimiter symbols (SOF, EOD, EOF, IFR).

3.1.10 MODIFY—The modify command indicates the operation of using the message data parameter value to change (e.g., increment, decrement, or toggle) the current/existing value.

3.1.11 PARAMETER—A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

3.1.12 PHYSICAL ADDRESSING—Physical addressing allows a message to be addressed to a specific node or to all nodes or to a non-existent, null node. The information in this message is of relevance only to a particular node, so the other nodes on the bus should ignore the message, except for the case of the "all nodes" address.

3.1.13 PRIMARY ID—The primary ID identifies the target for this functional message. This is the primary discriminator used to group functions into main categories.

3.1.14 PRIORITY—The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

3.1.15 REPORT—A report indicates the transmission of parametric data values, based on: a change of state; a change of value; on a periodic rate basis; or as a response to a specific request.

3.1.16 REQUEST—A request is a command to, or a query for data, or action from another node on the network.

3.1.17 RESPONSE DATA—The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

3.1.18 SECONDARY ID—The secondary ID (along with the primary ID or Frame ID) identifies the functional target mode for a message. The purpose of the secondary ID field within the frame is to further define the function or action being identified by the primary ID.

3.2 Abbreviations and Acronyms

A/C	-	Air Conditioning
ASC	-	ASCII Encoded SLOT
BCD	-	Binary Coded Decimal (BCD) SLOT
BMM	-	Bit Mapped with Mask SLOT
BMF	-	Bit Mapped without Mask SLOT
CRC	-	Cyclic Redundancy Check
CS	-	Checksum
DTC	-	Diagnostic Trouble Code
EOD	-	End of Data
EOF	-	End of Frame
EDR	-	Error Detection
HVAC	-	Heating, Ventilation, Air Conditioning
ID	-	Identifier
IFR	-	In-Frame Response
LSB	-	Least Significant Bit / Byte
MSB	-	Most Significant Bit / Byte
NB	-	Normalization Bit
PID	-	Parameter Identification (number, NOT the primary ID). See Section 6
PDT	-	Multiple Parameter Packet SLOT
PRN	-	Parameter Reference Number
SED	-	State Encoded SLOT
SFF	-	Signed Floating Point (Scientific Notation) SLOT
SLOT	-	Scaling, Limit, Offset, and Transfer Function (See Section 7)
SNM	-	2's Complement Signed Numeric SLOT
SOF	-	Start of Frame
UNM	-	Unsigned Numeric SLOT
VIN	-	Vehicle Identification Number

4. General Information

4.1 Part 1 Overview—The messages defined by this four part document are specified for networks using single byte headers or consolidated one and three byte headers as specified in SAE J1850. Sections 5 and 6 of SAE J1178/1 provide the system architecture for the different possible headers used in Class B network communication (see Appendix A for supporting discussion). Section 7 of SAE J1178/1 defines the data fields used by the different header byte formats. Section 8 of SAE J1178/1 defines the physical address assignments.

Figure 3 shows an overview of this part (Part 1) which encompasses the different possible messages and their component parts.

SAE J1850 defines two and only two formats of message headers. They are the Single Byte Header format and the Consolidated header format. The Consolidated header format has two forms, identified by the value of the H Bit. The two forms are: a three byte form and a five byte form. The information in the header field for both formats contains target, source, priority and message type information, while the data field contains additional addressing and/or parametric information and/or diagnostic test modes. This information is explicitly defined in some headers and implicitly defined in others. Messages defined by this document (Parts 1, 2, 3, and 4) are classified generally into two types:

a. Requests, that is, commands (load or modify) or queries for data, and
b. Responses, that is, reports or acknowledgements.

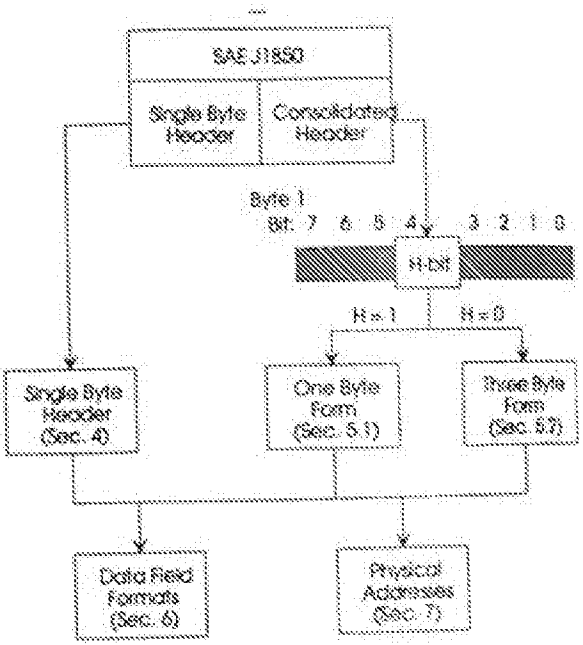


FIGURE 3—PART 1 OVERVIEW

When a node generates a request, the target nodes which are responsible for the requested data or function must respond by reporting the requested information or by performing the requested function. For responses (that is, reports or acknowledgements), data information that a node responds with may have been previously requested by another node, or reported by the node when the desired information has changed, or reported by the node on a periodic basis.

SAE J1178/1 describes the overall structure of messages. In total, part 1, 2, 3, and 4:

a. Fully define SAE (automotive industry) standard messages.
b. Reserve messages for future SAE standardization.
c. Reserve messages for manufacturers to allocate, which are (plant) unique or proprietary to that manufacturer.

In order to comply with this document, implementations need to use the defined messages on SAE J1850 networks in the exact way that they are defined here. However, there are a large number of message codes that are reserved for each manufacturer to independently allocate.

4.2 In-Frame Response Field Formats—The total number of bytes in the frame (not including frame delimiters) is 12, including the header (1 or 3 depending on header type), data (both in the message and IFR), and single byte CRC. Therefore, the total number of message and IFR data bytes can be 11 using a single byte header or the one byte form of the consolidated header, or 9 bytes if using the three byte form of the consolidated header.

4.2.1 IN-FRAME RESPONSE TYPE 0—The in-frame response type 0 is used to indicate the form without any in-frame response.

4.2.2 IN-FRAME RESPONSE TYPE 1—The in-frame response type 1 is a single byte response from a single responder. The response byte shall be the physical address of a receiver of the message. No CRC byte is included for this response data.

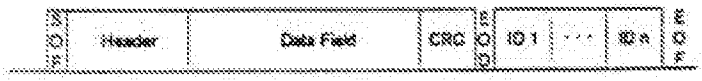
4.2.3 IN-FRAME RESPONSE TYPE 2—The in-frame response type 2 is a single byte response from multiple responders. The response byte(s) shall be the physical address of the receiver(s) of the message. No CRC byte is included in the response data.

4.2.4 IN-FRAME RESPONSE TYPE 3—The in-frame response type 3 is a multiple byte response from a single responder. The response bytes shall be data (generally not its address) from a single responder. The second CRC byte is included for the data integrity of the response data. The actual in-frame response data shall be one byte in length, as a minimum.

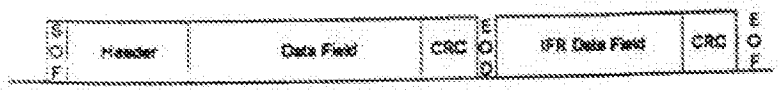
Figure 4 illustrates the four IFR types.

Type 0 - None

Type 1 - Single Byte From a Single Responder



Type 2 - Single Byte From Multiple Responders



Type 3 - Multiple Bytes From a Single Responder

FIGURE 4—TYPES OF IN-FRAME RESPONSE

5. *Single Byte Header Messages and Format*—For single byte header messages, the entire byte is used to define the message identifier (ID) as shown in Figure 5. This allows up to 256 unique message identifiers to be defined. Standard message identifiers that utilize this header format are found in SAE J1708/3.

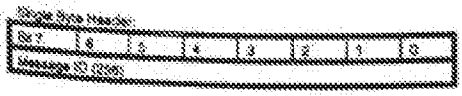


FIGURE 5—SINGLE BYTE HEADER

All single byte header messages utilize one of the four in-frame response (IFR) types (see Figures 4).

6. *Consolidated Header Messages and Format*—The consolidated header format includes both a one byte form and a three byte form.

6.1 One Byte Form of the Consolidated Header Format—The one byte form utilizes 7 bits for the message identifier thereby allowing up to 128 distinct IDs. The H bit (bit 4) is always a logic "1" signifying the one byte form of the consolidated header. Figure 6 illustrates this message header form. Standard message identifiers that utilize this header form are defined in SAE J1708/3.

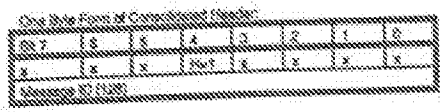


FIGURE 6—ONE BYTE FORM OF CONSOLIDATED HEADER

In order to accommodate a one byte header form and a three byte header form on the same network, the header type bit (H bit) in the first byte of the message has been defined to indicate the header form. This bit is defined in Table 1.

TABLE 1—H BIT DEFINITION

H Bit	Header Byte Form
0	Three Byte Form
1	One Byte Form

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All one byte header form messages of the consolidated header format utilize one of the four in-frame response (IFR) types (see Figure 4).

6.2 **Three Byte Form of the Consolidated Header Format**—This header form utilizes the first three bytes of the message. The H bit (bit 4) is always a logic "0" signifying the three byte form. Standard message identifiers that utilize this header form are defined in SAE J2178/4. The remaining seven bits of the first byte contain information about priority (PPP) and message type (KYZZ). The second byte contains the target address information. The target can be either functionally addressed or physically addressed. The third byte contains the physical address of the source of the message. Arbitration is always resolved by the end of the third byte, since the source address must be unique. Figures 7 and 8 illustrate this message header form.

Three Byte Form of Consolidated Header

Byte 1	Byte 2	Byte 3
See Figure 8	Target Address	Source Address

FIGURE 7—THREE BYTE FORM OF CONSOLIDATED HEADER

Byte 1 of Three Byte Form of Consolidated Header

Bit 7	6	5	4	3	2	1	0
P	P	P	H	K	Y	Z	Z
Priority (0 to 7)			H=0	Message Type (see below)			

Bit	Definition	Value	Meaning
K	In-Frame Response (IFR)	0	IFR Required
		1	IFR Not Allowed
Y	Addressing Mode	0	Functional Addressing
		1	Physical Addressing
ZZ	Specific Message Type	00	See Table 6
		01	
		10	
		11	

FIGURE 8—FIRST BYTE OF THREE BYTE FORM OF CONSOLIDATED HEADER

All three byte header messages utilize one of the four in-frame response (IFR) types (see Figure 4, 3.2).

6.2.1 PRIORITY/TYPE-BYTE 1—The priority/type byte contains information about priority, in-frame response, addressing type, and type modifier. Each of the field definitions is described in the following paragraphs.

6.2.1.1 Priority (PPP Bits)—The priority field is three bits in length and immediately proceeds the header type (H) bit. The priority bit definition is shown in Table 2. The priority bit assignments for a particular message are manufacturer specific and are not assigned by SAE J2178.

TABLE 2—PRIORITY FIELD ASSIGNMENTS

PPP Bits	Priority	Level
000	0	Highest
001	1	.
010	2	.
011	3	.
100	4	.
101	5	.
110	6	.
111	7	Lowest

6.2.1.2 Header Type (H Bit)—In order to accommodate a one byte header form and a three byte header form on the same network, the header type bit (H bit) in the first byte of the message has been defined to indicate the header form. This bit is defined in Table 3.

TABLE 3—H BIT DEFINITION

H Bit	Head Byte Form
0	Three Byte Form
1	One Byte Form

6.2.1.3 In-Frame Response (K Bit)—The necessity for in-frame response is encoded into a single bit in the priority/ type byte. This bit definition is shown in Table 4.

6.2.1.4 Addressing Type (Y Bit)—Message addressing is encoded with a single bit in the priority/type byte. This bit definition is shown in Table 5.

TABLE 4—"K" BIT ASSIGNMENTS

K Bit	In-Frame Response
0	Required
1	Not Allowed

TABLE 5—"Y" BIT ASSIGNMENTS

Y Bit	Addressing Type
0	Functional
1	Physical

6.2.1.5 Type Modifier (ZZ Bits)—The type modifier is encoded as a two bit field (ZZ) and is used in conjunction with the in frame response bit (K) and the address type bit (Y) to define sixteen message types, see Table 6.

TABLE 6—THE SIXTEEN MESSAGE TYPES

Msg Type	KYZZ	Response (K bit)	Addressing (Y bit)	IFR Type	Message Type (Name)
0	0000	Required	Functional	3	Function
1	0001	Required	Functional	1	Broadcast
2	0010	Required	Functional	2	Function Query
3	0011	Required	Functional	3	Function Reset
4	0100	Required	Physical	1	Node-to-Node
5	0101	Required	Physical	—	Reserved - MFG
6	0110	Required	Physical	—	Reserved - SAE
7	0111	Required	Physical	—	Reserved - MFG
8	1000	Not Allowed	Functional	0	Function Command / Data
9	1001	Not Allowed	Functional	0	Function Request / Query
10	1010	Not Allowed	Functional	0	Function Ext. Command / Data
11	1011	Not Allowed	Functional	0	Function Ext. Request / Query
12	1100	Not Allowed	Physical	0	Node to Node
13	1101	Not Allowed	Physical	0	Reserved - MFG
14	1110	Not Allowed	Physical	0	Acknowledgement
15	1111	Not Allowed	Physical	0	Reserved - MFG

NOTES:
1. Functional addresses for the three byte form of the consolidated header are defined in SAE J2178/4. Physical address ranges are defined in Section 7 of this part.
2. Message types 8 and 9 use functional data format #2 only, message types 10 and 11 use functional data format #3 only.
3. Reserved - SAE indicates reserved for future SAE Committee action. Reserved - MFG indicates that manufacturers are allowed to allocate these definitions without assuring any commonality between motor vehicle manufacturers.

6.2.2 TARGET ADDRESS-BYTE 2—The second byte of the three byte form of the consolidated header contains either a functional or physical target address. The physical address assignments are found in Section 7 of this part while functional message address assignments are in SAE J2178/4.

Functional addresses are assigned in pairs where the only difference between the ID values is the least significant bit (W bit). Figure 9 illustrates the functional target address with W bit.

Bit 7	6	5	4	3	2	1	0
X	X	X	X	X	X	X	W
Primary ID (1/8 pairs)							

FIGURE 9—FUNCTIONAL TARGET ADDRESS

The W bit is logic "0" to signify a Command target and logic "1" to signify Status target. This bit is defined in Table 7.

TABLE 7—W BIT DEFINITION

W Bit	Functional Target Address Type
0	Command
1	Status

6.2.3 SOURCE ADDRESS-BYTE 3—The third byte of the three byte format of the consolidated header format is the physical address of the source of the message. Physical address assignments are found in Section 8. These physical address assignments shall be unique for each node of a network.

7. *Data Field Formats*—In both message header formats, single byte and consolidated, the data field can usually be encoded in the same way. This section briefly describes the different ways that information can be formatted in the data field. The data field immediately follows the header field. The number of bytes in this field will vary, based upon the content of the header field. The maximum data field length is limited by the requirements of SAE J1939. Because of differences in functionally and physically addressed messages or with in-frame response data, these cases are defined separately.

7.1 **Functional Data Field Formats**

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7.1.1 FUNCTIONAL DATA FIELD FORMAT 0—One of the functional data field formats is, in fact, no additional bytes of data (an empty data field). The message consists of the header, error checking byte, and in-frame response byte. This is the format used for functional message types 2 and 3. Because the data field does not actually exist but to allow referencing in other parts of the document, it has been identified as the functional data field format 0.

7.1.2 FUNCTIONAL DATA FIELD FORMAT 1—In the simplest case including data (format 1), the data field contains only parametric data. The first byte of the data field in this case contains the most significant byte of data. The data field must contain one byte as a minimum. Figure 10 illustrates this message format. This data field format may be used for message types 0 and 1 only.

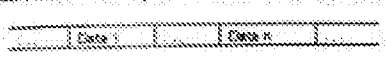

FIGURE 10—FUNCTIONAL DATA FIELD FORMAT 1

7.1.3 FUNCTIONAL DATA FIELD FORMAT 2—In a data field format 2 message, the data field contains a byte which is used to further define the target function being addressed. In this format type, the data field would appear as shown in Figure 11. This data format may be used for message types 0, 1, 8 and 9.

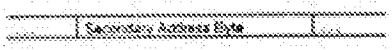

FIGURE 11—FUNCTIONAL DATA FIELD FORMAT 2

The secondary address byte consists of a parameter/quantity bit (Q bit) in which binary data (such as, on/off or yes/no) can be encoded. There is a listing of the possible uses for this bit in SAE J2178/4. The control bit (C bit) is used to distinguish between an immediate load of data or a modify of the current data for command messages, or to distinguish between request/report and query message operations. The remaining six bits specify a secondary ID address. The order of these bits within the secondary address byte is shown in Figure 12.

Bit 7	6	5	4	3	2	1	0
Q	C	Secondary ID (6 bits)					

FIGURE 12—SECONDARY ADDRESS BYTE FORMAT

In many cases, a single data bit (i.e., the Q bit) is not adequate to define the data parameter being sent. In this case, the identifier field is followed by an additional data field as illustrated in Figure 13. The combination of the primary and secondary addresses defines whether additional data is used by that message.

FIGURE 13—FUNCTIONAL DATA FIELD FORMAT 2, WITH DATA BYTES

7.1.3.1 The Parameter/Quantity Bit (Q bit)—The Q bit is used to represent single, binary values. Refer to SAE J2178/4 for a list of valid uses for the Q bit.

7.1.3.2 The Control Bit (C bit)—The C bit represents an action or operation to be taken with the associated data values. Table 8 shows how the W and C bits are used in conjunction with the eight functionally addressed message types (0–3, and 8–11) to define a particular message operation.

Modify messages adjust (e.g., increment/decrement) or toggle the state of existing data. Load messages replace current or existing data. Request messages "ask" for existing status or command data. Report messages "tell" existing status. Query messages "ask" for the receivers of a message without asking for the associated data.

7.1.3.3 The Secondary ID—The secondary identification field is used to further identify the particular function or operation being addressed by this message. It is used to distinguish a function when the primary ID is not sufficient, or to define a specific operation to be performed by the function addressed by the primary ID. These secondary identification addresses are assigned in SAE J2178/3 and SAE J2178/4.

7.1.4 FUNCTIONAL DATA FIELD FORMAT 3—In a data field format 3 message, depending on the particular primary and secondary ID, the data field may also contain an extended address byte which defines the geographical location within the vehicle of the target function being addressed. This data field format may be used for message types 0 and 1 and must be used for message types 10 and 11. In this data field type, the data field appears as shown in Figure 14.

TABLE 8—MESSAGE OPERATIONS

Msg Type	KYZ2	W	C	Message Type	Message Operation
0	0000	0	0	Function	Load Command
		0	1		Modify Command
		1	0		Report Status
		1	1		MFG Specific
1	0001	0	0	Broadcast	Load Command
		0	1		Modify Command
		1	0		Report Status
		1	1		MFG Specific
2	0010	0	n/a	Function Query	Command Query
		1	n/a		Status Query
3	0011	n/a	n/a	Function Read	Not Applicable
8	1000	0	0	Function Command /Status	Load Command
		0	1		Modify Command
		1	0		Report Status
		1	1		MFG Specific
9	1001	0	0	Function Request / Query	Status Request
		0	1		Report Acknowledge
		1	0		Command Request
		1	1		Function Query
10	1010	0	0	Function Ext. Command / Status	Load Command Extended
		0	1		Modify Command Extended
		1	0		Report Status Extended
		1	1		MFG Specific
11	1011	0	0	Function Ext. Request / Query	Status Request Extended
		0	1		Report Acknowledge Extended
		1	0		Command Request Extended
		1	1		Function Query Extended

FIGURE 14—FUNCTIONAL DATA FIELD FORMAT 3

The extended address byte is used to determine where, geographically on a vehicle, a particular function is located. The exact definition of the extended address values can be found in 7.3. The secondary address in Figure 14 is used as defined in 7.1.3.

As in the other data field formats, a parameter data field may also be needed and in this case it is then appended to the end of the other identifiers. This format is shown in Figure 15.

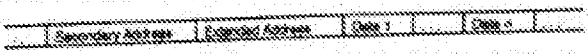

FIGURE 15—FUNCTIONAL DATA FIELD FORMAT 3, WITH DATA BYTES

7.1.5 FUNCTIONAL DATA FIELD FORMAT 4—In this data field format message, the data field contains a byte which defines the diagnostic test mode of the target function being addressed. In this type, the data field would appear as shown in Figure 16. This data format may be used for message types 0, 1, 8 and 9.

FIGURE 16—FUNCTIONAL DATA FIELD FORMAT 4

The test mode byte is used to determine which diagnostic function is involved. It may then be followed by parameter data fields. In this case, the additional data bytes follow the test mode byte. This format is shown in Figure 17. This is the format for functionally addressed diagnostic messages such as those found in SAE J1979.

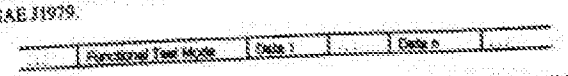

FIGURE 17—FUNCTIONAL DATA FIELD FORMAT 4, WITH DATA BYTES

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7.2 **Physical Data Field Formats**—The previous section (7.1) defined the data field formats for functionally addressed messages. This section (7.2) defines the data field formats for physically addressed messages.

7.2.1 PHYSICAL DATA FIELD FORMAT 0—One of the physical data field formats is, in fact, no additional bytes of data (an empty data field). The message consists of the header, error checking byte, and may be with or without in-frame response bytes. This is the format used for the acknowledgement message type. This message type simply confirms to another node that the message has been received correctly. Because this data field does not actually exist but to allow referencing in other parts of this document, it has been identified as the physical data field format 0.

7.2.2 PHYSICAL DATA FIELD FORMAT 1—Physical data field format 1 is generally associated with the node-to-node message types. This message type is the one utilized for enhanced E/E diagnostic test modes (see SAE J2190). This format assumes the three byte form of the consolidated header format. The single byte format and the one byte form of the consolidated header format are covered in physical data field format 2 (see 7.2.3). Many of the specific diagnostic messages are defined in SAE J2190. This description of the format is consistent with SAE J2190 but expands the definition to allow the format to be used in other messages as well. In particular, the manufacturer specific applications of this node-to-node message are expected to follow this format. The basic format is similar to the functional data field format 4. The format is shown in Figure 18.

	Physical Test Mode	

FIGURE 18—PHYSICAL DATA FIELD FORMAT 1

The format will often include data bytes as shown in Figure 19. The contents of the test mode byte indicate if additional data bytes are used.

	Physical Test Mode	Data 1	...	Data n	...

FIGURE 19—PHYSICAL DATA FIELD FORMAT 1, WITH DATA BYTES

The physical test mode byte details are shown SAE J2190.

7.2.3 PHYSICAL DATA FIELD FORMAT 3—In order to maximize commonality between the different header byte formats, the physical data field format 2 is essentially the same as physical data field format 1 with the insertion of the physical target address byte ahead of the physical test mode byte. This allows the single byte header format and the one byte form of the consolidated header format to operate consistently with the three byte header form. The format is shown in Figures 20 and 21 for the two cases, without and with additional data bytes, respectively.

	Physical Target Address	Physical Test Mode	

FIGURE 20—PHYSICAL DATA FIELD FORMAT 2

...	Physical Target Address	Physical Test Mode	Data 1	...	Data n	...

FIGURE 21—PHYSICAL DATA FIELD FORMAT 2, WITH DATA BYTES

7.3 **Extended Addressing**—Extended addressing defines an extended (geographical) location in the vehicle. The upper two bits of the extended address (RR) are used to allow up to four different types of extended addressing. Table 9 shows these bit assignments.

TABLE 9—EXTENDED ADDRESS TYPES

RR	Type
00	Geographical Addressing
01	Reserved - SAE
10	Reserved - MFG
11	Reserved - MFG

The extended address format for geographical addressing is encoded as shown in Figure 22.

Bit 7	6	5	4	3	2	1	0
RR = 00	XXX = Row #			YYY = Col #			

FIGURE 22—EXTENDED ADDRESSING

The codes XXX = 000 (for rows) and YYY = 000 (for columns) indicate that ALL rows and/or ALL columns are indicated. In other words, to address all of the items in a specific row, regardless of which column, use XXX = 000. For all items in the same column, independent of which row, use YYY = 000. Using all combinations of XXX and YYY, there are 64 total geographical zones that can be addressed. Table 10 shows the different combinations available.

TABLE 10—EXTENDED ADDRESS AREAS

XXX Range	YYY Range	Description	# zones
000	000	ALL Rows and Columns	1
000	001 - 111	ALL Rows x 7 Columns	7
001 - 111	000	ALL Columns x 7 Rows	7
001 - 111	001 - 111	49 Distinct Areas	49
Total	—	—	64

SAE J2178/4 lists the valid extended address assignments based on message.

A map illustrating the 49 zones of the vehicle is shown in Figure 23. It generally represents a top view of the vehicle and supports both Left/Right and Driver/Passenger side references.

XXX \ YYY	001	010	011	100	101	110	111
001	Left Side Front Surface	Driver Side Front Surface	Left Center Front Surface	Center Point Front Surface	Right Center Front Surface	Passenger Side Front Surface	Right Side Front Surface
010	Left Side Under Hood	Driver Side Under Hood	Left Center Under Hood	Center Point Under Hood	Right Center Under Hood	Passenger Side Under Hood	Right Side Under Hood
011	Left Side Aft Bulkhead	Driver Side Aft Bulkhead	Left Center Aft Bulkhead	Center Point Aft Bulkhead	Right Center Aft Bulkhead	Passenger Side Aft Bulkhead	Right Side Aft Bulkhead
100	Left Side Aft "A" Pillar	Driver Side Aft "A" Pillar	Left Center Aft "A" Pillar	Center Point Aft "A" Pillar	Right Center Aft "A" Pillar	Passenger Side Aft "A" Pillar	Right Side Aft "A" Pillar
101	Left Side Mid Vehicle	Driver Side Mid Vehicle	Left Center Mid Vehicle	Center Point Mid Vehicle	Right Center Mid Vehicle	Passenger Side Mid Vehicle	Right Side Mid Vehicle
110	Left Side Trunk	Driver Side Trunk	Left Center Trunk	Center Point Trunk	Right Center Trunk	Passenger Side Trunk	Right Side Trunk
111	Left Side Rear Surface	Driver Side Rear Surface	Left Center Rear Surface	Center Point Rear Surface	Right Center Rear Surface	Passenger Side Rear Surface	Right Side Rear Surface

NOTE—Refer to J2178/4 for range of address explanation.

FIGURE 23—EXTENDED ADDRESS MAP

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A. Physical Address Assignments—The physical address assignment ranges for nodes on a network are shown in Table 11. It is important to note that node address assignments on any network must be unique. In other words, no two nodes can have the same physical address assignment.

TABLE 11—NODE PHYSICAL ADDRESS ASSIGNMENTS

Node Category	Address (hex)	# of Nodes
Powertrain Controllers:	00 - 1F	32
Integration / Manufacturer Expansion	00 - 0F	16
Engine Controllers	10 - 17	8
Transmission Controllers	18 - 1F	8
Chassis Controllers:	20 - 3F	32
Integration / Manufacturer Expansion	20 - 27	8
Brake Controllers	28 - 2F	8
Steering Controllers	30 - 37	8
Suspension Controllers	38 - 3F	8
Body Controllers:	40 - C7	136
Integration / Manufacturer Expansion	40 - 57	24
Reserved	58 - 5F	8
Driver Information / Displays	60 - 6F	16
Lighting	70 - 7F	16
Entertainment / Audio	80 - 8F	16
Personal Communications	90 - 97	8
Climate Control (HVAC)	98 - 9F	8
Convenience (Doors, Seats, Windows, etc.)	A0 - BF	32
Security	C0 - C7	8
Future Expansion:	C8 - CF	8
Manufacturer Specific:	D0 - EF	32
On-Board Testers / Diagnostic Tools:	F0 - FD	14
All Nodes:	FE	1
Not Valid:	FF	1

APPENDIX A
NETWORK ARCHITECTURES AND HEADER SELECTION

A.1 Architectures of Networks—A wide variety of network topologies can be envisioned by network designers. The message structure described in this document is very flexible and useful in exchanging information between network nodes. The following discussion describes two network architectures that are likely configurations to use this message definition set:

a. A single network architecture

b. A multiple network architecture

Which of the different message definitions to use for these two network architectures is left as the system designer's choice, because the selection would be application specific. It should be noted that the hardware that supports these two message structures is generally not interchangeable. It is recommended that this be taken in choosing which message definition to use because the selection is generally irreversible because of these hardware limitations.

Considerations must be given by the network designer as to whether a single network architecture or a multiple network architecture, within the same vehicle, is preferable for that application. For example, a multiple network architecture could be based on one network optimized around data communication (Class B) protocol requirements, and another network optimized around sensor type (Class A) multiplexing requirements. The Class B network may be characterized such that time is a significant characteristic of the protocol where the functional "broadcast" type of message strategy can most effectively be used. The functional messages strategy can, if required, define the source or destination of a particular message by making it part of the message. However, it is unnecessary to designate or specify the source or destination of functional broadcast type messages. Reception becomes the exclusive responsibility of the receiving node.

A Class A network could handle the vehicle's event-driven multiplexing requirements. A single network architecture is based on the concept of a network that handles both Class A and B requirements. It should be clear that both network architectures must be cost effective for the application and the specific nodes on each network.

In Class B communications, the network consists of the interconnection of intelligent nodes such as: an engine controller, a body computer, a vehicle instrument cluster, and other modules. Such a network normally does not significantly reduce the base vehicle wiring but provides an inter-module data communications capability for distributed processing. The data shared between modules may be repetitive in nature and sometimes requires handshaking between modules or acknowledgment of data reception. As a result of handling the repetitive data and response type data, a network can be optimized around functional addressing. Functional addressing sends data on the network which can be received by one or more nodes without regard to the physical location of the module but only by their "interest" in those specific functions. In general, the transmitting node doesn't care which, if any, nodes receive the data it is sending. When physical addressing is required in a data communications (Class B) network, it is usually for vehicle diagnostic purposes and can be easily handled without reducing network bandwidth. See Section 6 for a discussion of these two types of message addressing.

In Class A communications, the network generally consists of the interconnection of limited intelligence nodes, often simply sensors or actuators. These Class A networks can significantly reduce the base vehicle wiring as well as potentially remove redundant sensors from the vehicle. The data shared between nodes in this case are generally event driven in nature. In most vehicles, the number of event driven signals predominates but they are only needed infrequently. The message to "turn headlamps on," for example, can be easily seen as event driven. Because these messages are infrequent (only sent once when the signal changes), they generally require acknowledgment, either within the same message or a separate handshake / response message. Both of these approaches are supported by SAE J1850 and in this document.

The single network architecture carries both the Class A and Class B messages on one network. The characteristics of both time critical and event driven messages must be accommodated on a message by message basis. In general, this level of complexity will need the flexibility of the consolidated header structure. For some applications, however, the single byte header may be adequate and is in no way limited by this specification.

The multiple network architecture tends to separate the Class A messages from the Class B messages and optimize each network and node interface for the specific characteristics of each network Class. The time critical messages could be exchanged on one network while the event driven messages sent to another. For example, the data communication (Class B) repetitive messages can be handled on one network and the sensor and control (Class A) multiplexing requirements on another network. This architecture requires both networks to work together to achieve the total vehicle network requirements. If information is needed between the multiple networks, care must be exercised to meet the needs of each of the networks. This concept of multiple networks is not limited to two, but can be extended to several separate networks, if desired.

A.2 Header Selection—The selection of headers is dependent on a number of factors. Hardware cost is related to the complexity of interface hardware required, as opposed to level of software required to implement the system.

The three byte form of the consolidated header offers systems designers advantages over the single byte only header format. More bits are available for use in assigning message identifiers, priorities, message types, etc. In addition, the three byte header is not restricted to 256 addresses. The "R" bit of the consolidated header format is used to indicate the use of one byte or three byte header messages which provides flexibility for future applications. This consolidated format generally requires increased hardware implementations because of the variety of message forms allowed. However, because of the increased hardware definition, software complexity and coding error problems are reduced. The consolidated header format offers the flexibility to readily handle both Class A and Class B requirements, matching header length to each specific message, as needed.

The single byte only header format is a simple and efficient method of identifying messages in a Class B data communications optimized network. This type of header can be simply called the Message Identifier or ID. The ID becomes the name of the message that is broadcast to all the other nodes on the network. The message ID concept supports a very easily understood message protocol leading to the utilization of a simple hardware interface circuit.

The single byte only header format in a Class B data communications environment is required to support a repetitive message strategy and manage network bandwidth efficiently. The results can yield an average message length of less than four bytes. Message overhead can be kept small and message latency minimized to improve the network's capability for handling time critical data. Another resulting feature of this method of message identification is that arbitration events are reduced (resolved within the first byte) and the need to carefully assign message priority is reduced.

As is the case of network architectures above, the choice of single byte header format or consolidated header format is left to the systems designer. The choice must be made for each separate network for each application but this offers the ability to select which characteristic is important for the specific case.

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Report of the Vehicle Network for Multiplexing and Data Communications Standards Committee approved June 1993.

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8. Multiple Frame, Single Parameter Formats

1. *Scope*—This SAE Recommended Practice defines the information contained in the header and data fields of non-diagnostic messages for automotive serial communications based on SAE J1850 Class B networks. This document describes and specifies the header fields, data fields, field sizes, scaling, representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scope of frame fields defined by this document for non-diagnostic messages. Refer to SAE J1979 for specifications of emissions-related diagnostic message header and data fields. Refer to SAE J2190 for the definition of other diagnostic data fields. The description of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC byte are given in SAE J1850.

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The consolidated header format has two forms, a single byte form and a three byte form. This document covers all of these formats and forms to identify the contents of messages which could be sent on a SAE J1850 network.

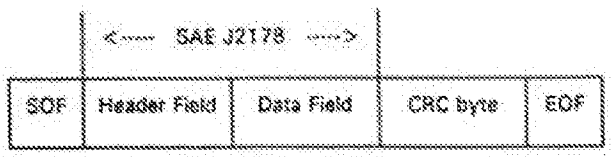

FIGURE 1—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE (IFR)

FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

This document consists of four parts, each published separately.

Part 1 of SAE J2178 (Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats, single byte and consolidated. It also contains the physical node address range assignments for the typical subsystems of an automobile.

Part 2 of SAE J2178 (this part, Titled: Data Parameter Definitions) defines the standard parametric data which may be exchanged on SAE J1850 (Class B) networks. The parameter scaling, ranges, and transfer functions are specified. Messages which refer to these parametric definitions shall always adhere to these parametric definitions. It is intended that at least one of the definitions for each parameter in this part match the SAE J1979 definition. The details of this part are fully described in 3.1.

Part 3 of SAE J2178 (Titled: Frame IDs for Single Byte Forms of Headers) defines the message assignments for the single byte header format and the one byte form of the consolidated header format.

Part 4 of SAE J2178 (Titled: Message Definition for Three Byte Headers) defines the message assignments for the three byte form of the consolidated header format.

1.1 Standardized Parameter Definitions—The parameters used to describe data variables are one of the most important functions of this document. To achieve commonality of messages in Class B networks, the data parameters must become standardized. This applies to data parameter definitions for use during normal vehicle operations as well as during diagnostic operations. By using common parameter definitions for non-diagnostic and diagnostic functions on the network, the modules which form the network can maintain one image or description of a data parameter.

When parameters have been defined in the Diagnostic Test Modes documents (SAE J1979 and J2190), such as Parameter Identifiers for diagnostic inputs, the definitions in Part 2 of this document match the diagnostic definition.

SAE J2178, Part 2 defines the parameters to be used for non-diagnostic and diagnostic data format definitions. For new parameter definitions which are needed in the future, the new definitions, if they are expected to become widely used, must be integrated into this document for commonality across these types of applications. Of course, manufacturers are free to assign their own definitions to data parameters which are unique or proprietary to their products. They are, however, restricted to using the "Manufacturer Reserved" message header assignments in Parts 3 and 4 of this document when using these unique or proprietary data parameter definitions.

2. *References*

2.1 Applicable Documents—The following publications form a part of the specification to the extent specified herein. The latest issue of SAE publications shall apply.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1850—Class B Data Communication Network Interface

SAE J1979—E/E Diagnostic Test Modes

SAE J2190—Enhanced E/E Diagnostic Test Modes

2.1.2 ANSI PUBLICATIONS—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI/IEEE Std 754-1985, August 12, 1985—IEEE Standard for Binary Floating-Point Arithmetic

2.2 Related Publications—The following publications are provided for information purposes only and are not a required part of this document.

2.2.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1213/1—Glossary of Vehicle Networks for Multiplex and Data Communications

SAE J1930—Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms

2.3 Terms and Definitions

2.3.1 DATA (DATA FIELD)—Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or test modes which further defines a particular message content being exchanged over the network.

2.3.2 EXTENDED ADDRESS—The extended address is a means to allow a message to be addressed to a specific geographical location or zone of the vehicle, independent of any node's physical address.

2.3.3 FRAME—A frame is one complete transmission of information which may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" definition).

2.3.4 FRAME ID—The Frame ID is the header byte for the Single Byte Header format and the one byte form of the consolidated header format. The definition of the Frame ID is found in SAE J2178, Part 3. This header byte defines the target and source and content of the frame.

2.3.5 FUNCTIONAL ADDRESSING—Functional addressing allows a message to be addressed or sent to one or more nodes on the network interested in that function. Functional addressing is intended for messages that may be of interest to more than a single node. For example, an exterior lamp "off" message could be sent to all nodes controlling the vehicle exterior lamps by using a functional address. The functional address consists of a primary ID and may include a secondary ID and may also include an extended address.

2.3.6 HEADER (HEADER FIELD)—The header (or header field, used interchangeably) is a one or three byte field within a frame which contains information about the message priority, message source and target addressing, message type, and in-frame response type.

2.3.7 IN-FRAME RESPONSE (IFR) TYPE—The IFR type identifies the form of the in-frame response which is expected within that message.

2.3.8 LOAD—The load command indicates the operation of directly replacing the current/existing value of a parameter with the parameters value(s) contained in the message.

2.3.9 MESSAGE—A message consists of all of the bytes of a frame excluding the delimiter symbols (SOF, EOD, EOF, NB).

2.3.10 MODIFY—The modify command indicates the operation of using the message data parameter value to change (e.g., increment, decrement, or toggle) the current/existing value.

2.3.11 PARAMETER—A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

2.3.12 PHYSICAL ADDRESSING—Physical addressing allows a message to be addressed to a specific node or to all nodes or to a non-existent, null node. The information in this message is only of relevance to a particular node, so the other nodes on the bus should ignore the message, except for the case of the "all nodes" address.

2.3.13 PRIMARY ID—The primary ID identifies the target for this functional message. This is the primary discriminator used to group functions into main categories.

2.3.14 PRIORITY—The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

2.3.15 REPORT—A report indicates the transmission of parametric data values, based on: a change of state; a change of value; on a periodic rate basis; or as a response to a specific request.

2.3.16 REQUEST—A request is a command to, or a query for data, or action from another node on the network.

2.3.17 RESPONSE DATA—The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

2.3.18 SECONDARY ID—The secondary ID (along with the primary ID or Frame ID) identifies the functional target node for a message. The purpose of the secondary ID field within the frame is to further define the function or action being identified by the primary ID.

2.4 Abbreviations and Acronyms

A/C	-	Air Conditioning
ASC	-	ASCII Encoded SLOT
BCD	-	Binary Coded Decimal (BCD) SLOT
BMM	-	Bit Mapped with Mask SLOT
BMP	-	Bit Mapped without Mask SLOT
CRC	-	Cyclic Redundancy Check
CS	-	Checksum
DTC	-	Diagnostic Trouble Code
EOD	-	End of Data
EOF	-	End of Frame
ERR	-	Error Detection
HVAC	-	Heating, Ventilation, Air Conditioning
ID	-	Identifier
IFR	-	In-Frame Response
LSB	-	Least Significant Bit/Byte
MSB	-	Most Significant Bit/Byte
NB	-	Normalization Bit
PID	-	Parameter IDentification (number, NOT the primary ID, See Section 6)
PKT	-	Multiple Parameter Packet SLOT
PRN	-	Parameter Reference Number
SED	-	State Encoded SLOT
SFP	-	Signed Floating Point (Scientific Notation) SLOT
SLOT	-	Scaling, Limit, Offset, and Transfer Function (See Section 7)
SNM	-	2's Complement Signed Numeric SLOT
SOF	-	Start of Frame
UNM	-	Unsigned Numeric SLOT
VIN	-	Vehicle Identification Number

3. *General Information*

3.1 Part 2 Overview—Section 4 provides a description of the parameter reference number (PRN) number groupings used for assigning PRN numbers to

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individual parameters. Section 5 defines the formats used to define all standard parameters to be used in SAE J2178 messages. Section 6 defines the specific parameter assignments in terms of names, units, and scale factor reference. Section 7 defines the actual parameter specifications (SLOT), in terms of the length, bit resolution, range, scale factor details, etc. Section 8 describes the case of very long parameters which cannot be transmitted in a single message. Appendix A provides a numerical cross reference to assist in finding the correct name of a parameter if the parameter identification number is known. Appendix B is an alphabetical cross reference to assist in finding the correct parameter identification number if the parameter name is known.

The messages contain header fields and data fields, described in Part 1 of SAE J2178. The header field contains target, source, priority, and message type information, while the data field contains optional additional addressing and parametric information. This document defines the parametric information.

For some applications, it is desirable to include multiple parameters in a single message. The multiple parameter format is called a packet in this document. For example, some diagnostic messages consist of combinations of these parameters to improve information density or to insure simultaneous readings of different variables. A very limited set of these combinations are defined here as industry standards but individual manufacturers are free to use this form in manufacturer specific messages, as needed.

3.2 How To Use This Document—This part (Part 2 of SAE J2178) provides the definition of parameters which are commonly found, or could be expected in vehicle Electrical/Electronic Systems today. These parameters have been defined to allow messages on a Class B communication system to have consistent meaning between manufacturers and over time. The parameter definition consists of two parts, the "PRN" and the "SLOT." The "PRN" (Parameter Reference Number) is a number used to identify a specific parameter by name, unit of measure, and its associated "SLOT." The "SLOT" defines the mathematical characteristics of parameters in terms of its representation (Binary, Unsigned Numeric, ASCII, BCD, etc.), its scaling (1 Bit =), its limits and offsets, and its transfer function.

To find a parameter by name or PRN number, Appendixes A and B provide cross references to the page of this document where the PRN can be found. The PRN numbers have also been grouped by subsystem to enable the reader to look for parameters if the name is not known.

If the parameter has not as yet been included in the list of PRNs, users can define new parameters in terms of the SLOTs which have been defined.

4. Parameter Reference Number (PRN) Structure—Parameter Reference Numbers (PRNs) are used to simplify documentation. They do not, in themselves, have particular significance. PRNs do allow simplification of reference, particularly for diagnostic purposes. To this end, a structure for PRN number assignments has been developed. The structure is described in the following paragraphs. Some of the PRN numbers are assigned or reserved for SAE definitions but the majority are reserved for individual motor vehicle manufacturers to coordinate and assign.

All PRN addresses are two bytes long, with the first byte identifying a grouping or classification reference (refer to Tables 1 and 2). The second byte is then a sequence number pointing to the specific parameter used (refer to Tables 4 through 19). There has not been any attempt made to group or communize the meaning in the second byte. The specific assignments are found in Section 6. Note that all PRN addresses are listed as hexidecimal numbers throughout this document.

SAE J1979 refers to PID numbers which are a single byte reference number. The first 256 PRNs defined here (first byte = 00), are identical with the SAE J1979 PID definitions.

Figure 3 shows the basic structure of PRNs and Tables 1 and 2 show bit assignments and address ranges based on these assignments.

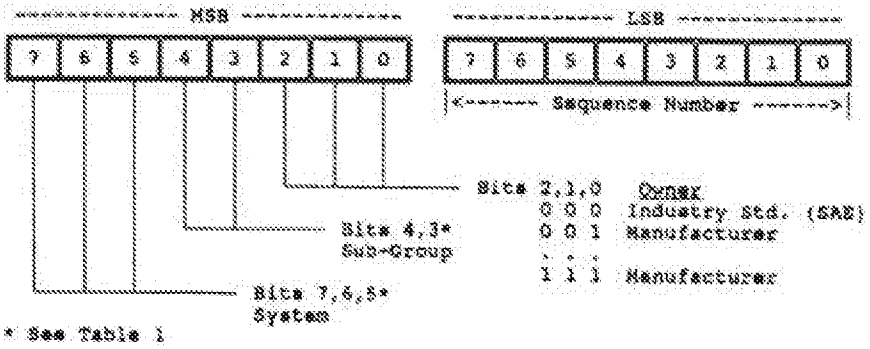

FIGURE 3—PRN STRUCTURE

5. Parameter Formats—Parameter values are represented in bit, byte, word, and multi-byte forms. The length of the parameter is uniquely associated with the message header and any included secondary ID field. These parameter definitions are referenced by one or more messages. The parameters allow a wide variety of variables, data definitions,and representations to provide the ability to use this definition for all messages, even when the industry standard messages are not useful for particular applications.

5.1 Bit Mapped Parameters—The bit mapped parameters, that is, those which have only two logical values (for example: True/False), are handled in one of two ways. The "Q" bit described in Section 6 of Part 1 of SAE J2178, is used if there is only one bit of information. In many cases, however, the bit values are associated together and form byte groupings, generally around common functional characteristics. Bit mapped data are transmitted either with or without corresponding mask bytes as described as follows.

5.1.1 Bit Mapped Data Without Mask Byte(s)—In some cases, such as configuration identification, there is information which can be grouped as binary bits which represent whether, for example, a function or test is supported in a system. This form does not allow the bits to be supplied from different nodes in the network. If the bits potentially come from more than one node, the form with mask bytes described in 5.1.2, is used. The general form of the bit data bytes without mask is shown in Figure 4.

For these bit data cases, the bit names (that is: items) are somewhat different to emphasize the difference in format. These names are shown in Figure 5. If there is more than one byte of data of this form, the item numbers are incremented by one, sequentially, beginning at one from the MSB of the first byte.

For definition purposes, it is also possible to describe a single or multiple bit group which is smaller than a byte but which are combined into a byte or multiple bytes when the complete message is defined. This is a convenience used in this document to define some parameters. This definition notation applies equally to byte(s) with or without masks.

5.1.2 Bit Mapped Data With Mask Byte(s)—For bit mapped data value groups that may come from several nodes or may not be valid for an application, a special format has been defined. Figures 6 and 7 show the data byte formats used. The data format allows two options in the number of bits in a group; 8 or 16. Since the defined bits for such groupings may not always come from a single network node, the format includes mask bytes indicating if an individual bit is valid for this message or if it should be ignored. The mask bytes map directly to the data bits with which they are associated. Figures 8 and 9 show how these bits are mapped within each byte. Table 3 shows the bit value for the mask bits.

TABLE 1—PGN GROUPINGS

7 8 5	System	4 3	Subgroup	Address (Hex)
0 0 0	Powertrain	0 0	J1979 Compatible	0000-00FF
		0 0	Reserved	0100-07FF
		0 1	Reserved	0800-0FFF
		1 0	Engine	1000-17FF
		1 1	Transmission	1800-1FFF
0 0 1	Chassis	0 0	Reserved	2000-27FF
		0 1	Brakes/Tires/Wheels	2800-2FFF
		1 0	Steering	3000-37FF
		1 1	Suspension	3800-3FFF
0 1 0	Body 1	0 0	Reserved	4000-47FF
		0 1	Reserved	4800-4FFF
		1 0	Reserved	5000-57FF
		1 1	Reserved	5800-5FFF
0 1 1	Body 2	0 0	Driver Info	6000-67FF
		0 1	Reserved	6800-6FFF
		1 0	Lighting	7000-77FF
		1 1	Reserved	7800-7FFF
1 0 0	Body 3	0 0	Audio	8000-87FF
		0 1	Reserved	8800-8FFF
		1 0	Pers. Comm.	9000-97FF
		1 1	HVAC	9800-9FFF
1 0 1	Body 4	0 0	Convenience	A000-A7FF
		0 1	Reserved	A800-AFFF
		1 0	Reserved	B000-B7FF
		1 1	Reserved	B800-BFFF
1 1 0	Other 1	0 0	Security	C000-C7FF
		0 1	Reserved	C800-CFFF
		1 0	Reserved	D000-D7FF
		1 1	Reserved	D800-DFFF
1 1 1	Other 2	0 0	Config. Codes	E000-E7FF
		0 1	Reserved	E800-EFFF
		1 0	Tester/Diag.	F000-F7FF
		1 1	Miscellaneous	F800-FFFF

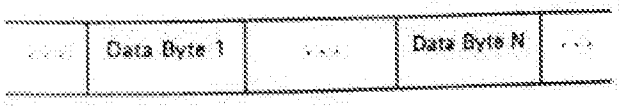

FIGURE 4—BIT DATA FIELD WITHOUT MASK FORMAT

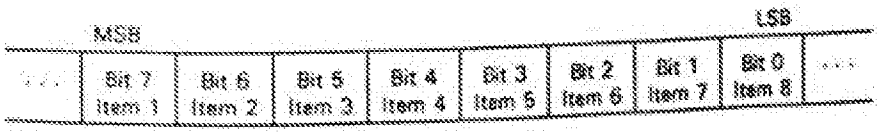

FIGURE 5—BITS WITHOUT MASK BYTE

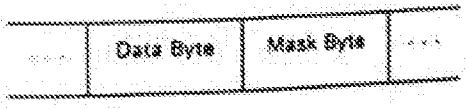

FIGURE 6—FORMAT FOR 8-BIT DATA WITH MASK

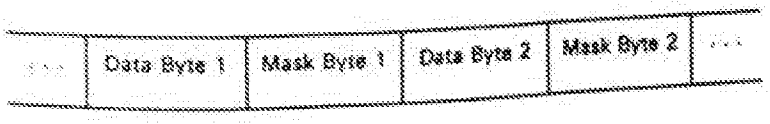

FIGURE 7—FORMAT FOR 16-BIT DATA WITH MASK

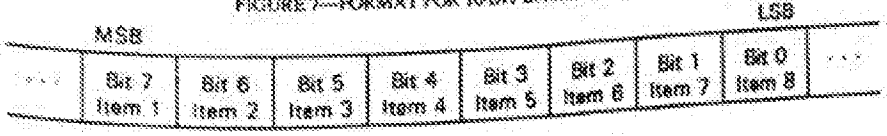

FIGURE 8—BIT MAPPED DATA BYTE

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TABLE 3—SAE/MFG PID RANGES

System	Subgroup	Address Map	Size
Powertrain	J1979 Compatible - SAE	0000 - 00FF	0.25K
	Reserved - MFG	0100 - 07FF	1.75K
	Reserved - SAE	0800 - 08FF	0.25K
	Reserved - MFG	0900 - 0FFF	1.75K
	Engine - SAE	1000 - 10FF	0.25K
	Engine - MFG	1100 - 17FF	1.75K
	Transmission - SAE	1800 - 18FF	0.25K
	Transmission - MFG	1900 - 1FFF	1.75K
Chassis	Reserved - SAE	2000 - 20FF	0.25K
	Reserved - MFG	2100 - 27FF	1.75K
	Brakes/Tires/Wheels - SAE	2800 - 28FF	0.25K
	Brakes/Tires/Wheels - MFG	2900 - 2FFF	1.75K
	Steering - SAE	3000 - 30FF	0.25K
	Steering - MFG	3100 - 37FF	1.75K
	Suspension - SAE	3800 - 38FF	0.25K
	Suspension - MFG	3900 - 3FFF	1.75K
Body 1	Reserved - SAE	4000 - 40FF	0.25K
	Reserved - MFG	4100 - 47FF	1.75K
	Reserved - SAE	4800 - 48FF	0.25K
	Reserved - MFG	4900 - 4FFF	1.75K
	Reserved - SAE	5000 - 50FF	0.25K
	Reserved - MFG	5100 - 57FF	1.75K
	Restraints - SAE	5800 - 58FF	0.25K
	Restraints - MFG	5900 - 5FFF	1.75K
Body 2	Driver Information - SAE	6000 - 60FF	0.25K
	Driver Information - MFG	6100 - 67FF	1.75K
	Reserved - SAE	6800 - 68FF	0.25K
	Reserved - MFG	6900 - 6FFF	1.75K
	Lighting - SAE	7000 - 70FF	0.25K
	Lighting - MFG	7100 - 77FF	1.75K
	Reserved - SAE	7800 - 78FF	0.25K
	Reserved - MFG	7900 - 7FFF	1.75K
Body 3	Audio - SAE	8000 - 80FF	0.25K
	Audio - MFG	8100 - 87FF	1.75K
	Reserved - SAE	8800 - 88FF	0.25K
	Reserved - MFG	8900 - 8FFF	1.75K
	Personal Communications - SAE	9000 - 90FF	0.25K
	Personal Communications - MFG	9100 - 97FF	1.75K
	HVAC - SAE	9800 - 98FF	0.25K
	HVAC - MFG	9900 - 9FFF	1.75K
Body 4	Convenience - SAE	A000 - A0FF	0.25K
	Convenience - MFG	A100 - A7FF	1.75K
	Reserved - SAE	A800 - A8FF	0.25K
	Reserved - MFG	A900 - AFFF	1.75K
	Reserved - SAE	B000 - B0FF	0.25K
	Reserved - MFG	B100 - B7FF	1.75K
	Reserved - SAE	B800 - B8FF	0.25K
	Reserved - MFG	B900 - BFFF	1.75K
Other 1	Security - SAE	C000 - C0FF	0.25K
	Security - MFG	C100 - C7FF	1.75K
	Reserved - SAE	C800 - C8FF	0.25K
	Reserved - MFG	C900 - CFFF	1.75K
	Reserved - SAE	D000 - D0FF	0.25K
	Reserved - MFG	D100 - D7FF	1.75K
	Reserved - SAE	D800 - D8FF	0.25K
	Reserved - MFG	D900 - DFFF	1.75K
Other 2	Configuration Codes - SAE	E000 - E0FF	0.25K
	Configuration Codes - MFG	E100 - E7FF	1.75K
	Reserved - SAE	E800 - E8FF	0.25K
	Reserved - MFG	E900 - EFFF	1.75K
	Tools/Diagnostics - SAE	F000 - F0FF	0.25K
	Tools/Diagnostics - MFG	F100 - F7FF	1.75K
	Miscellaneous - SAE	F800 - F8FF	0.25K
	Miscellaneous - MFG	F900 - FFFF	1.75K

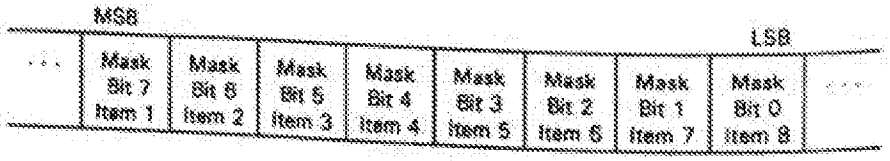

FIGURE 9—BIT MAPPED MASK BYTE

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TABLE 5—MASK BIT ASSIGNMENT

Mask Bit	Bit Mapped Meaning
0	Not A Valid Bit
1	Valid Bit

5.1.1 BIT VALUES—The general form of binary data is that 1 = true and 0 = false. One bit can carry a wide variety of interpretations, depending on the object that it describes.

5.2 Byte (8 Bit) Parameters—Data parameters which can be expressed in 8 bits or less are expressed in a byte format. Byte parameters are the most common format. Figure 10 shows this format.

5.3 Word (16 Bit) Parameters—Data parameters which can be expressed in 9 to 16 bits are expressed in word format with the most significant byte transmitted first (high byte/low byte). Figure 11 shows this format.

5.4 Multi-Byte (>16 Bit) Parameters—Data parameters which can be expressed in more than 16 bits are expressed in multi-byte format with the most significant byte transmitted first (highest byte /.../ lowest byte). Figure 12 shows this format.

5.5 Multiple Parameter Packets—It is often useful to group parameters together into a packet to increase the information density of messages. For example, sending a fluid level and maximum capacity value in the same message, or a packet of single bit(s) or multiple bit definitions that may be smaller than a full byte, can be combined in this way. Parameter packets will be defined in this document in the same way as any other parameter, having a packet PRN number and SLOT reference assignment. If bit mapped parameters are included in a packet, the bit mapped byte(s) and the associated mask byte(s) are grouped together as a set representing a parameter. Thus, the data bytes and mask bytes for each parameter are together within the packet. Note that packets may be made of other packets, but each will be uniquely defined by combining each subpart into a message. Figure 13 shows the general form of a parameter packet.

A few examples, such as some of the SAE J1979 compatible PRN definitions in Section 6 will make this format clear.

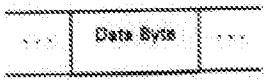

FIGURE 10—BYTE PARAMETERS

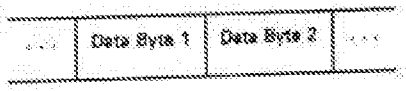

FIGURE 11—WORD PARAMETERS

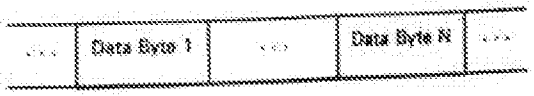

FIGURE 12—MULTI-BYTE PARAMETERS

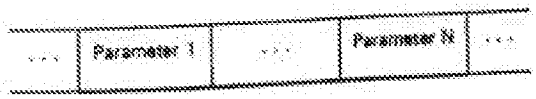

FIGURE 13—MULTIPLE PARAMETER PACKETS

6. *Specific Parameter (PRN) Assignments*—This section defines industry standard parameters used in messages found in parts 3 and 4. These parameters have been listed in random order based on when they were defined. Note that any PRN address in the SAE range that is not currently defined is reserved for SAE use. Cross references are provided in Appendices A and B of this part of SAE J2178 to assist the reader in finding the specific definition for each parameter.

6.1 Specific Parameters—The following definitions include the Parameter Reference Number (PRN), parameter name, units of measure, and associated SLOT number. The SLOT number is a reference to the Scaling, Limit, Offset, and Transfer function (SLOT) definition found in Section 7 as follows. The SLOT reference numbers have a format of: P-NN-#, where P is a three-letter mnemonic indicating the format code type (see Section 7), N is the number of bits in the parameter, and # is the sequence number for that type of

SLOT. There is no relationship between sequence numbers for different format codes or number of bytes. Note that the sequence number is randomly assigned. Decimal sequence numbers of 1000 and above are available for manufacturers to assign. All SAE-assigned sequence numbers will be in the range from 1 to 999 exclusively and are not to be used by manufacturers. The sequence number ZERO (0) has the special purpose of a fill sequence which is used in packet definitions. The ZERO sequence number is all zeros, for the number of bits specified. The Parameter Reference Numbers (PRNs) are the index reference used by the message definitions found in Parts 3 and 4 of this document. The specific parameters are grouped as follows:

- Table 4 - SAE J1979 Compatible PRN Assignments
- Table 5 - Engine PRN Assignments
- Table 6 - Transmission PRN Assignments
- Table 7 - Brakes/Tires/Wheels PRN Assignments
- Table 8 - Steering PRN Assignments
- Table 9 - Suspension PRN Assignments
- Table 10 - Restraint PRN Assignments
- Table 11 - Driver Information PRN Assignments
- Table 12 - Lighting PRN Assignments
- Table 13 - Audio PRN Assignments
- Table 14 - Personal Communication PRN Assignments
- Table 15 - HVAC PRN Assignments
- Table 16 - Convenience PRN Assignments
- Table 17 - Security PRN Assignments
- Table 18 - Configuration Codes PRN Assignments
- Table 19 - Tester/Diagnostics PRN Assignments
- Table 20 - Miscellaneous PRN Assignments

TABLE 4 - SAE J1979 COMPATIBLE PRN ASSIGNMENTS
(PRNs 0000 - 00FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Data B (P-N-B)
0000	PIDs Supported (01h - 20h)	-	Bit Mapped	0000-32-1
0001	Number of Emission-Related Trouble Codes & MIL Status	-	Packeted	PKT-16-1
0002	Trouble Code That Caused Freeze Frame Storage	-	Packeted	PKT-16-1
0003	Fuel System Status	-	Packeted	PKT-16-2
0004	Calculated Load Value	100/255	% Full Load	0000-08-01
0005	Engine Coolant Temperature	1	Degrees Centigrade	0000-08-102
0006	Short Term Fuel Trim - Bank 1	100/128	% Enrichment	0000-08-02
0007	Long Term Fuel Trim - Bank 1	100/128	% Enrichment	0000-08-02
0008	Short Term Fuel Trim - Bank 2	100/128	% Enrichment	0000-08-02
0009	Long Term Fuel Trim - Bank 2	100/128	% Enrichment	0000-08-02
000A	Fuel Pressure (Gage)	3	kPa(g)	0000-08-151
000B	Intake Manifold Absolute Pressure	1	kPaA	0000-08-151
000C	Engine RPM - High Resolution	0.5	RPM	0000-16-31
000D	Vehicle Speed - Low Resolution - Metric	1	km/h	0000-08-103
000E	Ignition Timing Advance (#1)	1/2	Degrees before TDC	0000-08-72
000F	Intake Air Temperature	1	Degrees Centigrade	0000-08-102
0010	Air Flow Rate from MAF	1/100	grams/sec	0000-16-11
0011	Absolute Throttle #1 Position	100/255	% Full Throttle	0000-08-01
0012	Commanded Secondary Air	-	Bit Mapped	0000-08-5
0013	Oxygen Sensor Location	-	Bit Mapped	0000-08-6
0014	Oxygen Sensor - BANK 1 - Sensor 1	-	Packeted	PKT-16-3
0015	Oxygen Sensor - BANK 1 - Sensor 2	-	Packeted	PKT-16-3
0016	Oxygen Sensor - BANK 1 - Sensor 3	-	Packeted	PKT-16-3
0017	Oxygen Sensor - BANK 1 - Sensor 4	-	Packeted	PKT-16-3
0018	Oxygen Sensor - BANK 2 - Sensor 1	-	Packeted	PKT-16-3
0019	Oxygen Sensor - BANK 2 - Sensor 2	-	Packeted	PKT-16-3
001A	Oxygen Sensor - BANK 2 - Sensor 3	-	Packeted	PKT-16-3
001B	Oxygen Sensor - BANK 2 - Sensor 4	-	Packeted	PKT-16-3
001C	Reserved SAE	-	-	-
001D	Reserved SAE	-	-	-
001E	Reserved SAE	-	-	-
001F	Reserved SAE	-	-	-
0020	PIDs Supported (21h - 40h)	-	Bit Mapped	0000-32-9
0021-003F	Reserved SAE	-	-	-
0040	PIDs Supported (41h - 60h)	-	Bit Mapped	0000-32-3
0041-00FF	Reserved SAE	-	-	-

TABLE 5—ENGINE PRN ASSIGNMENTS
(PRNs 1000 - 10FF)

PRN	PARAMETER NAME	RESOLUTION (1 Bit =)	UNITS OF MEASURE	SLOT # (F-N-#)
1000	MIL Status	-	Bit Mapped	BMP-01-1
1001	Number of Emissions Related DTCs	1	Quantity	UNM-07-1
1002	Continuous Evaluation Supported	-	Bit Mapped	BMP-08-1
1003	Trip Evaluation Supported	-	Bit Mapped	BMP-08-2
1004	Trip Evaluation Complete	-	Bit Mapped	BMP-08-3
1005	Sub-System Category of DTC	-	State Encoded	SED-02-1
1006	Most Significant Digit of DTC	-	State Encoded	SED-02-2
1007	Lower 3 Digits of DTC	-	BCD	BCD-12-1
1008	Fuel System Status - Bank 1	-	Bit Mapped	BMP-08-4
1009	Fuel System Status - Bank 2	-	Bit Mapped	BMP-08-4
100A	Oxygen Sensor Voltage	1/200	volts	UNM-08-11
100B	Short Term Fuel Trim	100/128	% Enrichment	UNM-08-92
100D	Most Significant Digit of VIN Number	-	ASCII	ASC-08-01
100E	A/C Clutch Load	25	Watts	UNM-08-185
1015	Injector On Time	2048	microseconds	UNM-08-231
1018	Crankshaft Torque - Absolute	4	N.m Torque	UNM-08-141
1020	Crankshaft Torque - Percent	100/255	% Maximum Torque	UNM-08-61
1021	Engine Boost	100/255	% Full Boost	UNM-08-61
1022	Engine RPM - Low Resolution	32	RPM	UNM-08-171
1023	Engine Idle RPM	16	RPM	UNM-08-161
1024	Engine Revolutions	2	Quantity	UNM-08-121
1025	Barometric Pressure	1	kPaA	UNM-08-101
1026	Engine Coolant Level - Percent	1/2	% Full	UNM-08-71
1027	Engine Coolant Level - Volume	1/10	liters	UNM-08-41
1028	Engine Coolant Capacity	1/10	liters	UNM-08-41
1029	Engine Coolant Pressure	4	kPaG	UNM-08-141
102A	Engine Coolant Fan #1 Speed	100/255	% Full On	UNM-08-61
102B	Engine Oil Temperature	1	Degrees Centigrade	UNM-08-102
102C	Engine Oil Level - Percent	1/2	% Full	UNM-08-71
102D	Engine Oil Level - Volume	1/10	liters	UNM-08-41
102E	Engine Oil Capacity	1/10	liters	UNM-08-41
102F	Engine Oil Pressure	4	kPaG	UNM-08-141
1030	Engine Oil Remaining Life	100/255	% Remaining Life	UNM-08-61
1031	Hydraulic Fan Speed	100/255	% Full On	UNM-08-61
1032	Methanol Content	100/255	% Methanol	UNM-08-61
1033	Maximum Crankshaft Torque	4	N.m Torque	UNM-08-141
1034	Accelerator Pedal Position	100/255	% Pressed Down	UNM-08-61
1035	Absolute Throttle #2 Position	100/255	% Full Throttle	UNM-08-61
1036	Absolute Throttle #3 Position	100/255	% Full Throttle	UNM-08-61
1037	Bank #1 - Converter #1 Temperature	8	Degrees Centigrade	UNM-08-151
1038	Bank #1 - Converter #2 Temperature	8	Degrees Centigrade	UNM-08-151
1039	Bank #2 - Converter #1 Temperature	8	Degrees Centigrade	UNM-08-151
103A	Bank #2 - Converter #2 Temperature	8	Degrees Centigrade	UNM-08-151
103B	Engine Coolant #2 Fan Speed	100/255	% Full On	UNM-08-61
103C	Engine Coolant Temperature - Low Range	1	Degrees Centigrade	UNM-08-104
103D	Engine Coolant Remaining Life	100/255	% Remaining Life	UNM-08-61
103F	Engine Oil Viscosity	1/10	Centistokes (cSt)	UNM-08-41
1040	Number of Engine Cylinders	1	Quantity	UNM-08-101
1041	Number of Valves per Cylinder	1	Quantity	UNM-08-101
1043	Engine Displacement	1/10	liters	UNM-08-41
1044	Fuel Temperature	1	Degrees Centigrade	UNM-08-102
1047	Ignition Switch Position	-	State Encoded	SED-08-5
1048	Engine Redline - Low Resolution	32	RPM	UNM-08-171
1049	Engine Redline - High Resolution	1/4	RPM	UNM-16-31

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TABLE 6—TRANSMISSION PIN ASSIGNMENTS
(PIDs 1536 - 1567)

PID	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
1601	Transmission Fluid Level - Percent	1/2	% Full	UNM-08-71
1602	Transmission Fluid Level - Volume	1/10	liters	UNM-08-41
1603	Transmission Fluid Capacity	1/10	liters	UNM-08-41
1604	Transmission Oil Life	100/255	% Remaining Life	UNM-08-61
1605	Transmission Gear & Locking Status	-	Packated	PKT-08-1
1606	Transmission Range Actual (PRNDL)	-	State Encoded	SED-08-4
1607	Transmission Lockup Status	-	State Encoded	SED-08-3
1608	Transmission Actual Gear	-	State Encoded	SED-08-1
1609	Transmission Range Selected (PRNDL)	-	State Encoded	SED-08-4
160A	Transmission Transfer Case (4WD)	-	State Encoded	SED-08-6
160B	Transmission Fluid Temperature	1	Degrees Centigrade	UNM-08-102
160C	Transmission Fluid Pressure	8	kPaG	UNM-08-151
160D	Transmission Commanded Gear	-	State Encoded	SED-08-4
160E	Transmission Actual Gear	-	State Encoded	SED-08-4

TABLE 7—BRAKES/TIRES/WHEELS PIN ASSIGNMENTS
(PIDs 2560 - 2587)

PID	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
2601	Wheel Speed - Low Resolution	1	km/h	UNM-08-101
2602	Wheel Speed - High Resolution	1/128	km/h	UNM-16-3
2603	Wheel Slip	1/255	Dimensionless	UNM-08-6
2618	Hydraulic Brake Fluid Supply Pump Pressure	32	kPaG	UNM-08-171
261A	Hydraulic Brake Fluid Temperature	1	Degrees Centigrade	UNM-08-102
2618	Hydraulic Brake Fluid Recirculation Pump Pressure	1	kPaG	UNM-08-101
2621	Wheel Rate		SAE Reserved	SAE Reserved
2629	Wheel Angular Velocity		SAE Reserved	SAE Reserved
2631	Wheel Angular Acceleration		SAE Reserved	SAE Reserved
2639	Wheel Load	100/255	% Full Load	UNM-08-61
2641	Brake Fluid Level - Percent	1/2	% Full	UNM-08-71
2642	Brake Fluid Level - Volume	1/100	liters	UNM-08-15
2643	Brake Fluid Remaining Life	100/255	% Remaining Life	UNM-08-61
2644	Brake Fluid Capacity	1/100	liters	UNM-08-15
2649	Tire Temperature	1	Degrees Centigrade	UNM-08-102
2651	Tire Pressure	4	kPaG	UNM-08-141
2659	Tire Type		SAE Reserved	SAE Reserved
2661	Tire Tread Wear Level	100/255	% tread remaining	UNM-08-61

TABLE 8—STEERING PIN ASSIGNMENTS
(PIDs 3072 - 3087)

PID	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
3001	Steering Wheel Angle	8	Degrees CW from center	SNM-08-61
3005	Power Steering Fluid Temperature	1	Degrees Centigrade	UNM-08-102
3006	Power Steering Fluid Pressure	100	kPaG	UNM-08-185
3007	Power Steering Fluid Level - Percent	1/2	% Full	UNM-08-71
3008	Power Steering Fluid Level - Volume	1/100	liters	UNM-08-15
3009	Power Steering Fluid Remaining Life	100/255	% Remaining Life	UNM-08-61
300B	Power Steering Fluid Capacity	1/100	liters	UNM-08-15
300C	Steering Wheel Rate	1	RPM	UNM-08-109
300D	Steering Wheel Torque	1	N.m Torque	UNM-08-101
300E	Wheel Steer Angle	1/2	Degrees CW from Center	SNM-08-11

TABLE 9—SUSPENSION PRN ASSIGNMENTS
(PRNs 5800 - 5877)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
5801	Lateral Acceleration		SAE Reserved	SAE Reserved
5802	Longitudinal Acceleration		SAE Reserved	SAE Reserved
5803	Yaw Acceleration		SAE Reserved	SAE Reserved
5804	Suspension Ride Setting	100/255	% Stiff Setting	UNM-08-81
5805	Suspension Fluid Temperature	1	Degrees Centigrade	UNM-08-102
5806	Suspension Fluid Pressure	100	kPaG	UNM-08-185
5807	Suspension Fluid Level - Percent	1/2	% Full	UNM-08-71
5808	Suspension Fluid Level - Volume	1/32	liters	UNM-08-25
5809	Suspension Fluid Remaining Life	100/255	% Remaining Life	UNM-08-81
5810	Suspension Fluid Capacity	1/32	liters	UNM-08-25
5811	Vehicle Lateral Velocity		SAE Reserved	SAE Reserved
5812	Vehicle Longitudinal Velocity		SAE Reserved	SAE Reserved
5813	Vehicle Yaw Velocity		SAE Reserved	SAE Reserved

TABLE 10—RESTRAINTS PRN ASSIGNMENTS
(PRNs 5800 - 5877)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
5801	Shoulder Belt Position	1	Unscaled A/D Counts	UNM-08-101

TABLE 11—DRIVER INFORMATION PRN ASSIGNMENTS
(PRNs 6000 - 6077)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
6001	Vehicle Speed - High Resolution - Metric	1/128	km/h	UNM-16-5
6002	Vehicle Speed - High Resolution - English	1/128	mph	UNM-16-5
6003	Compass Direction	3/2	Degrees Off from North	UNM-08-81
6004	Odometer - Vehicle - Metric	1/64	kilometers	UNM-08-81
6005	Fuel Level - Percent	100/255	% Full	UNM-16-11
6006	Fuel Level - Volume	1/100	liters	UNM-16-11
6007	Fuel Capacity	1/100	liters	UNM-08-32
6008	Battery Voltage - Low Resolution	1/16	volts	UNM-08-102
6009	Battery Temperature	1	Degrees Centigrade	UNM-08-101
6010	Electrical Energy Load	1	amps	PKT-03-2
6011	Data (Day DD MM YY)	-	Packaged	BCD-08-1
6012	Year (YY)	-	BCD	UNM-08-103
6013	Year (YY)	1	year	BCD-04-2
6014	Month (Mn)	-	State Encoded	BCD-08-1
6015	Month (Mm)	-	BCD	BCD-04-1
6016	Day of Week (Day)	-	State Encoded	BCD-08-2
6017	Day of Week (Day)	-	State Encoded	BCD-08-2
6018	Day of Month (Dm)	-	State Encoded	BCD-08-1
6019	Day of Month (DD)	-	BCD	PKT-04-1
6020	Time of Day (HH MM SS)	-	Packaged	BCD-08-1
6021	Hours (HH)	-	BCD	BCD-08-1
6022	Minutes (MM)	-	BCD	BCD-08-1
6023	Seconds (SS)	-	BCD	UNM-16-5
6024	Battery Voltage - High Resolution	1/128	volts	UNM-08-1
6025	Distance Traveled - English	1/8000	miles	UNM-16-6
6026	Fuel Used - Metric	1/64	liters	UNM-16-21
6027	Distance To Empty - English	1/10	miles	UNM-08-101
6028	Vehicle Speed - Low Resolution - English	1	MPH	UNM-08-101
6029	Hours (Hr) - 0 to 23 numeric	1	hour	
6030	Average Fuel Economy - Low Resolution - Metric	1	liters/100 kilometers	UNM-08-101
6031	Average Fuel Economy - Low Resolution - English	1	MPG	UNM-08-101
6032	Elapsed Time - Seconds	1	Seconds	PKT-16-5
6033	Data (Day/Mn Dm)	-	Packaged	

Continued

TABLE 11—DRIVER INFORMATION PGN ASSIGNMENTS
(PGNs 65002 - 65071) (CONTINUED)

PGN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Std.# (F-N-#)
6524	Elapsed Time - Minutes	1	Minutes	UNM-08-101
6525	Accumulated Ignition On Time	-	Packetized	PKT-24-2
6526	Fuel Used - English	1/64	gallons	UNM-18-8
6527	Distance To Empty - Metric	1/10	kilometers	UNM-18-21
6528	Average Fuel Economy - High Resolution - Metric	1/10	liters/100 kilometers(UNM-18-21	
6529	Average Fuel Economy - High Resolution - English	1/512	MPG	UNM-18-21
652A	Elapsed Time - Hours	1	Hours	UNM-08-101
652B	Display Brightness	100/255	% Full On	UNM-08-61
652C	Ignition Off Duration	1	Minutes	UNM-08-101
652D	Outside Air Temperature - High Resolution	1/256	Degrees Centigrade(UNM-18-3	
652E	Outside Air Temperature Display	1/2	Degrees Centigrade	UNM-08-72
652F	Minutes (Bit) 0 - 59 numeric	1	minute	UNM-08-101
6530	Time (HHMM)	-	Packetized	PKT-16-3
6531	Odometer - Vehicle - High Resolution - English	1/8000	miles	UNM-32-11
6532	Odometer - Trip - High Resolution - English	125/8000	miles	UNM-24-21
6533	Odometer - Vehicle - Low Resolution - English	1/10	miles	UNM-24-11
6534	Odometer - Trip - Low Resolution - English	1/10	miles	UNM-18-21
6535	Charging Voltage - Low Resolution	1/16	volts	UNM-08-32
6536	Charging Voltage - High Resolution	1/128	volts	UNM-18-5
6537	Charging Current	1	amps	UNM-08-101
6538	Battery Current	1	amps	UNM-08-21
6539	Odometer - Trip - Metric	1/64	kilometers	UNM-24-41
653A	Instantaneous Fuel Economy - Low Resolution - Metric	1	liters/100 kilometers	UNM-08-101
653B	Fuel Used - Percent	100/255	% Used	UNM-08-61
653C	Fuel Used - Volume	1/100	liters	UNM-18-11
653D	Audible Signal Volume	100/255	% Full Volume	UNM-08-61
653E	Audible Signal Type		SAE Reserved	SAE Reserved
653F	Instantaneous Fuel Economy - High Resolution - Metric	1/20	liters/100 kilometers	UNM-18-21
6540	Instantaneous Fuel Economy - Low Resolution - English	1	MPG	UNM-08-101
6541	Instantaneous Fuel Economy - High Resolution - English	1/20	MPG(UNM-18-21	
6542	Seconds (Sc) 0 - 59 numeric	1	seconds	UNM-08-101
6543	Alarm Time (HHMMSS)	-	Packetized	PKT-24-1
6544	Elapsed Years	1	years	UNM-08-101
6545	Elapsed Months	1	months	UNM-08-101
6546	Elapsed Days	1	days	UNM-08-101

TABLE 12—LIGHTING PGN ASSIGNMENTS
(PGNs 70656 - 70911)

PGN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Std.# (F-N-#)

TABLE 13—AUDIO PGN ASSIGNMENTS
(PGNs 65000 - 65071)

PGN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Std.# (F-N-#)

TABLE 14—PERSONAL COMMUNICATION PGN ASSIGNMENTS
(PGNs 65000 - 65071)

PGN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Std.# (F-N-#)

TABLE 15—HVAC PRN ASSIGNMENTS
(PRNs 9800 - 98FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
9801	HVAC Fan Speed	100/255	% Full On	UNM-08-61
9803	HVAC Door Position	100/255	% Open	UNM-08-61
9804	Electric Defrost Temperature	1	Degrees Centigrade	UNM-08-102
9808	HVAC High-Side Fluid Temperature	1	Degrees Centigrade	UNM-08-102
9809	HVAC Low-Side Fluid Temperature	1	Degrees Centigrade	UNM-08-102
9808	HVAC Low-Side Pressure	5/2	kPaG	UNM-08-125
9808	HVAC Fluid Charge - % Full Charge	100/255	% Full	UNM-08-61
9809	HVAC Fluid Charge - Absolute Weight	10	grams	UNM-08-155
9809	HVAC Fluid Charge Remaining Life	100/255	% Remaining Life	UNM-08-61
9808	HVAC Fluid Charge Capacity	10	grams	UNM-08-155
9810	HVAC Intake Temperature	1/2	Degrees Centigrade	UNM-08-73
9813	HVAC High-Side Pressure	14	kPaG	UNM-08-153
9815	Interior Humidity Level	100/255	% Relative Humidity	UNM-08-61
9816	Interior Air Filter Remaining Life	100/255	% Remaining Life	UNM-08-61
9817	Heat Load Sensor	1/2	mW/cm2	UNM-08-71
9820	Interior Set Temperature	1/2	Degrees Centigrade	UNM-08-73
9830	HVAC Zone Temperature	1/2	Degrees Centigrade	UNM-08-73

TABLE 16—CONVENIENCE PRN ASSIGNMENTS
(PRNs A000 - A0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
A001	Seat Temperature	1/2	Degrees Centigrade	UNM-08-73
A003	Wiper Mode	-	State Encoded	SED-08-1
A004	Wiper Delay	1/4	seconds	UNM-08-61
A006	Washer Fluid Temperature	1	Degrees Centigrade	UNM-08-109
A007	Washer Fluid Pressure	4	kPaG	UNM-08-141
A008	Washer Fluid Level - Percent	100/255	% Full	UNM-08-61
A009	Washer Fluid Level - Volume	1/10	liters	UNM-08-41
A00A	Washer Fluid Capacity	1/10	liters	UNM-08-41
A00C	Mirror Dimming Level	100/255	% Full Dim	UNM-08-61
A00D	Mirror Horizontal Position	1	Unscaled A/D Counts	UNM-08-101
A00E	Mirror Vertical Position	1	Unscaled A/D Counts	UNM-08-101
A00F	Window Position	1	Unscaled A/D Counts	UNM-08-101
A010	Door Lock Cylinder State	-	State Encoded	SED-08-7
A011	Steering Column Horizontal Position	1	Unscaled A/D Counts	UNM-08-101
A012	Steering Column Vertical Position	1	Unscaled A/D Counts	UNM-08-101
A014	Autotemp Off Delay Time	1	Seconds	UNM-08-101
A015	Vehicle Speed Setting - Low Resolution - Metric	1	km/h	UNM-08-101
A016	Vehicle Speed Setting - High Resolution - Metric	1/128	km/h	UNM-16-5
A017	Vehicle Speed Setting - Low Resolution - English	1	MPH	UNM-08-101
A018	Vehicle Speed Setting - High Resolution - English	1/128	MPH	UNM-16-5

TABLE 17—SECURITY PRN ASSIGNMENTS
(PRNs C000 - C0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
C001	Remote Transmitter ID	1	ID Number	UNM-08-101

TABLE 18—CONFIGURATION CODES PRN ASSIGNMENTS
(PRNs E000 - E0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	Slot # (F-N-#)
E001	Vehicle Id Number (VIN) #1	-	VIN character 1	PKT-30-2
E002	Vehicle Id Number (VIN) #2	-	VIN characters 2 - 5	ASC-32-1
E003	Vehicle Id Number (VIN) #3	-	VIN characters 6 - 9	ASC-32-1
E004	Vehicle Id Number (VIN) #4	-	VIN characters 10 - 13	ASC-32-1
E005	Vehicle Id Number (VIN) #5	-	VIN characters 14 - 17	ASC-32-1
E006	Vehicle Id Number (VIN) #6 (reserved for future use)	-	Reserved - SAE	Reserved - SAE
E007	Vehicle Id Number (VIN) #7 (reserved for future use)	-	Reserved - SAE	Reserved - SAE

TABLE 19—TEST/DIAGNOSTICS PRN ASSIGNMENTS
(PRNs F000 - F0FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	SLOT (F-N-#)

TABLE 20—MISCELLANEOUS PRN ASSIGNMENTS
(PRNs F800 - F8FF)

PRN	Parameter Name	Resolution (1 Bit =)	Units Of Measure	SLOT (F-N-#)
F801	One Byte Zero Fill	0	Zero	UNM-08-0
F802	Two Byte Zero Fill	0	Zero	UNM-16-0
F803	Three Byte Zero Fill	0	Zero	UNM-24-0
F804	Four Byte Zero Fill	0	Zero	UNM-32-0
F805	Five Byte Zero Fill	0	Zero	UNM-40-0
F806	Six Byte Zero Fill	0	Zero	UNM-48-0
F807	Seven Byte Zero Fill	0	Zero	UNM-56-0

7. Scaling, Units, Offset, and Transfer Function (SLOT) Definitions—This section defines the parameter scaling, limit(s), offset value, and transfer function for bit, byte, or larger variables. These SLOT definitions have been grouped together to avoid duplication in this document and to offer a common list of definitions for use in assigning new parameter definitions. The wide range of these definitions are expected to cover a large number of applications, and should be used for most new definitions as well. Each of these definitions has been assigned a SLOT number for reference purposes but are formatted to include a three-letter mnemonic representing the format, the parameter length in bits, followed by a random sequence number.

The transfer function is shown in two forms to allow use in implementing messages in modules and in interpreting messages found on a network. The two forms are identical but are solved for each of the two variables. The transfer function defines the relationship between computer units (N) in decimal, and engineering units (E) of the data.

The format of the SLOT, identified by the three-letter mnemonic, indicates the category of bit representation. These formats include:

- Multiple Parameter Packeted	PKT
- Bit Mapped with Mask	BMM
- Bit Mapped without Mask	BMP
- Unsigned Numeric	UNM
- 2's Complement Signed Numeric	SNM
- State Encoded	SED
- ASCII Encoded	ASC
- Binary Coded Decimal (BCD)	BCD
- Signed Floating Point (Scientific Notation)	SFP

These formats for each are described in the following paragraphs.

7.1 **Multiple Parameter Packeted (PKT) SLOTs**—The multiple parameter packet is used to define PRNs which refer to more than one parameter as a group that are related. By grouping multiple parameters, the network bandwidth can be improved, if the groupings are done such that the individual parameters need to be associated such that the each need to be transmitted together. These packets are defined as a sequence of other PRN numbers, in the order that they appear in the message (MSB first). In some cases, a PRN may be assigned to fill bits or bytes with zeros. Each zero fill PRN is an assigned numeric SLOT with zero as the sequence number.

7.1.1 MULTIPLE PARAMETER PACKETED ASSIGNMENTS

PKT-08-1 Transmission Gear & Lockup Status (PRN 1805)

MSB	PRN 1807	Transmission Lockup Status	2 bits
LSB	PRN 1808	Transmission Gear Engaged	6 bits

PKT-16-1 Trouble Code That Caused Freeze Frame Storage (PRN 0002)

MSB	PRN 1005	Sub-System Category	2 bits
	PRN 1006	MSB of Trouble Code	2 bits
LSB	PRN 1007	Lower Bytes of Trouble Code - BCD	12 bits

PKT-16-2 Fuel System Status (PRN 0003)

MSB	PRN 1008	Fuel System Status - Bank 1	8 bits
LSB	PRN 1009	Fuel System Status - Bank 2	8 bits

PKT-16-3 Oxygen BANK 1, 2 - Sensor 1, 2, 3, or 4 (PRN 0014 - 0018)

MSB	PRN 100A	Oxygen Sensor Voltage	8 bits
LSB	PRN 100B	Short Term Fuel Trim	8 bits

PKT-16-5 Time (Hr:Min) (PRN 6030)

MSB	PRN 601F	Hours (0 - 23)	8 bits
LSB	PRN 602F	Minutes (0 - 59)	8 bits

PKT-16-6 Date (Day/Mo:Day) (PRN 6023)

MSB	PRN 6012	Day of Week (1 - 7)	4 bits
	PRN 6010	Month (1 - 12)	4 bits
LSB	PRN 6014	Day of Month (1 - 31)	8 bits

RT-24-1	Time of Day (HH:MM:SS) (PRN 6016)			
	MSB	PRN 6017	Hours (HH) - BCD	8 bits
		PRN 6018	Minutes (MM) - BCD	8 bits
	LSB	PRN 6019	Seconds (SS) - BCD	8 bits
RT-24-2	Accumulated Ignition On Time (PRN 6022)			
	MSB	PRN 6022A	Elapsed Time-Hours (0-99)	8 bits
		PRN 6023	Elapsed Time-Minutes (0-59)	8 bits
	LSB	PRN 6022	Elapsed Time-Seconds (0-59)	8 bits
RT-33-1	Number of Emission-Related Trouble Codes & MIL Status (PRN 0001)			
	MSB	PRN 1000	MIL Status	1 bit
		PRN 1001	Number of Emission-Related Trouble Codes	7 bits
		PRN 1002	Continuous Evaluation Supported	8 bits
		PRN 1003	Trip Evaluation Supported	8 bits
	LSB	PRN 1004	Trip Evaluation Complete	8 bits
RT-33-2	Vehicle Id Number (VIN) #1 (PRN 0021)			
	MSB	PRN F802	Three Byte - Zero Fill	24 bits
	LSB	PRN 1008	MSB of VIN Number	8 bits
RT-33-3	Date (Day,DD MM YY) (PRN 600D)			
	MSB	PRN 6013	Day of Week (1 - 7)	8 bits
		PRN 6015	Day of Month (DD) - BCD	8 bits
		PRN 6011	Month (MM) - BCD	8 bits
	LSB	PRN 600E	Year (YY) - BCD	8 bits

3.2 Bit Mapped Without Mask (BMP) SLOTs—Bit mapped (BMP) SLOTs are used to encode data that typically contains several binary parameters, and a status bits or flags, grouped into a single byte or several bytes. Bit mapped SLOTs can also be used for discrete output control such as warning lamps where each bit would indicate the state of a particular lamp. The data in these bit mapped SLOTs is not followed by a MASK byte. There can be up to 4 bytes of data without a mask.

3.2.1 BIT MAPPED WITHOUT MASK PARAMETER ASSIGNMENTS

BMP-01-1 MIL Status (PRN 1000)

Length: 1 bit

		0	1
Item 1:	Malfunction Indicator Lamp (MIL)	Not Commanded On	Commanded On

BMP-08-1 Continuous Evaluation Supported (PRN 1002)

Length: 8 bits

		0	1
Item 1:	Not Used		
Item 2:	Not Used		
Item 3:	Not Used		
Item 4:	Not Used		
Item 5:	Not Used		
Item 6:	Comprehensive Component Monitoring	Not Supported	Supported
Item 7:	Fuel System Monitoring	Not Supported	Supported
Item 8:	Misfire Monitoring	Not Supported	Supported

BMP-08-2 Trip Evaluation Supported (PRN 1002)

Length: 8 bits

		0	1
Item 1:	EGR System	Not Supported	Supported
Item 2:	Oxygen Sensor Heater	Not Supported	Supported
Item 3:	Oxygen Sensor	Not Supported	Supported
Item 4:	A/C System Refrigerant	Not Supported	Supported
Item 5:	Secondary Air System	Not Supported	Supported
Item 6:	Evaporative Purge System	Not Supported	Supported
Item 7:	Heated Catalyst	Not Supported	Supported
Item 8:	Catalyst	Not Supported	Supported

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BMP-08-3 Trip Evaluation Complete (PRN 1006)

		0	1
Length:	8 bits		
Item 1:	EGR System	Test Complete	Test Not Complete
Item 2:	Oxygen Sensor Heater	Test Complete	Test Not Complete
Item 3:	Oxygen Sensor	Test Complete	Test Not Complete
Item 4:	A/C System Refrigerant	Test Complete	Test Not Complete
Item 5:	Secondary Air System	Test Complete	Test Not Complete
Item 6:	Evaporative Purge System	Test Complete	Test Not Complete
Item 7:	Heated Catalyst	Test Complete	Test Not Complete
Item 8:	Catalyst	Test Complete	Test Not Complete

BMP-08-4 Fuel System Status (PRN 1008 & 1009)

		0	1
Length:	8 bits		
Item 1:	Reserved		
Item 2:	Reserved		
Item 3:	Reserved		
Item 4:	Closed Loop, Faulty O_2 Sensor	False	True
Item 5:	Open Loop, Detected Fault	False	True
Item 6:	Open Loop, Driving Conditions	False	True
Item 7:	Closed Loop, Using O_2 Sensor	False	True
Item 8:	Open Loop, Not Ready for Closed	False	True

BMP-08-5 Commanded Secondary Air Status (PRN 0012)

		0	1
Length:	8 bits		
Item 1:	Reserved		
Item 2:	Reserved		
Item 3:	Reserved		
Item 4:	Reserved		
Item 5:	Reserved		
Item 6:	Atmosphere/Off	Not Supported	Supported
Item 7:	Downstream - First Catalyst	Not Supported	Supported
Item 8:	Upstream - First Catalyst	Not Supported	Supported

BMP-08-6 O_2 Sensor Location (PRN 0013)

		0	1
Length:	8 bits		
Item 1:	Bank 2 - Sensor 4 (B4 - S2)	Not Present	Present
Item 2:	Bank 2 - Sensor 3 (B4 - S1)	Not Present	Present
Item 3:	Bank 2 - Sensor 2 (B3 - S2)	Not Present	Present
Item 4:	Bank 2 - Sensor 1 (B3 - S1)	Not Present	Present
Item 5:	Bank 1 - Sensor 4 (B2 - S2)	Not Present	Present
Item 6:	Bank 1 - Sensor 3 (B2 - S1)	Not Present	Present
Item 7:	Bank 1 - Sensor 2	Not Present	Present
Item 8:	Bank 1 - Sensor 1	Not Present	Present

BMP-32-1 PIDs Supported 01h - 20h (PRN 0600)

		0	1
Length:	32 bits		
Byte 1:			
Item 1 - 8:	PID 01h - 08h Supported	Not Supported	Supported
Byte 2:			
Item 9 - 16:	PID 09h - 10h Supported	Not Supported	Supported
Byte 3:			
Item 17 - 24:	PID 11h - 18h Supported	Not Supported	Supported
Byte 4:			
Item 25 - 32:	PID 19h - 20h Supported	Not Supported	Supported

BMP-32-2 PIDs Supported 21h - 40h (PRN 0020)

Length:	32 bits	0	1
Byte 1: Item 1 - 8:	Byte 1: PID 21h - 28h Supported	Not Supported	Supported
Byte 2: Item 9 - 16:	Byte 2: PID 29h - 30h Supported	Not Supported	Supported
Byte 3: Item 17 - 24:	Byte 3: PID 31h - 38h Supported	Not Supported	Supported
Byte 4: Item 25 - 32:	Byte 4: PID 39h - 40h Supported	Not Supported	Supported

BMP-32-3 PIDs Supported 41h - 60h (PRN 0040)

Length:	32 bits	0	1
Byte 1: Item 1 - 8:	PID 41h - 48h Supported	Not Supported	Supported
Byte 2: Item 9 - 16:	PID 49h - 50h Supported	Not Supported	Supported
Byte 3: Item 17 - 24:	PID 51h - 58h Supported	Not Supported	Supported
Byte 4: Item 25 - 32:	PID 59h - 60h Supported	Not Supported	Supported

5.3 Bit Mapped With Mask Bytes (BMM) SLOTs—Bit mapped with mask (BMM) SLOTs are used to encode data that typically contains several unary parameters, such as status bits or flags, grouped into a single byte or word byte. Bit mapped SLOTs can also be used for discrete output control such as warning lamps where each bit would indicate the state of a particular lamp. The data in these bit mapped SLOTs are always followed by a MASK byte which is used to indicate which bits of the data byte are valid. There can be up to 4 bytes of data including the mask bytes. Valid combinations include up to 3 data bytes each with mask.

5.3.1 BIT MAPPED WITH MASK PARAMETER ASSIGNMENTS—None defined.

5.4 Unsigned Numeric (UNM) SLOTs—Unsigned numeric (UNM) SLOTs are used to encode data that is typically associated with information such as temperature, speed, or percent. The SLOT can be 8, 16, 24, ... 56 bits in length (1 to 7 bytes) and may or may not have an offset. Unsigned numeric SLOTs can also be used for sequential data such as month (1 - 12) or day of month (1 - 31). Each SLOT definition contains a field for: resolution per bit; minimum and maximum value; and transfer function. The transfer function defines the relationship between computer units (N) in decimal, and engineering units (E) of the data.

5.4.1 UNSIGNED NUMERIC VARIABLE ASSIGNMENTS—The unsigned numeric variables have been grouped as follows:

- Table 23 - UNM-08, 8 Bit SLOTs
- Table 24 - UNM-16, 16 Bit SLOTs
- Table 25 - UNM-24, 24 Bit SLOTs
- Table 26 - UNM-32, 32 Bit SLOTs Assignments

TABLE 23—ZEROs SLOT ASSIGNMENTS

Slot #	Description	Length
UNM-01-0	Zero (0)	1 Bit
UNM-02-0	Zero (0)	2 Bits
UNM-03-0	Zero (0)	3 Bits
UNM-04-0	Zero (0)	4 Bits
UNM-05-0	Zero (0)	5 Bits
UNM-06-0	Zero (0)	6 Bits
UNM-07-0	Zero (0)	7 Bits
UNM-08-0	Zero (0)	8 Bits
UNM-16-0	Zero (0)	16 Bits
UNM-24-0	Zero (0)	24 Bits
UNM-32-0	Zero (0)	32 Bits
UNM-40-0	Zero (0)	40 Bits
UNM-48-0	Zero (0)	48 Bits
UNM-56-0	Zero (0)	56 Bits

TABLE 24 - UNM-xx, SHORT (< 8 BIT) SLOTs

Slot #	Scaling (Resolution; 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
01-1	1	0	1	-	E	N	
02-1	1	0	3	-	E	N	
03-1	1	0	7	-	E	N	
04-1	1	0	15	-	E	N	
05-1	1	0	31	-	E	N	
06-1	1	0	63	-	E	N	
07-1	1	0	127	-	E	N	

TABLE 23 - UMM-3d, 8 BIT SLOTs

Slot #	Scaling (Resolution; 1 bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function R =	Transfer Function E =	Comment
1	1/8000	0	0.031875	-	E * 8000	R / 8000	+0.000125
2	1/4000	0	0.06375	-	E * 4000	R / 4000	+0.00025
3	1/2000	0	0.1275	-	E * 2000	R / 2000	+0.0005
4	1/1000	0	0.255	-	E * 1000	R / 1000	+0.001
5	1/511	0	0.499	-	E * 511	R / 511	+0.0019561
6	1/255	0	1	-	E * 255	R / 255	+0.0039062
7	1/100	0	>1.27	-	(E+1.28) * 100	(R / 100) - 1.28	+0.01 w/ offset
8	1/200	0	1.275	-	E * 200	R / 200	+0.005
9	1/100	0	2.55	-	E * 100	R / 100	+0.01
10	1/64	0	3.96	-	E * 64	R / 64	+0.01138
11	1/32	0	7.969	-	E * 32	R / 32	+0.031128
12	1/25	0	10.2	-	E * 25	R / 25	+0.04
13	1/16	0	15.94	-	E * 16	R / 16	+0.0625
14	1/10	0	25.5	-	E * 10	R / 10	+0.1
15	1/4	0	63.75	-	E * 4	R / 4	+0.25
16	1/3	0	85	-	E * 3	R / 3	+0.333333
17	1/200/256	0	100	-	E * 2.56	R / 2.56	+0.390215
18	1/2	0	127.5	-	E * 2	R / 2	+0.5
19	1/2	-64	+63.5	-	(E+64) * 2	(R / 2) - 64	+0.5 w/ offset
20	1/2	-64	+63.5	-	(E+64) * 2	(R / 2) - 64	+0.5 w/ offset
21	1/1.5	0	170	-	E * 1.5	R / 1.5	+0.6666667
22	1/1.5	0	169	169.3 to 170	E * 1.5	R / 1.5	+0.6666667 w/ limits
23	1/0.75	0	191.25	-	E / 0.75	R * 0.75	+0.75
24	1/0.75	-90 (0.0)	+90 (0.0)	90.75 (Pole - 270)	(E+90) / 0.75	(R*0.75) - 90	+0.75 w/ offset
25	180/128	0	180.23	-	E * 1.28	R / 1.28	+0.781125
26	180/128	-128	+49.22	-	(E+128) / 1.28	(R*1.28) - 128	+0.781125 w/ Offset
27	1	0	255	-	E	R	+1
28	1	-40	+215	-	E + 40	R - 40	+1 w/ Offset
29	1	-128	+127	-	E + 128	R - 128	+1 w/ Offset
30	1/2	0 (0.0)	382 (0.0)	361.5 (Pole - 720)	E / 1.5	R * 1.5	-
31	2	0	510	-	E / 2	R * 2	-
32	2/3	0	637.5	-	E * 2 / 3	R * 3 / 2	-
33	3	0	765	-	E / 3	R * 3	-
34	4	0	1020	-	E / 4	R * 4	-
35	6	0	1530	-	E / 6	R * 6	-
36	10	0	2550	-	E / 10	R * 10	-
37	14	0	3570	-	E / 14	R * 14	-
38	16	0	4080	-	E / 16	R * 16	-
39	25	0	6375	-	E / 25	R * 25	-
40	50	0	12750	-	E / 50	R * 50	-
41	64	0	16320	-	E / 64	R * 64	-
42	100	0	25500	-	E / 100	R * 100	-
43	128	0	32640	-	E / 128	R * 128	-
44	256	0	65280	-	E / 256	R * 256	-
45	512	0	130560	-	E / 512	R * 512	-
46	1024	0	261120	-	E / 1024	R * 1024	-
47	2048	0	522240	-	E / 2048	R * 2048	-
48	4096	0	1044480	-	E / 4096	R * 4096	-

TABLE 24 - UMM-7d, 16 BIT SLOTs

Slot #	Scaling (Resolution; 1 bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function R =	Transfer Function E =	Comment
1	1/256	0	255.99	-	E * 256	R / 256	+0.003906
2	1/256	-32	191.99	-	(E + 32) * 256	(R / 256) - 32	+0.003906 w/ offset
3	1/128	0	511.99	-	E * 128	R / 128	+0.0078153
4	1/64	0	1023.984	-	E * 64	R / 64	+0.015625
5	1/32	0	2047.94	-	E * 32	R / 32	+0.03
6	1/16	0	4095.5	-	E * 16	R / 16	+0.1
7	1	0	16383.75	-	E * 4	R / 4	+0.25
8	-	0	65535	-	E	R	-

TABLE 25—UNM-24, 24 BIT SLOTs

Slot #	Scaling (Resolution: 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
11	1/10	0	1677721.5	-	E * 10	N / 10	=0.1
21	128/8000	0	268435.44	-	(E/128) * 8000	(N * 128) / 8000	=0.016
31	128/4000	0	536870.88	-	(E/128) * 4000	(N * 128) / 4000	=0.032
41	1/64	0	262143.98	-	E * 64	N / 64	=0.01563

TABLE 26—UNM-32, 32 BIT SLOTs

Slot #	Scaling (Resolution: 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
11	1/8000	0	536870.9	-	E * 8000	N / 8000	=0.000125
21	1/4000	0	1073741.8	-	E * 4000	N / 4000	=0.00025
31	1/64	0	67108864	-	E * 64	N / 64	=0.01563

7.5 2's Complement Signed Numeric (SNM) SLOTs—Signed numeric (SNM) SLOTs are represented in 2's complement notation. If the most significant bit of the number is set (one, 1), then the number is negative and the absolute value of the number is found by taking the 2's complement of the number. The 2's complement is found by inverting each bit of the number and then adding a binary one (1) to the result. For example, the number FFh, which has its most significant bit set, corresponds to -1.

7.5.1 2's COMPLEMENT SIGNED NUMERIC VARIABLE ASSIGNMENTS—The 2's complement signed numeric variables are grouped as follows:

- Table 27 - SNM-08, 8 Bit SLOTs

TABLE 27—SNM-08, 8 BIT SLOTs

Slot #	Scaling (Resolution: 1 Bit =)	Minimum Limit	Maximum Limit	Invalid Range	Transfer Function N =	Transfer Function E =	Comment
11	1/2	-64	+63.5	-	E * 2	N / 2	=0.5
21	1	-128	+127	-	E	N	-
41	4	-512	+508	-	E / 4	N * 4	-
51	3/2	-192	+190.5	-	E * 2/3	N * 3/2	-
61	8	-768	+762	-	E / 8	N * 8	-

7.6 State Encoded (SED) SLOTs—State encoded (SED) SLOTs are used for data that can take one of several states such as Day of Week or Wiper Mode. Each SLOT definition contains a field for describing each state within the SLOT. There can be between 1 and 8 bits in any given SLOT with $^{n}2$ possible states where n is the number of bits in the SLOT.

7.6.1 STATE ENCODED VARIABLE ASSIGNMENTS

SED-02-1 Sub-System Category Reference Letter (PRN 1005)

Length:	2 bits (0 - 3)
0	"P" = Powertrain
1	"C" = Chassis
2	"B" = Body
3	"U" = Undefined

SED-02-2 Most Significant Digit of Trouble Code (PRN 1006)

Length:	2 bits (0 - 3)
0	"0"
1	"1"
2	"2"
3	"3"

SED-02-3 Transmission Lock-up Status (PRN 1807)

Length:	2 bits (0 - 3)
0	Unlock
1	Partial Lock
2	Full Lock
3	Invalid

SED-04-1 Day of the Week (PRN 6012)

Length:	4 bits (0 - F)
0	Unknown
1	Sunday
2	Monday
3	Tuesday
4	Wednesday
5	Thursday
6	Friday
7	Saturday
8 - F	Invalid

SED-04-2 Month (PRN 6010)

Length:	4 bits (0 - F)
0	Unknown
1	January
2	February
3	March
4	April
5	May
6	June
-	July
8	August
9	September
A	October
B	November
C	December

D - F	Invalid

SED-06-1 Transmission Gear Engaged (PRN 1808)

Length:	8 bits (00 - 3F)
00	Neutral
01	Reverse
02	Forward 1
04	Forward 2
08	Forward 3
10	Forward 4
20	Forward 5
Others	Invalid

SED-08-1 Wiper Mode (PRN A003)

Length:	8 bits (00 - FF)
00	Invalid
01	Off
02	Intermittent
03	Low Speed
04	Medium Speed
05	High Speed
06	Pulse
07 - FF	Invalid

SED-08-2 Day of the Week (PRN 6013)

Length:	8 bits (00 - FF)
00	Unknown
01	Sunday
02	Monday
03	Tuesday
04	Wednesday
05	Thursday
06	Friday
07	Saturday
08 - FF	Invalid

SED-08-3 Day of Month (PRN 6014)

Length:	8 bits (00 - FF)
00	Invalid
01	1st
02	2nd
03	3rd
04	4th
05	5th
06	6th
07	7th
08	8th
09	9th
0A	10th
0B	11th
0C	12th
0D	13th
0E	14th
0F	15th
10	16th
11	17th
12	18th
13	19th
14	20th
15	21st
16	22nd
17	23rd
18	24th
19	25th
1A	26th
1B	27th
1C	28th
1D	29th
1E	30th
1F	31st
20 - FF	Invalid

SED-08-4 Transmission Range (PRN 1806, 1809, 180D, & 180E)

Length:	8 bits (00 - FF)
00	Invalid
01	Reverse
02	Forward 1
04	Forward 2
08	Forward 3
10	Forward 4
20	Forward 5
40	Forward 6/Park
80	Neutral
Others	Invalid

SED-08-5 Ignition Switch Position (PRN 1617)

Length:	8 bits (00 - FF)
00	Invalid
01	ACC
02	OFF/LOCK
04	OFF/UNLOCK
08	RUN
10	START
Others	Invalid

SED-08-6 Transmission Transfer Case (4WD) (PRN 180A)

Length:	8 bits (00 - FF)
00	Invalid
01	Neutral
02	Two Wheel Drive
03	Four Wheel Drive - Low
04	Four Wheel Drive - High
05 - FF	Invalid

SED-08-07 Door Lock Cylinder State (PRN C002)

Length:	8 bits (00 - FF)
00	Key Out
01	Key In Lock Position
02	Key In Unlock Position
03 - FF	Invalid

7.7 ASCII Encoded (ASC) SLOTs—ASCII (ASC) SLOTs are used to encode ASCII data. The least significant 7 bits represent the standard ASCII codes from 0 to 127. The most significant bit is reserved at this time but may be assigned a special function in the future. Several ASCII characters can be included in a single message by placing up to 7 ASCII characters sequentially in the data field. This allows a character string of up to 7 characters to be sent in a single message.

The ASCII character set is included in Table 27.

7.7.1 ASCII ENCODED VARIABLE ASSIGNMENTS

ASC-08-1 One ASCII Character

Length:	8 bits
Byte 1:	One ASCII Character

ASC-16-1 Two ASCII Characters

Length:	16 bits
Byte 1:	Left Most Character
Byte 2:	Right Most Character

ASC-24-1 Three ASCII Characters

Length:	24 bits
Byte 1:	Left Most Character
Byte 2:	Middle Character
Byte 3:	Right Most Character

ASC-32-1 Four ASCII Characters

Length:	32 bits
Byte 1:	Left Most Character
Byte 2:	Middle Left Character
Byte 3:	Middle Right Character
Byte 4:	Right Most Character

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ASC-40-1 Five ASCII Characters
Length: 40 bits
Byte 1: Left Most Character
Byte 2: Middle Left Character
Byte 3: Middle Character
Byte 4: Middle Right Character
Byte 5: Right Most Character

ASC-48-1 Six ASCII Characters
Length: 48 bits
Byte 1: Left Most Character
Byte 2: Middle Left Character
Byte 3: Middle Middle Left Character
Byte 4: Middle Middle Right Character
Byte 5: Middle Right Character
Byte 6: Right Most Character

ASC-56-1 Seven ASCII Characters
Length: 56 bits
Byte 1: Left Most Character
Byte 2: Middle Left Character
Byte 3: Middle Middle Left Character
Byte 4: Middle Character
Byte 5: Middle Middle Right Character
Byte 6: Middle Right Character
Byte 7: Right Most Character

7.12 ASCII Character Set—The conversion chart, Table 28, can be used to insert from a two-digit (one byte) hexadecimal number to an ASCII character a text to ASCII character to a two-digit hexadecimal number.

TABLE 28—ASCII CONVERSION CHART

Bits 4 to 8 / First Hex Digit (MSB)	0	1	2	3	4	5	6	7
0	NUL	DLE	SP	0	@	P	`	p
1	SOH	DC1	!	1	A	Q	a	q
2	STX	DC2	"	2	B	R	b	r
3	ETX	DC3	#	3	C	S	c	s
4	EOT	DC4	$	4	D	T	d	t
5	ENQ	NAK	%	5	E	U	e	u
6	ACK	SYN	&	6	F	V	f	v
7	BEL	ETB	'	7	G	W	g	w
8	BS	CAN	(	8	H	X	h	x
9	HT	EM	)	9	I	Y	i	y
A	LF	SUB	*	:	J	Z	j	z
B	VT	ESC	+	;	K	[	k	{
C	FF	FS	,	<	L	\	l	|
D	CR	GS	-	=	M	]	m	}
E	SO	RS	.	>	N	^	n	~
F	SI	US	/	?	O	_	o	DEL

7.13 Binary Coded Decimal (BCD) SLOTs—BCD SLOTs are similar to ASCII SLOTs and are used to encode BCD data. The upper nibble is used to represent the most significant digit in a two-digit number and the lower nibble is the least significant digit. For example, the data value 38h would represent 38 decimal. Invalid data ranges include any value that has either nibble greater than 9 (i.e., A, B, ..., F in either nibble). Therefore, a valid value can represent a number from 0 to 9. Several BCD numbers can be included in a single message by packing up to 14 BCD digits sequentially in the data field. This allows any number from 0 to 99,999,999,999,999 to be sent in a single message.

7.13.1 Binary Coded Decimal (BCD) Variable Assignments

BCD-8-1 1 digit
Length: 4 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0
Maximum: 9

BCD-8-1 2 digits
Length: 8 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00
Maximum: 99

BCD-12-1 3 digits
Length: 12 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000
Maximum: 999

BCD-16-1 4 digits
Length: 16 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000
Maximum: 9999

BCD-20-1 5 digits
Length: 20 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000
Maximum: 99999

BCD-24-1 6 digits
Length: 24 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000000
Maximum: 999999

BCD-28-1 7 digits
Length: 28 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000000
Maximum: 9999999

BCD-32-1 8 digits
Length: 32 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000000
Maximum: 99999999

BCD-36-1 9 digits
Length: 36 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000000000
Maximum: 999999999

BCD-40-1 10 digits
Length: 40 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000000000
Maximum: 9999999999

BCD-44-1 11 digits
Length: 44 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000000000
Maximum: 99999999999

BCD-48-1 12 digits
Length: 48 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 000000000000
Maximum: 999999999999

BCD-52-1 13 digits
Length: 52 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 0000000000000
Maximum: 9999999999999

BCD-56-1 14 digits
Length: 56 bits
Scaling (Resolution): 1 bit = 1 (BCD)
Limit:
Minimum: 00000000000000
Maximum: 99999999999999

7.9 **Signed Floating Point (Scientific Notation) (SFP) SLOT**—The Signed Floating Point (SFP) SLOT is used to encode data that needs to be represented in floating point arithmetic, and always includes a leading sign character. The format exactly follows the ANSI/IEEE Standard (Std 754-1985) Single format. Please note that the data byte boundaries of the transmitted frame do not align with the boundaries of this format. The floating point parameter is sent as a 32 bit (4 byte) variable. The bit order is shown in Figure 14.

7.9.1 SIGNED FLOATING POINT VARIABLE ASSIGNMENT

SFP-32-1 Floating Point

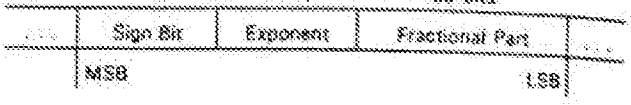

FIGURE 14—SIGNED FLOATING POINT (SCIENTIFIC NOTATION) (SFP) SLOT

8. Multiple Frame, Single Parameter Format—This section defines the method of encoding long parameters that require more than one frame to complete. The first data byte for this format is a sequence number as shown in Figure 15. The sequence byte consists of an upper nibble that identifies this frame by number in the sequence. The lower nibble is the total number of frames that make up this grouping. The sequence byte is followed by up to the maximum number of data bytes allowed by SAE J1850, for each frame. The entire parameter is thus built up from the total number of frames shown in the sequence tracking byte, in the order carried in that byte. The data field format will thus have an order indicated by Figure 16.

A simple example of this format is shown in Figures 17, 18, and 19, sending an ASCII string of characters.

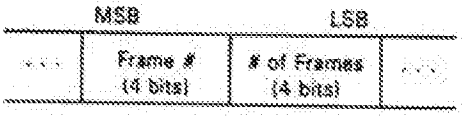

FIGURE 15—SEQUENCE TRACKING BYTE

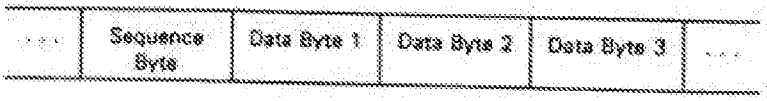

FIGURE 16—MULTIPLE FRAME, SINGLE PARAMETER FIELD

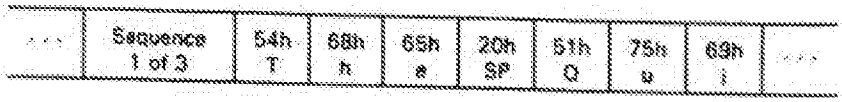

FIGURE 17—FIRST SEQUENCE FRAME

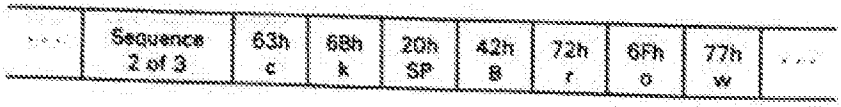

FIGURE 18—SECOND SEQUENCE FRAME

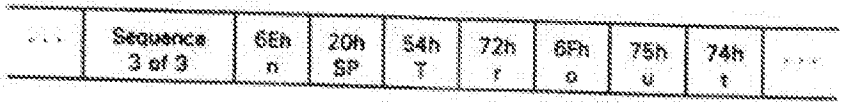

FIGURE 19—LAST SEQUENCE FRAME

CLASS B DATA COMMUNICATION NETWORK MESSAGES—PART 3: FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS—SAE J2178/3 SEP93

SAE Recommended Practice

Report of the Vehicle Network for Multiplexing and Data Communications Standards Committee approved September 1993.

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1. *Scope*—This SAE Recommended Practice defines the information stored in the header and data fields of nondiagnostic messages for in-vehicle serial communications based on SAE J1850 Class B networks. This document identifies and specifies the header fields, data fields, field sizes, data representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scopes of header fields defined by this document for nondiagnostic messages. Refer to SAE J1979 for specifications of emissions-related diagnostic message header and data fields. Refer to SAE J2190 for the definition of other diagnostic message header and data fields. The description of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC field are given in SAE J1850.

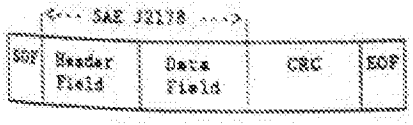

FIGURE 1—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE

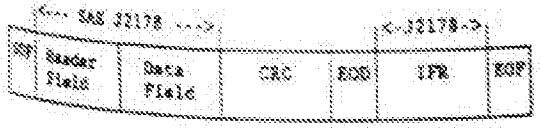

FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The consolidated header format has two forms: a single byte form and a three byte form. This document covers all of these formats and forms to identify the contents of messages which could be sent on a SAE J1850 network.

This document consists of four parts, each published separately.

Part 1 of SAE J2178 (Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats: single byte and consolidated. It also contains the physical node address range assignments for the typical subsystems of an automobile.

Part 2 of SAE J2178 (Titled: Data Parameter Definitions) defines the standard parametric data which may be exchanged on SAE J1850 (Class B) networks. The parameters scaling, ranges, and transfer functions are specified. Messages which refer to these parametric definitions shall always adhere to these parametric definitions. It is intended that at least one of the definitions for each parameter in this part match the SAE J1979 definition. The details of this part are fully described in 3.1.

Part 3 of SAE J2178 (this part, Titled: Frame IDs for Single Byte Forms of Headers) defines the message assignments for the single byte header format and the one byte form of the consolidated header format.

Part 4 of SAE J2178 (Titled: Target Address (Second Byte) for Three Byte Headers) defines the message assignments for the second byte in the three byte form of the consolidated header format.

1.1 *Standardized Parameter Definitions*—The parameters used to describe data variables are one of the most important functions of this document. To achieve commonality of messages in Class B networks, the data parameters must become standardized. This applies to data parameter definitions for use during normal vehicle operations as well as during diagnostic operations. By using common parameter definitions for nondiagnostic and diagnostic functions on the network, the modules which form the network can maintain one image or description of a data parameter.

Where parameters have been defined in the Diagnostic Test Modes documents (SAE J1979 and J2190), such as Parameter Identifiers for diagnostic purposes, the definitions in Part 2 of this document match the diagnostic definition.

SAE J2178, Part 2 defines the parameters to be used for nondiagnostic and diagnostic data format definitions. For new parameter definitions which are needed in the future, the new definitions, if they are expected to become widely used, must be integrated into this document for commonality across these types used, must be integrated into this document for commonality across these types of applications. Of course, manufacturers are free to assign their own definitions of applications. Of course, manufacturers are free to assign their own definitions to data parameters which are unique or proprietary to their products. They are, however, restricted to using the "Manufacturers Reserved" message header assignments in Parts 3 and 4 of this document when using these unique or proprietary data parameter definitions.

2. *References*

2.1 *Applicable Documents*—The following publications form a part of this specification to the extent specified herein. The latest issue of SAE publications shall apply.

SAE J1850—Class B Data Communication Network Interface

SAE J1979—E/E Diagnostic Test Modes

SAE J2178/1—Detailed Header Formats and Physical Address Assignments

SAE J2178/3—Data Parameter Definitions

SAE J2178/4—Target Address (Second Byte) for Three Byte Headers (Draft)

SAE J2190—Enhanced E/E Diagnostic Test Modes

2.2 *Related Publications*—The following publications are provided for information purposes only and are not a required part of this document.

SAE J1213/1—Glossary of Vehicle Networks for Multiplex and Data Communication

SAE J1930—Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms

2.3 *Terms and Definitions*

2.3.1 DATA (DATA FIELD)—Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or test modes which further defines a particular message content being exchanged over the network.

3.3.2 FRAME—A frame is one complete transmission of information which may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" 2.3.5).

3.3.3 HEADER (HEADER FIELD)—The header (or header field, used interchangeably) is a one or three byte field within a frame which contains information about the message priority, message source and target addressing, message type, and in-frame response type.

3.3.4 IN-FRAME RESPONSE (IFR) TYPE—The IFR type identifies the form of the in-frame response which is expected within that message.

3.3.5 MESSAGE—A message consists of all of the bytes of a frame excluding the delimiter symbols (SOF, EOD, EOF, NB).

3.3.6 PARAMETER—A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

3.3.7 PRIORITY—The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

3.3.8 RESPONSE DATA—The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

2.4 Abbreviations and Acronyms

CRC - Cyclic Redundancy Check
EOD - End of Data
EOF - End of Frame
ID - Identifier
IFR - In-Frame Response
LSB - Least Significant Bit / Byte
MSB - Most Significant Bit / Byte
NB - Normalization Bit
PKT - Multiple Parameter Packet SLOT
PRN - Parameter Reference Number
SLOT - Scaling, Limit, Offset, and Transfer Function
SOF - Start of Frame

3. *General Information*

3.1 Document Overview—The messages defined by this document are specified for networks using one byte headers or the single byte form of the consolidated header as specified in SAE J1850. This document focuses on the Frame ID which is the first byte of the message. The first byte of the one byte header is defined in Section 4 under Frame ID as an 8 Bit hexadecimal number and the first byte of the single byte form of the consolidated header is defined under 7 Bit as a hexadecimal number. Bit four (H bit) of the 7 Bit header is always a logic "1" (see Section 5 of SAE J2178 Part 1). The information in the header field implicitly defines the target, source, priority and message type information, while the data field contains additional addressing and parametric information (see Section 4 of SAE J2178 Part 1). The header defines the Message Identifier or Frame ID and becomes the name that is broadcast normally periodically to all the nodes on the network.

This document describes the overall structure of messages and is expected to have wide application. Designers are required to use the defined messages on SAE J1850 networks in the exact way that they are defined here. There are a large number of message codes which are reserved for each manufacturer to define. If the user cannot find a needed message, he or she is expected to define a manufacturer-specific message in these reserved codes. Therefore, messages on different manufacturer's products using these "Manufacturer Reserved" codes will only have meaning for that manufacturer or specific vehicle. These will most likely be different between manufacturers. The codes that are defined here, however, shall always carry the same meaning from one manufacturer to another and from one model and year to the next.

3.2 Parameter Reference Number (PRN)—With the Single Byte form of header, the Frame ID corresponds with a particular Parameter Reference Number (PRN) or a grouping of PRNs (see Section 6 of SAE J2178 Part 2). The PRN is an arbitrarily assigned number and defines the following:

a. Length of data in number of bits
b. Units
c. Scaling, Limit, Offset, and Transfer Function, i.e., SLOT (see Section 7 of SAE J2178 Part 2)
d. Type or category of data

SAE J2178 Part 2, Section 7 defines the following data Types:

(1) BMP Bit Mapped
(2) UNM Unsigned Numeric
(3) SNM 2's Complement Signed Numeric
(4) SED State Encoded
(5) ASC ASCII Encoded
(6) BCD Binary Coded Decimal
(7) SFP Signed Floating Point (Scientific Notation)

3.3 Message Identification (FRAME ID)—The FRAME ID of the single byte header implicitly and uniquely defines the following characteristics of the message:

a. The message priority
b. The data content of the message specified by a PRN or packet of PRNs
c. The length of message
d. Source of the message
e. Type of the message
f. The event or repetition rate for transmission
g. CRC byte requirements

3.3.1 PRN ASSIGNMENTS—A FRAME ID shall have one or more PRNs assigned to it. Some PRNs may be composed of a packet (PKT) of PRNs (see paragraph 7.1 of SAE J2178 Part 2). The bytes of the data field shall be composed of the parameter given in the "PRNs" column of the figure defined in Section 4. When more than one PRN is shown, the data field shall contain the PRNs in the order given left to right.

3.3.2 IN-FRAME RESPONSE (IFR) TYPE—The IFR Type shall be given under "IFR Type" column of the figure defined in Section 4. The different IFR Types are defined in Section 3 of J2178 Part 1.

3.3.3 REPETITION RATE—The vehicle manufacturer shall choose which message frames are event driven or defined by a repetition rate. Refer to SAE J2178 Part 1 Appendix A for further information on event- or time-based message frames.

3.3.4 CRC BYTE REQUIREMENTS—The CRC byte requirements shall be defined by the manufacturer as specified by SAE J1850.

4. *Frame IDs for Single Byte Forms of Headers*—Figure 3 defines the Frame ID for one byte headers and the first byte of the single byte form of the consolidated header.

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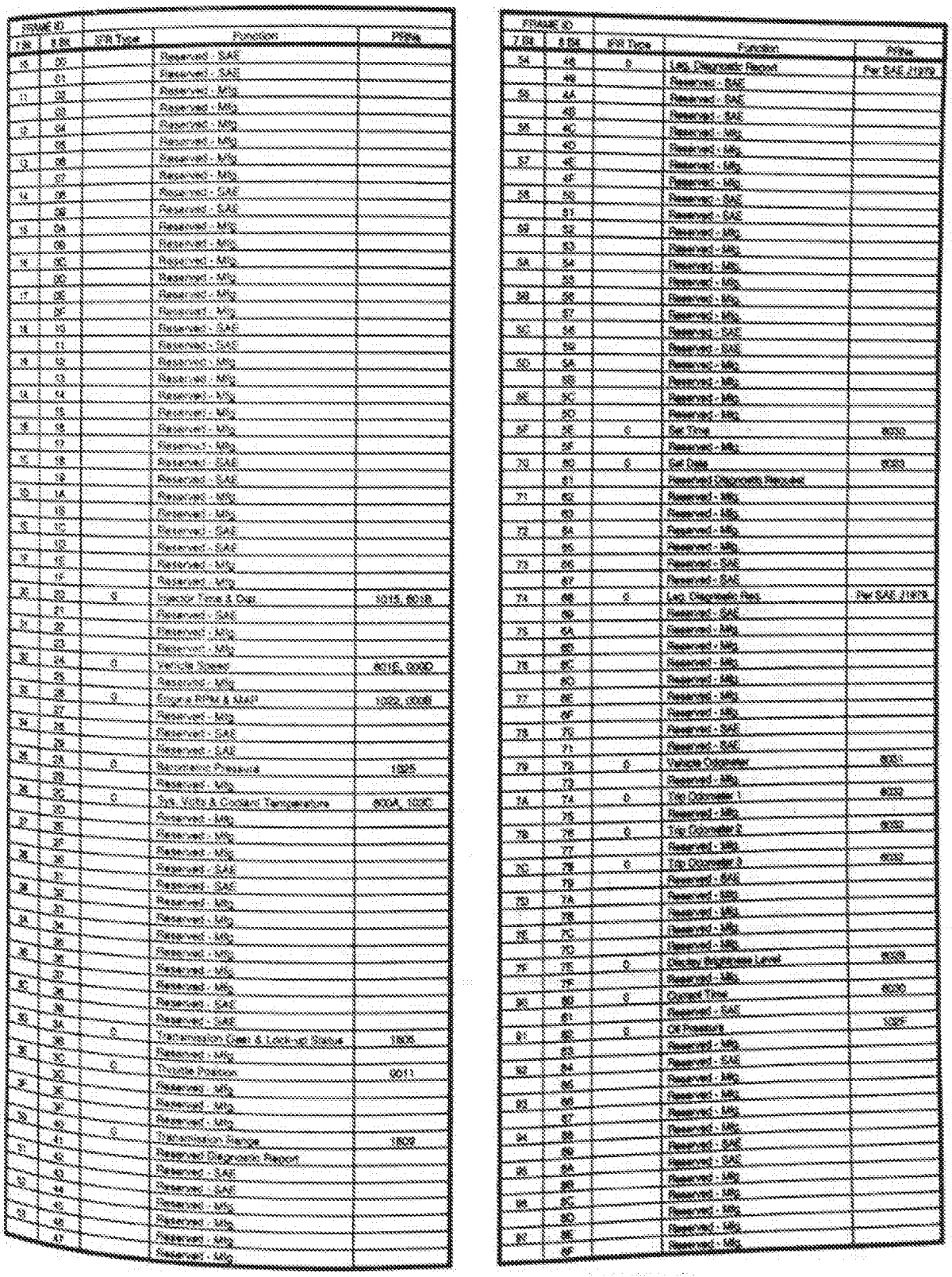
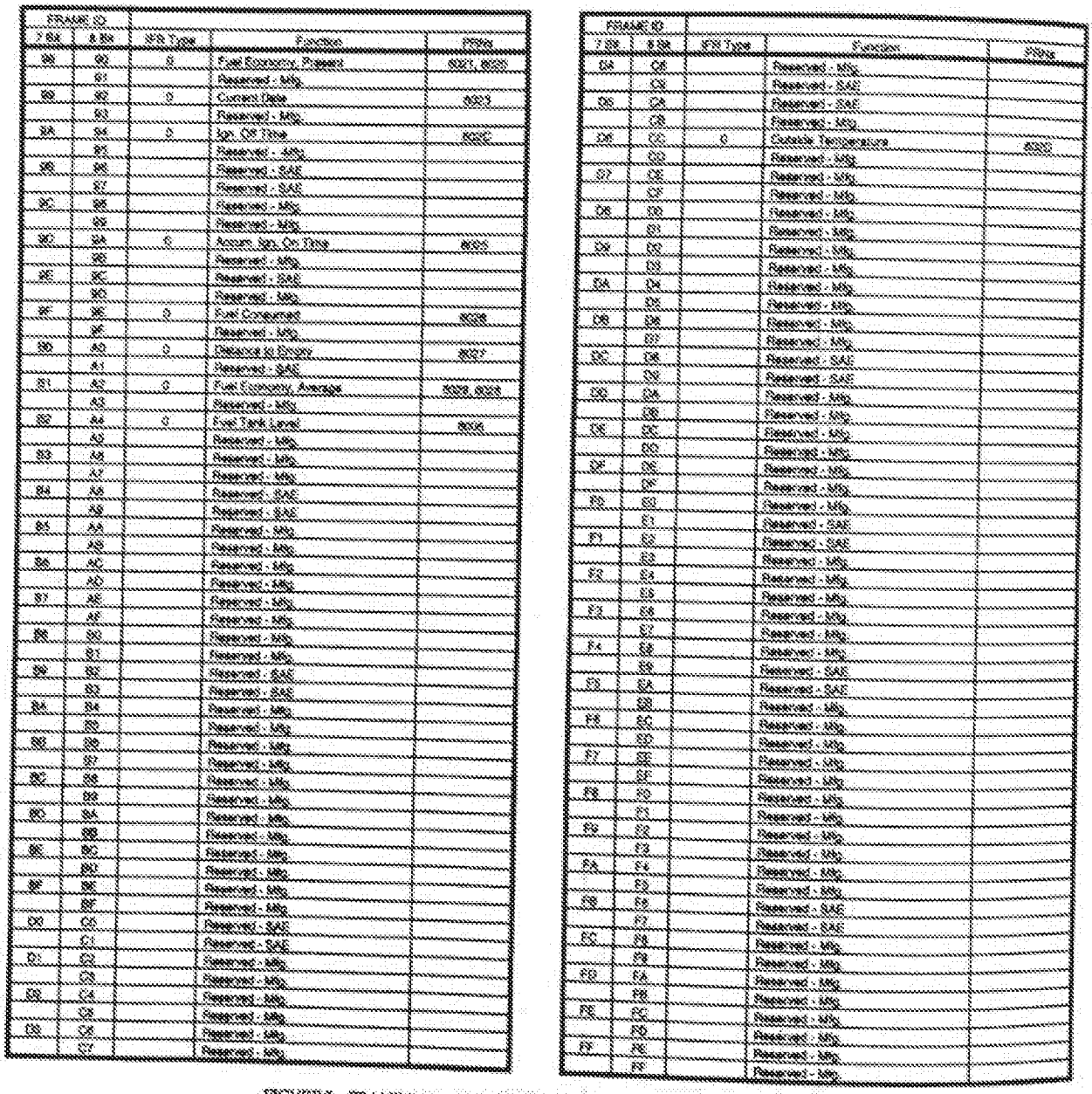


FRAME ID				
7 Bit	8 Bit	NW Type	Function	PGNs
34	68		Reserved - SAE	
	69		Reserved - SAE	
35	70		Reserved - Mfg	
	71		Reserved - Mfg	
36	72		Reserved - Mfg	
	73		Reserved - Mfg	
37	74		Reserved - Mfg	
	75		Reserved - Mfg	
38	76		Reserved - Mfg	
	77		Reserved - SAE	
39	78		Reserved - SAE	
	79		Reserved - Mfg	
40	80		Reserved - Mfg	
	81		Reserved - Mfg	
41	82		Reserved - Mfg	
	83		Reserved - Mfg	
42	84		Reserved - Mfg	
	85		Reserved - Mfg	
43	86		Reserved - SAE	
	87		Reserved - SAE	
44	88		Reserved - Mfg	
	89		Reserved - Mfg	
45	90		Reserved - Mfg	
	91		Reserved - Mfg	
46	92		Reserved - Mfg	
	93		Reserved - Mfg	
47	94		Reserved - Mfg	
	95		Reserved - Mfg	
48	96		Reserved - Mfg	
	97		Reserved - Mfg	
49	98		Reserved - SAE	
	99		Reserved - SAE	
50	100		Reserved - Mfg	
	101		Reserved - Mfg	
51	102		Reserved - Mfg	
	103		Reserved - Mfg	
52	104		Reserved - Mfg	
	105		Reserved - Mfg	
53	106		Reserved - SAE	
	107		Reserved - SAE	
54	108		Reserved - Mfg	
	109		Reserved - Mfg	
55	110		Reserved - Mfg	
	111		Reserved - Mfg	
56	112		Reserved - Mfg	
	113		Reserved - Mfg	
57	114		Reserved - SAE	
	115		Reserved - SAE	
58	116		Reserved - Mfg	
	117		Reserved - Mfg	
59	118		Reserved - Mfg	
	119		Reserved - Mfg	
60	120		Reserved - Mfg	
	121		Reserved - Mfg	
61	122		Reserved - SAE	
	123		Reserved - SAE	
62	124		Reserved - Mfg	
	125		Reserved - Mfg	
63	126		Reserved - Mfg	
	127		Reserved - Mfg	
64	128	6	Transmission Time & Date	1015, 8018
	129		Reserved - SAE	
65	130		Reserved - SAE	
	131		Reserved - Mfg	
66	132		Reserved - Mfg	
	133		Reserved - Mfg	
67	134	6	Vehicle Speed	8016, 8030
	135		Reserved - Mfg	
68	136	6	Engine RPM & MAP	1002, 8008
	137		Reserved - Mfg	
69	138		Reserved - SAE	
	139		Reserved - SAE	
70	140	6	Barometric Pressure	1905
	141		Reserved - Mfg	
71	142	6	Oil, Coolt & Coolant Temperature	8004, 1006
	143		Reserved - Mfg	
72	144		Reserved - Mfg	
	145		Reserved - Mfg	
73	146		Reserved - SAE	
	147		Reserved - SAE	
74	148		Reserved - Mfg	
	149		Reserved - Mfg	
75	150		Reserved - Mfg	
	151		Reserved - Mfg	
76	152		Reserved - Mfg	
	153		Reserved - Mfg	
77	154		Reserved - SAE	
	155		Reserved - SAE	
78	156		Reserved - Mfg	
	157		Reserved - Mfg	
79	158	6	Transmission Gear & Lock-up Status	1805
	159		Reserved - Mfg	
80	160	6	Throttle Position	8011
	161		Reserved - Mfg	
81	162		Reserved - Mfg	
	163		Reserved - Mfg	
82	164	6	Transmission Range	1802
	165		Reserved Diagnostic Report	
83	166		Reserved - SAE	
	167		Reserved - SAE	
84	168		Reserved - Mfg	
	169		Reserved - Mfg	
85	170		Reserved - Mfg	
	171		Reserved - Mfg	

FRAME ID				
7 Bit	8 Bit	NW Type	Function	PGNs
34	68	6	Last Diagnostic Report	Per SAE J1979
	69		Reserved - SAE	
35	70		Reserved - SAE	
	71		Reserved - SAE	
36	72		Reserved - Mfg	
	73		Reserved - Mfg	
37	74		Reserved - Mfg	
	75		Reserved - Mfg	
38	76		Reserved - Mfg	
	77		Reserved - SAE	
39	78		Reserved - SAE	
	79		Reserved - Mfg	
40	80		Reserved - Mfg	
	81		Reserved - Mfg	
41	82		Reserved - Mfg	
	83		Reserved - Mfg	
42	84		Reserved - Mfg	
	85		Reserved - Mfg	
43	86		Reserved - SAE	
	87		Reserved - SAE	
44	88		Reserved - Mfg	
	89		Reserved - Mfg	
45	90		Reserved - Mfg	
	91		Reserved - Mfg	
46	92		Reserved - Mfg	
	93		Reserved - Mfg	
47	94		Reserved - Mfg	
	95		Reserved - Mfg	
48	96		Reserved - Mfg	
	97		Reserved - Mfg	
49	98		Reserved - SAE	
	99		Reserved - SAE	
50	100		Reserved - Mfg	
	101		Reserved - Mfg	
51	102		Reserved - Mfg	
	103		Reserved - Mfg	
52	104		Reserved - Mfg	
	105		Reserved - Mfg	
53	106		Reserved - SAE	
	107		Reserved - SAE	
54	108		Reserved - Mfg	
	109		Reserved - Mfg	
55	110		Reserved - Mfg	
	111		Reserved - Mfg	
56	112		Reserved - Mfg	
	113		Reserved - Mfg	
57	114		Reserved - SAE	
	115		Reserved - SAE	
58	116		Reserved - Mfg	
	117		Reserved - Mfg	
59	118		Reserved - Mfg	
	119		Reserved - Mfg	
60	120		Reserved - Mfg	
	121		Reserved - Mfg	
61	122		Reserved - SAE	
	123		Reserved - SAE	
62	124		Reserved - Mfg	
	125		Reserved - Mfg	
63	126		Reserved - Mfg	
	127		Reserved - Mfg	
64	128	6	Set Time	8030
	129		Reserved - Mfg	
65	130	6	Set Date	8033
	131		Reserved Diagnostic Request	
66	132		Reserved - Mfg	
	133		Reserved - Mfg	
67	134		Reserved - Mfg	
	135		Reserved - Mfg	
68	136		Reserved - SAE	
	137		Reserved - SAE	
69	138	6	Last Diagnostic Part	Per SAE J1979
	139		Reserved - SAE	
70	140		Reserved - Mfg	
	141		Reserved - Mfg	
71	142		Reserved - Mfg	
	143		Reserved - Mfg	
72	144		Reserved - Mfg	
	145		Reserved - Mfg	
73	146		Reserved - SAE	
	147		Reserved - SAE	
74	148		Reserved - Mfg	
	149		Reserved - Mfg	
75	150		Reserved - Mfg	
	151		Reserved - Mfg	
76	152		Reserved - Mfg	
	153		Reserved - Mfg	
77	154		Reserved - SAE	
	155		Reserved - SAE	
78	156		Reserved - Mfg	
	157		Reserved - Mfg	
79	158	6	Vehicle Odometer	8001
	159		Reserved - Mfg	
80	160	6	Trip Odometer 1	8020
	161		Reserved - Mfg	
81	162	6	Trip Odometer 2	8020
	163		Reserved - Mfg	
82	164	6	Trip Odometer 3	8020
	165		Reserved - SAE	
83	166		Reserved - Mfg	
	167		Reserved - Mfg	
84	168		Reserved - Mfg	
	169		Reserved - Mfg	
85	170	6	Display Brightness Level	8009
	171		Reserved - Mfg	
86	172	6	Current Time	8030
	173		Reserved - SAE	
87	174	6	Oil Pressure	1007
	175		Reserved - Mfg	
88	176		Reserved - SAE	
	177		Reserved - Mfg	
89	178		Reserved - Mfg	
	179		Reserved - Mfg	
90	180		Reserved - Mfg	
	181		Reserved - Mfg	
91	182		Reserved - SAE	
	183		Reserved - SAE	
92	184		Reserved - Mfg	
	185		Reserved - Mfg	
93	186		Reserved - Mfg	
	187		Reserved - Mfg	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS



FRAME ID				
7 Bit	8 Bit	SPN Type	Function	PGNs
98	90	0	Fuel Economy, Present	65271, 65266
	91		Reserved - Mfg.	
99	93	0	Current Data	65253
	93		Reserved - Mfg.	
9A	94	0	Ign. Off Time	65252
	95		Reserved - Mfg.	
9B	96		Reserved - SAE	
	97		Reserved - SAE	
9C	98		Reserved - Mfg.	
	99		Reserved - Mfg.	
9D	9A	0	Accum. Ign. On Time	65253
	9B		Reserved - Mfg.	
9E	9C		Reserved - SAE	
	9D		Reserved - Mfg.	
9F	9E	0	Fuel Consumed	65257
	9F		Reserved - Mfg.	
A0	A0	0	Distance to Empty	65271
	A1		Reserved - SAE	
A1	A2	0	Fuel Economy, Average	65266, 65239
	A3		Reserved - Mfg.	
A2	A4	0	Fuel Tank Level	65276
	A5		Reserved - Mfg.	
A3	A6		Reserved - Mfg.	
	A7		Reserved - Mfg.	
A4	A8		Reserved - SAE	
	A9		Reserved - SAE	
A5	AA		Reserved - Mfg.	
	AB		Reserved - Mfg.	
A6	AC		Reserved - Mfg.	
	AD		Reserved - Mfg.	
A7	AE		Reserved - Mfg.	
	AF		Reserved - Mfg.	
A8	B0		Reserved - Mfg.	
	B1		Reserved - Mfg.	
A9	B2		Reserved - SAE	
	B3		Reserved - SAE	
AA	B4		Reserved - Mfg.	
	B5		Reserved - Mfg.	
AB	B6		Reserved - Mfg.	
	B7		Reserved - Mfg.	
AC	B8		Reserved - Mfg.	
	B9		Reserved - Mfg.	
AD	BA		Reserved - Mfg.	
	BB		Reserved - Mfg.	
AE	BC		Reserved - Mfg.	
	BD		Reserved - Mfg.	
AF	BE		Reserved - Mfg.	
	BF		Reserved - Mfg.	
B0	C0		Reserved - Mfg.	
	C1		Reserved - SAE	
B1	C2		Reserved - SAE	
	C3		Reserved - Mfg.	
B2	C4		Reserved - Mfg.	
	C5		Reserved - Mfg.	
B3	C6		Reserved - Mfg.	
	C7		Reserved - Mfg.	

FRAME ID				
7 Bit	8 Bit	SPN Type	Function	PGNs
B4	C8		Reserved - Mfg.	
	C9		Reserved - SAE	
B5	CA		Reserved - SAE	
	CB		Reserved - Mfg.	
B6	CC	0	Outside Temperature	65269
	CD		Reserved - Mfg.	
B7	CE		Reserved - Mfg.	
	CF		Reserved - Mfg.	
B8	D0		Reserved - Mfg.	
	D1		Reserved - Mfg.	
B9	D2		Reserved - Mfg.	
	D3		Reserved - Mfg.	
BA	D4		Reserved - Mfg.	
	D5		Reserved - Mfg.	
BB	D6		Reserved - Mfg.	
	D7		Reserved - Mfg.	
BC	D8		Reserved - SAE	
	D9		Reserved - SAE	
BD	DA		Reserved - Mfg.	
	DB		Reserved - Mfg.	
BE	DC		Reserved - Mfg.	
	DD		Reserved - Mfg.	
BF	DE		Reserved - Mfg.	
	DF		Reserved - Mfg.	
C0	E0		Reserved - Mfg.	
	E1		Reserved - SAE	
C1	E2		Reserved - SAE	
	E3		Reserved - Mfg.	
C2	E4		Reserved - Mfg.	
	E5		Reserved - Mfg.	
C3	E6		Reserved - Mfg.	
	E7		Reserved - Mfg.	
C4	E8		Reserved - Mfg.	
	E9		Reserved - Mfg.	
C5	EA		Reserved - Mfg.	
	EB		Reserved - Mfg.	
C6	EC		Reserved - Mfg.	
	ED		Reserved - Mfg.	
C7	EE		Reserved - Mfg.	
	EF		Reserved - Mfg.	
C8	F0		Reserved - Mfg.	
	F1		Reserved - Mfg.	
C9	F2		Reserved - Mfg.	
	F3		Reserved - Mfg.	
CA	F4		Reserved - Mfg.	
	F5		Reserved - Mfg.	
CB	F6		Reserved - SAE	
	F7		Reserved - SAE	
CC	F8		Reserved - Mfg.	
	F9		Reserved - Mfg.	
CD	FA		Reserved - Mfg.	
	FB		Reserved - Mfg.	
CE	FC		Reserved - Mfg.	
	FD		Reserved - Mfg.	
CF	FE		Reserved - Mfg.	
	FF		Reserved - Mfg.	

FIGURE 3—FRAME IDs FOR SINGLE BYTE FORMS OF HEADERS (CONTINUED)

CLASS B DATA COMMUNICATION NETWORK MESSAGES—MESSAGE DEFINITIONS FOR THREE BYTE HEADERS—SAE J2178/4 FEB95

SAE Recommended Practice

Report of the SAE Vehicle Network for Multiplex and Data Communication Standards Committee approved February 1995.

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1. *Scope*—This SAE Recommended Practice defines the information contained in the header and data fields of non-diagnostic messages for automotive serial communications based on SAE J1850 Class B networks. This document describes and specifies the header fields, data fields, field sizes, scaling, representations, and data positions used within messages.

The general structure of a SAE J1850 message frame without in-frame response is shown in Figure 1. The structure of a SAE J1850 message with in-frame response is shown in Figure 2. Figures 1 and 2 also show the scope of frame fields defined by this document for non-diagnostic messages. Refer to SAE J1979 for specifications of emissions related diagnostic message header and data fields. Refer to SAE J2190 for the definition of other diagnostic data fields. The description of the network interface hardware, basic protocol definition, the electrical specifications, and the CRC byte are given in SAE J1850.

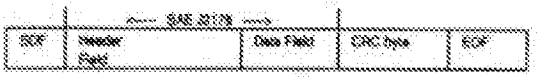

FIGURE 1—SCOPE OF SAE J1178 FOR A SAE J1850 FRAME WITHOUT IN-FRAME RESPONSE (IFR)

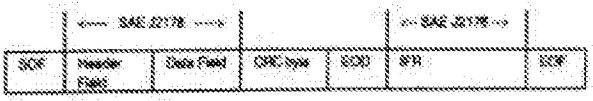

FIGURE 2—SCOPE OF SAE J2178 FOR A SAE J1850 FRAME WITH IN-FRAME RESPONSE (IFR)

SAE J1850 defines two and only two formats of message headers. They are the Single Byte header format and the Consolidated header format. The Consolidated header format has two forms, a Single Byte form and a three byte form. This document covers all of these formats and forms to identify the contents of messages which could be sent on a SAE J1850 network.

This document consists of four parts, each published separately.

SAE J2178/1 (Titled: Detailed Header Formats and Physical Address Assignments) describes the two allowed forms of message header formats, single byte and consolidated. It also contains the physical node address range assignments for the typical sub-systems of an automobile.

SAE J2178/2 (Titled: Data Parameter Definitions) defines the standard parametric data which may be exchanged on SAE J1850 (Class B) networks. The parameter scaling, ranges, and transfer functions are specified. Messages that refer to these parametric definitions shall always adhere to these parametric definitions. It is intended that at least one of the definitions for each parameter in this part match the SAE J1979 definition.

SAE J2178/3 (Titled: Frame IDs for Single Byte Forms of Headers) defines the message assignments for the single byte header format and the one byte form of the consolidated header format.

SAE J2178/4 (this part, Titled: Message Definition for Three Byte Headers) defines the message assignments for the three byte form of the consolidated header format.

2. *References*

2.1 **Related Publications**—The following publications are provided for information purposes only and are not a required part of this document.

2.1.1 SAE PUBLICATIONS—Available from SAE, 400 Commonwealth Drive, Warrendale, PA 15096-0001.

SAE J1213/1 JUN91—Glossary of Vehicle Networks for Multiplex and Data Communication

SAE J1850 AUG91—Class B Data Communication Network Interface

SAE J1930 SEP91—Electrical/Electronic Systems Diagnostic Terms, Definitions, Abbreviations, and Acronyms

SAE J1979 DEC91—E/E Diagnostic Test Modes

SAE J2190 JUN93—Enhanced E/E Diagnostic Test Modes

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2.1.3 ANSI Publication—Available from ANSI, 11 West 42nd Street, New York, NY 10036-8002.

ANSI/IEEE Std 754-1985, August 12, 1985—IEEE Standard for Binary Floating-Point Arithmetic

3.2 Abbreviations and Acronyms

A/C	- Air Conditioning
ASC	- ASCII Encoded SLOT
BCD	- Binary Coded Decimal (BCD) SLOT
BMM	- Bit Mapped with Mask SLOT
BMP	- Bit Mapped without Mask SLOT
CRC	- Cyclic Redundancy Check
CS	- Checksum
DTC	- Diagnostic Trouble Code
EOD	- End of Data
EOF	- End of Frame
ERR	- Error Detection
HVAC	- Heating, Ventilation, Air Conditioning
ID	- Identifier
IFR	- In-Frame Response
LSB	- Least Significant Bit / Byte
MSB	- Most Significant Bit / Byte
NB	- Normalization Bit
PID	- Parameter IDentification (number, NOT the primary ID, See Section 7)
PKT	- Multiple Parameter Packet SLOT
PRN	- Parameter Reference Number
SED	- State Encoded SLOT
SFP	- Signed Floating Point (Scientific Notation) SLOT
SLOT	- Scaling, Limit, Offset, and Transfer Function (See Section 8)
SNM	- 2's Complement Signed Numeric SLOT
SOF	- Start of Frame
UNM	- Unsigned Numeric SLOT
VIN	- Vehicle Identification Number

3. *Terms and Definitions*

3.1 **Data (Data Field)**—Data and data field are used interchangeably in this document and they both refer to a field within a frame that may include bytes with parameters pertaining to the message and/or secondary ID and/or extended addresses and/or test modes which further defines a particular message content being exchanged over the network.

3.2 **Extended Address**—The extended address is a means to allow a message to be addressed to a specific geographical location or zone of the vehicle, independent of any node's physical address.

3.3 **Frame**—A frame is one complete transmission of information which may or may not include an In-Frame Response. The frame is enclosed by the start of frame and end of frame symbols. For Class B networks, each frame contains one and only one message (see "message" definition below).

3.4 **Frame ID**—The Frame ID is the header byte for the Single Byte Header format and the one byte form of the Consolidated header format. The definition of the frame ID is found in SAE J2178/3. This header byte defines the target and source and content of the frame.

3.5 **Functional Addressing**—Functional addressing allows a message to be addressed or sent to one or more nodes on the network interested in that function. Functional addressing is intended for messages that may be of interest to more than a single node. For example, an exterior lamp "off" message could be sent to all nodes controlling the vehicle exterior lamps by using a functional address. The functional address consists of a primary ID and may include a secondary ID and may also include an extended address.

3.6 **Header (Header Field)**—The header (or header field, used interchangeably) is a one or three byte field within a frame that contains information about the message priority, message source and target addressing, message type, and in-frame response type.

3.7 **In-Frame Response (IFR) Type**—The IFR type identifies the form of the in-frame response which is expected within that message.

3.8 **Load**—The load command indicates the operation of directly replacing the current/existing value of a parameter with the parameter value(s) contained in the message.

3.9 **Message**—A message consists of all of the bytes of a frame excluding the delimiter symbols (SOF, EOD, EOF, NB).

3.10 **Modify**—The modify command indicates the operation of using the message data parameter value to change (e.g., increment, decrement, or toggle) the current/existing value.

3.11 **Parameter**—A parameter is the variable quantity included in some messages. The parameter value, scaling, offset, units, transfer function, etc., are unique to each particular message. (The assigned parameters are contained herein.)

3.12 **Physical Addressing**—Physical addressing allows a message to be addressed to a specific node or to all nodes or to a non-existent, null node. The information in this message is of relevance only to a particular node, so the other nodes on the bus should ignore the message, except for the case of the "all nodes" address.

3.13 **Primary ID**—The primary ID identifies the target for this functional message. This is the primary discriminator used to group functions into main categories.

3.14 **Priority**—The priority describes the rank order and precedence of a message. Based upon the SAE J1850, Class B arbitration process, the message with the highest priority will win arbitration.

3.15 **Report**—A report indicates the transmission of parametric data values, based on: a change of state; a change of value; on a periodic rate basis; or as a response to a specific request.

3.16 **Request**—A request is a command to, or a query for data, or action from another node on the network.

3.17 **Response Data**—The response data is the information from a node on the network in response to a request from another node on the network. This may be an in-frame response or a report type of message.

3.18 **Secondary ID**—The secondary ID (along with the primary ID or Frame ID) identifies the functional target node for a message. The purpose of the secondary ID field within the frame is to further define the function or action being identified by the primary ID.

4. *General Information*—The messages defined by this four part document are specified for networks using one byte headers or consolidated one and three byte headers as specified in SAE J1850. This part focuses on the message definition for the three byte form of the consolidated header format. Section 5 consists of the list of functional target addresses for all of the functionally addressed SAE J1850 messages except Type #3, Function Read. The SAE J1850 Type #3 messages have a separate address assignment because this message type does not support any secondary addressing. Functional target addresses (Primary IDs) are shown in Section 5 and secondary message definitions are shown in Section 7. Section 6 shows the valid extended address assignments which are referenced in the message definition tables.

The information in the header field contains target, source, priority and message type information, while the data field contains additional addressing and parametric information. This information is explicitly defined in some headers and implicitly defined in others. Messages can be classified generally into two types:

a. Requests, that is, commands (load or modify) or queries for data, and

b. Responses, that is, reports or acknowledgements.

When a node generates a request, the target node(s) which is/are responsible for the requested data or function must respond by sending the requested information or by performing the requested function. For responses (that is, reports or acknowledgements), data information that a node responds with may be requested by another node, or reported by the node when the desired information has changed, or reported by the node on a periodic basis.

This document defines a great number of specific messages which are expected to have wide application. Designers are required to use the defined messages on SAE J1850 networks in the exact way that they are defined here. There are a large number of message codes which are reserved for each manufacturer to define. If the user cannot find a needed message, he or she is expected to define a manufacturer specific message in these reserved codes. Therefore, messages on different manufacturer's products using these "Manufacturer Reserved" codes will have meaning only for that manufacturer or specific vehicle. These will most likely be different between manufacturers. The codes that are defined here, however, shall always carry the same meaning from one manufacturer to another and from one model and year to the next.

5. *Functional Target Address Assignments (Primary ID)*—Primary IDs are used to address a generic function. The second byte of the three byte header contains this primary ID. Each target function has a separate ID for command and status messages. The command ID is used to control a function while the status ID is used to report a condition or report that a command has been executed. Each primary ID pair then contains a secondary address, optional geographical extended address, and optional parametric data. Table 1 below lists the primary ID assignments, command and status, and a description. Those IDs labeled as "Reserved - SAE" are reserved for the SAE to define at a later time while those labeled "Reserved - MFG" are left for the individual manufacturers to use.

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TABLE 1—PRIMARY ID ASSIGNMENTS
BYTE 2 OF MESSAGE TYPES 0, 1, 2, 5, 8, 9, 10, 11

Command	Status	Function
0	0	Reserved - SAE
1	1	Reserved - MFG
2	2	Reserved - MFG
3	3	Reserved - MFG
4	4	Engine Torque
5	5	Engine Air Intake
6	6	Reserved - MFG
7	7	Reserved - MFG
8	8	Reserved - SAE
9	9	Throttle
10	A	A/C Clutch
11	B	Reserved - MFG
12	C	Reserved - MFG
13	D	Engine RPM
14	E	Reserved - MFG
15	F	Reserved - MFG
16	10	Reserved - SAE
17	11	Reserved - MFG
18	12	Wheels
19	13	Reserved - MFG
20	14	Vehicle Speed
21	15	Traction Control
22	16	Reserved - MFG
23	17	Reserved - MFG
24	18	Reserved - SAE
25	19	Brakes
26	1A	Steering / Steering Wheel
27	1B	Reserved - SAE
28	1C	Reserved - MFG
29	1D	Transmission / Transaxle / PRNDL
30	1E	Reserved - MFG
31	1F	Reserved - MFG
32	20	Reserved - SAE
33	21	Reserved - MFG
34	22	Reserved - MFG
35	23	Engine Sensors
36	24	Engine Coolant

TABLE 1—PRIMARY ID ASSIGNMENTS
BYTE 2 OF MESSAGE TYPES 0, 1, 2, 5, 8, 9, 10, 11 (CONTINUED)

Command	Status	Function
37	25	Engine Oil
38	26	Reserved - MFG
39	27	Reserved - MFG
40	28	Reserved - SAE
41	29	Engine Systems Other
42	2A	Reserved - MFG
43	2B	Reserved - SAE
44	2C	Suspension
45	2D	Non-Legislated Diagnostics
46	2E	Reserved - MFG
47	2F	Reserved - MFG
48	30	Reserved - SAE
49	31	Vehicle Speed Control
50	32	Reserved - MFG
51	33	Reserved - SAE
52	34	Reserved - MFG
53	35	Legislated Diagnostics
54	36	Reserved - MFG
55	37	Reserved - MFG
56	38	Reserved - SAE
57	39	Charging System
58	3A	Electrical Energy Management
59	3B	Reserved - SAE
60	3C	Reserved - MFG
61	3D	Odometer
62	3E	Reserved - MFG
63	3F	Reserved - MFG
64	40	Reserved - SAE
65	41	Fuel System
66	42	Vehicle Motion
67	43	Ignition Switch / Starter
68	44	Tell Tales
69	45	Reserved - MFG
70	46	Reserved - MFG
71	47	Reserved - MFG
72	48	Reserved - SAE
73	49	Vehicle Security
74	4A	Audio Control
75	4B	Audible Warnings
76	4C	Reserved - MFG
77	4D	Compact Disc
78	4E	Reserved - MFG
79	4F	Reserved - MFG

continued

TABLE 1—PRIMARY ID ASSIGNMENTS
BYTE 2 OF MESSAGE TYPES 0, 1, 2, 5, 8, 9, 10, 11 (CONTINUATION)

Command	Status	Function
80	50	Reserved - SAE
81	51	Digital Audio Tape
82	52	Audio Tuner / Receiver
83	53	Cassette Tape
84	54	Reserved - MFG
85	55	Reserved - MFG
86	56	Reserved - SAE
87	57	Climate Control (HVAC)
88	58	Reserved - MFG
89	59	Reserved - SAE
90	5A	Window Wiper / Washer
91	5B	Reserved - MFG
92	5C	Reserved - MFG
93	5D	Reserved - MFG
94	5E	Reserved - SAE
95	5F	Mirrors
96	60	Door Locks
97	61	External Access
98	62	Seat Motion / Control
99	63	Windows
100	64	Steering Column
101	65	Reserved - MFG
102	66	Seat Switches
103	67	Restraints
104	68	Reserved - MFG
105	69	Reserved - MFG
106	6A	External Lamp Outage
107	6B	External Lamps
108	6C	Interior Lamp Outage
109	6D	Interior Lamps
110	6E	Reserved - SAE
111	6F	Reserved - MFG
112	70	Tires
113	71	Electric Defrost
114	72	Navigation
115	73	Displays
116	74	Reserved - MFG
117	75	Reserved - MFG
118	76	Reserved - SAE
119	77	Exterior Environment
120	78	Interior Environment
121	79	Reserved - SAE
122	7A	Time
123	7B	Vehicle ID (VIN)
124	7C	Reserved - MFG
125	7D	Network Control

8. Function Read Target Address Assignments—Function Read IDs are used to address a specific function in a type 3 message. The second byte of the three byte header contains this function read ID. In a type 3 message (Function Read) the data is returned to the transmitting node in the In-Frame Response (IFR) portion of the message. The data returned is identified by a Parameter Reference Number (PRN). Table 2 lists the function read ID assignments, description, and PRN. Those IDs labeled as "Reserved - SAE" are reserved for the SAE to define at a later time while those labeled "Reserved - MFG" are left for the individual manufacturers to use.

TABLE 2—FUNCTION READ ID ASSIGNMENTS
BYTE 2 OF MESSAGE TYPE 3

ID	Function
00 - 0F	Reserved - MFG
10 - 1F	Reserved - SAE
20 - 2F	Reserved - MFG
30 - 3F	Reserved - SAE
40 - 4F	Reserved - MFG
50 - 5F	Reserved - SAE
60 - 6F	Reserved - MFG
70 - 7F	Reserved - SAE
FC - FF	Reserved - MFG

9. Message Assignments—The following tables contain the message assignments associated with the primary IDs for message types 0, 1, 2, 5, 8, 9, 10, and 11. A separate table is included for each primary ID pair that has at least one secondary ID currently defined. Table 3 is an example of how to interpret the tables to follow.

TABLE 3--EXAMPLE OF MESSAGE TABLES TO FOLLOW

Secondary ID Name	Sec ID	Msg Op	Q	C	Ext Addr	PRN
Secondary ID Name #1	xx	?	?	?	?	?
Secondary ID Name #2	xx	?	?	?	?	?
...	...	...	...	...	...	...
Secondary ID Name #n	xx	?	?	?	?	?

Each primary ID pair can have up to 64 secondary IDs. If a secondary ID is not defined here, it is assumed to be manufacturer specific. Future definitions of secondary IDs can be brought to the attention of the SAE J2178 task force and if all manufacturers agree, a new secondary ID can be defined. Following each secondary ID name is the 6-bit hexadecimal secondary ID. The secondary ID byte is made up of the Q bit (bit 7), C bit (bit 6), and 6-bit ID as listed in the table. Following the secondary ID is the message operation column. Up to three operations can be defined for any secondary ID. Table 4 lists the valid message operations and the appropriate primary ID (i.e., command or status) and C bit definitions for the operation.

TABLE 4--MESSAGE OPERATIONS

Operation	Msg Op	Primary ID	C-bit (bit 6)
Report Data	R	Status	0
Load Data	L	Command	0
Modify State	M	Command	1

Each secondary ID can support one or more of the operations listed above. Typically, a secondary ID will support report data only (R), report and load data (L / R), or report data, load data, and modify state (L / R / M). The other combinations are very unlikely.

Following the operation column is Q bit usage. Each secondary ID will have an entry under Q bit = "1" and Q bit = "0" indicating how the Q bit (bit 7) is used in the message. Table 5 lists the valid options.

TABLE 5--Q BIT DEFINITIONS

Q bit = "1"	Q bit = "0"	Meaning
-	-	Q bit not used. Defaults to logic "0"
#	-	Q bit not used. Defaults to logic "1"
Set	-	Q bit must be logic "1" and means Set
E	D	Enable(d) / Disable(d)
Inc	Dec	Increment / Decrement
O	C	Open(ed) / Close(d)
L	U	Lock(ed) / Unlock(ed)
On	Off	On / Off
R	-R	Reset / Not Reset
Y	N	Yes / No

The next column after the Q bit definitions is the Extended Address column. If extended addressing is used for a particular secondary ID, the paragraph number (in Section 8) which defines the valid extended addresses is listed. Otherwise, "-" is found.

The final column is used for those secondary IDs which contain data (e.g., coolant temperature, vehicle speed, etc.) that cannot be encoded in the Q bit (i.e., non-boolean). The PRN number is essentially a lookup into SAE J2178/2 where the complete data encoding, size, resolution, etc., can be found.

The specific message tables can be found as follows:

Table 6 - Engine Torque
Table 7 - Engine Air Intake
Table 8 - Throttle
Table 9 - Air Conditioning Clutch
Table 10 - Engine RPM
Table 11 - Wheels
Table 12 - Vehicle Speed
Table 13 - Traction Control
Table 14 - Brakes
Table 15 - Steering / Steering Wheel
Table 16 - Transmission / Transaxle / PRNDL
Table 17 - Engine Sensors - Other
Table 18 - Engine Coolant
Table 19 - Engine Oil
Table 20 - Engine Systems - Other
Table 21 - Suspension
Table 22 - Vehicle Speed Control
Table 23 - Charging System
Table 24 - Electrical Energy Management
Table 25 - Odometer
Table 26 - Fuel System
Table 27 - Ignition Switch / Starter
Table 28 - Tell Tales
Table 29 - Climate Control (HVAC)
Table 30 - Window Wiper / Washer
Table 31 - Mirrors
Table 32 - Door Locks
Table 33 - External Access
Table 34 - Seat Motion / Control
Table 35 - Windows
Table 36 - Steering Column
Table 37 - Seat Switches
Table 38 - Restraints
Table 39 - Exterior Lamps Outage
Table 40 - Exterior Lamps
Table 41 - Interior Lamps Outage
Table 42 - Interior Lamps
Table 43 - Tires
Table 44 - Defrost
Table 45 - Displays
Table 46 - Exterior Environment
Table 47 - Interior Environment
Table 48 - Time / Date
Table 49 - Vehicle Identification
Table 50 - Network Control

7.1 Engine Torque—(See Table 6.)
Primary ID: Engine Torque
Command ID: $38
Status ID: $09

7.2 Engine Air Intake—(See Table 7.)
Primary ID: Engine Air Intake
Command ID: $0A
Status ID: $0B

7.3 Throttle—(See Table 8.)
Primary ID: Throttle
Command ID: $12
Status ID: $13

7.4 Air Conditioning Clutch—(See Table 9.)
Primary ID: Air Conditioning Clutch
Command ID: $14
Status ID: $15

7.5 Engine RPM—(See Table 10.)
Primary ID: Engine RPM
Command ID: $1A
Status ID: $1B

TABLE 6--ENGINE TORQUE MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	PRN
Crankshaft Torque - Percent	01	L / R	-	#	-	1020
Crankshaft Torque - Absolute	02	L / R	-	#	-	1019
Maximum Crankshaft Torque	10	R	-	#	-	1009

7.6 Wheels—(See Table 11.)
Primary ID: Wheels
Command ID: $26
Status ID: $25
7.7 Vehicle Speed—(See Table 12.)
Primary ID: Vehicle Speed
Command ID: $28
Status ID: $29

7.8 Traction Control—(See Table 13.)
Primary ID: Traction Control
Command ID: $2A
Status ID: $2B
7.9 Brakes—(See Table 14.)
Primary ID: Brakes
Command ID: $32
Status ID: $33

TABLE 7—ENGINE AIR INTAKE MESSAGES

Parameter ID Name	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Boost On / Off	0	1/16	0	0	-	-	-	-
Boost Value	1	x	-	x	-	-	-	-
Mass Air Flow Rate	2	x	-	x	-	-	0.03	-
Manifold Absolute Pressure	3	x	-	x	-	-	0.03	-
Intake Air Temperature	4	x	-	x	-	-	1	-

TABLE 8—THROTTLE MESSAGES

Parameter ID Name	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Sensor 1 Position	0	x	-	x	-	-	0.03	-
Sensor 2 Position	1	x	-	x	-	-	0.03	-
Sensor 3 Position	2	x	-	x	-	-	0.03	-
Throttle Status	3	1/16	x	0	-	-	-	-
Pedal Position	4	x	-	x	-	-	0.4	-

TABLE 9—AIR CONDITIONING CLUTCH MESSAGES

Parameter ID Name	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Enable	0	1/16	x	0	-	-	-	-
Enable Pending	1	1/16	Y	x	-	-	-	-
Load	2	x	-	x	-	-	0.4	-
Request	3	1/16	Y	x	-	-	-	-

TABLE 10—ENGINE RPM MESSAGES

Parameter ID Name	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Low Resolution	0	x	-	x	-	-	0.25	-
High Resolution	1	x	-	x	-	-	0.125	-
Idle Speed	2	1/16	x	0	-	-	10	-

TABLE 11—WHEELS MESSAGES

Parameter ID Name	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Wheel Speed - Low Resolution	0	x	-	x	x	-	0.25	-
Wheel Slip	1	x	-	x	x	-	0.125	-
Wheel Load	2	x	-	x	x	-	0.125	-
Wheel Speed - High Resolution	3	x	-	x	x	-	0.05	-

TABLE 12—VEHICLE SPEED MESSAGES

Parameter ID Name	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Low Resolution	0	x	-	x	-	-	0.25	-
High Resolution	1	x	-	x	-	-	0.05	-

TABLE 13—TRACTION CONTROL MESSAGES

Parameter ID Name	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
Engine Traction Active	0	x	Y	x	-	-	-	-
Brake Traction Active	1	x	Y	x	-	-	-	-
Traction On/Off	2	1/16	0	x	-	-	-	-
Traction Active	3	x	Y	x	-	-	-	-
Traction Faulted	4	x	Y	x	-	-	-	-
Traction Engine Rel. Active	5	x	Y	x	-	-	-	-

TABLE 14—BRAKES MESSAGES

Parameter ID Name	Byte 1	Byte 2	Byte 3	Byte 4	Byte 5	Byte 6	Byte 7	Byte 8
ABS Active	0	x	Y	x	-	-	-	-
ABS Switch On / Off	1	1/16	0	x	-	-	-	-
Fluid Low Sense	2	1/16	x	x	-	-	-	-
Brakes Faulted	3	x	Y	x	-	-	-	-
Fluid Temperature	4	x	-	x	-	-	1	-40
Middle Pump Fluid Pressure	5	x	-	x	-	-	0.03	-
Fluid Level - Percent	6	x	-	x	-	-	0.4	-
Fluid Level - Volume	7	x	-	x	-	-	0.4	-
Fluid Remaining Life	8	x	-	x	-	-	0.4	-
Fluid Capacity	9	x	-	x	-	-	0.4	-
Parking Brake Rel. Active	10	x	Y	x	-	-	-	-
Trailer Connected Status	11	x	Y	x	-	-	-	-
Brake Rel. Active	12	x	Y	x	-	-	-	-
Brake Lamp - Brake Rel. Active	13	x	Y	x	-	-	-	-
ABS Lite Power Rel. Active	14	x	Y	x	-	-	-	-

7.10 Steering / Steering Wheel—(See Table 15.)
Primary ID: Steering / Steering Wheel
Command ID: $34
Status ID: $35
7.11 Transmission / Transaxle / PRNDL—(See Table 16.)
Primary ID: Transmission / PRNDL
Command ID: $3A
Status ID: $3B
7.12 Engine Sensors - Other—(See Table 17.)
Primary ID: Engine Sensors - Other
Command ID: $46
Status ID: $47
7.13 Engine Coolant—(See Table 18.)
Primary ID: Engine Coolant
Command ID: $48
Status ID: $49
7.14 Engine Oil—(See Table 19.)
Primary ID: Engine Oil
Command ID: $4A
Status ID: $4B

TABLE 15 - STEERING / STEERING WHEEL MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	PGN
Fluid Life Reset	26	L/R	R	-R	-	-
Fluid Temperature	10	R	-	-	-	3006
Fluid Pressure	11	R	-	-	-	3007
Fluid Level - Percent	12	R	-	-	-	3008
Fluid Level - Volume	13	R	-	-	-	3009
Fluid Remaining Life	14	R	-	-	-	3010
Fluid Capacity	15	R	-	-	-	3011
Steering Wheel Angle	16	R	-	-	-	3012
Steering Wheel Rate	17	R	-	-	-	3013
Steering Wheel Torque	1A	R	-	-	-	3014
Wheel Steer Angle	20	R	-	-	81	3008
Fluid Life Reset Svc. Active	29	R	Y	N	-	-

TABLE 16 - TRANSMISSION / PRNDL MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	PGN
Torque Converter Lock(ed)	01	L/R	Y	N	-	-
Clutch Enable	02	L/R	E	D	-	-
Actual Gear Position w/ Shift in Progress	03	R	Y	N	-	1806
Range Selected (PRNDL position)	04	R	-	-	-	1808
Transfer Case (4WD)	05	R	-	-	-	1804
Commanded Gear	06	L/R	-	-	-	1805
Range Actual (PRNDL sensed at transmission)	07	R	-	-	-	1806
Transmission Kickdown	08	L/R	Y	N	-	-
Fluid Life Reset	09	L/R	R	-R	-	-
Fluid Temperature	10	R	-	-	-	1800
Fluid Pressure	11	R	-	-	-	1800
Fluid Level - Percent	12	R	-	-	-	1801
Fluid Level - Volume	13	R	-	-	-	1802
Fluid Remaining Life	14	R	-	-	-	1804
Fluid Capacity	15	R	-	-	-	1803
Park / Neutral Svc. Active	28	R	Y	N	-	-
Fluid Life Reset Svc. Active	29	R	Y	N	-	-

TABLE 17 - ENGINE SENSORS - OTHER MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	PGN
Converter Bank 1, Sensor 1 Heater	01	L/R	On	Off	-	-
Converter Bank 1, Sensor 2 Heater	02	L/R	On	Off	-	-
Converter Bank 2, Sensor 1 Heater	03	L/R	On	Off	-	-
Converter Bank 2, Sensor 2 Heater	04	L/R	On	Off	-	-
Converter Bank 1, Sensor 1 Temperature	11	R	-	-	-	1027
Converter Bank 1, Sensor 2 Temperature	12	R	-	-	-	1028
Converter Bank 2, Sensor 1 Temperature	13	R	-	-	-	1029
Converter Bank 2, Sensor 2 Temperature	14	R	-	-	-	1030

TABLE 18 - ENGINE COOLANT MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	PGN
Fan 1 Speed	01	L/R	On	Off	-	1024
Fan 2 Speed	02	L/R	On	Off	-	1026
Fan 1 Clutch	06	L/R	E	D	-	-
Fan 2 Clutch	07	L/R	E	D	-	-
Fluid Life Reset	09	L/R	R	-R	-	-
Fluid Temperature	10	R	-	-	-	0005
Fluid Pressure	11	R	-	-	-	1029
Fluid Level - Percent	12	R	-	-	-	1029
Fluid Level - Volume	13	R	-	-	-	1029
Fluid Remaining Life	14	R	-	-	-	1029
Fluid Capacity	15	R	-	-	-	1029
Fluid Life Reset Svc. Active	29	R	Y	N	-	-
Fluid Temperature High	30	R	Y	N	-	-
Low Coolant Level	32	R	Y	N	-	-

7.15 Engine Systems - Other—(See Table 20.)
Primary ID: Engine Systems - Other
Command ID: $52
Status ID: $53
7.16 Suspension—(See Table 21.)
Primary ID: Suspension
Command ID: $58
Status ID: $59
7.17 Vehicle Speed Control—(See Table 22.)
Primary ID: Vehicle Speed Control
Command ID: $62
Status ID: $63
7.18 Charging System—(See Table 23.)
Primary ID: Charging System
Command ID: $72
Status ID: $73

TABLE 19—ENGINE OIL MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q6	Ext Addr	Page
Fluid Life Reset	00	L/R	R	-R	-	-
Fluid Temperature	10	R	-	x	-	1008
Fluid Pressure	11	R	-	x	-	1009
Fluid Level - Percent	12	R	-	x	-	1010
Fluid Level - Volume	13	R	-	x	-	1010
Fluid Remaining Life	14	R	-	x	-	1006
Oil Viscosity	15	R	-	x	-	1004
Fluid Capacity	16	R	-	x	-	1005
Fluid Life Reset Svc. Active	20	R	Y	R	-	-
Fluid Temperature High	30	R	Y	x	-	-
Low Oil Level	35	R	Y	x	-	-

TABLE 20—ENGINE SYSTEMS—OTHER MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q6	Ext Addr	Page
Engine Redline - Low Resolution	01	R	-	x	-	1048
Number Engine Cylinders	02	R	-	x	-	1046
Number Valves / Cylinder	03	R	-	x	-	1047
Engine Running	04	R	Y	R	-	-
Engine Displacement	05	R	-	x	-	1045
Engine Redline - High Resolution	06	R	-	x	-	1049
Engine Accelerating	20	R	Y	R	-	-

TABLE 21—SUSPENSION MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q6	Ext Addr	Page
Ride Setting	01	L/R	-	x	-	1054
Fluid Life Reset	00	L/R	R	-R	-	-
System Faulted	04	R	Y	R	-	-
Fluid Temperature	10	R	-	x	-	1008
Fluid Pressure	11	R	-	x	-	1009
Fluid Level - Percent	12	R	-	x	-	1010
Fluid Level - Volume	13	R	-	x	-	1010
Fluid Remaining Life	14	R	-	x	-	1006
Fluid Capacity	16	R	-	x	-	-
Fluid Life Reset Svc. Active	20	R	Y	R	-	-

TABLE 22—VEHICLE SPEED CONTROL MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q6	Ext Addr	Page
System On / Off	01	L/R	On	Off	-	-
Set Speed	02	L/R	R	0	-	2013
Coast Mode	03	L/R	R	0	-	-
Resume Mode	04	L/R	R	0	-	-
Accelerate Mode	05	L/R	R	0	-	-
Speed Control Active	06	R	Y	R	-	-
On / Off Svc. Active	21	R	Y	R	-	-
Set Speed Svc. Active	22	R	Y	R	-	-
Coast Svc. Active	23	R	Y	R	-	-
Resume Svc. Active	24	R	Y	R	-	-
Accelerate Svc. Active	25	R	Y	R	-	-

TABLE 23—CHARGING SYSTEM MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q6	Ext Addr	Page
Charging Voltage	01	R	-	x	-	6030
Charging Current	02	R	-	x	-	6031
Battery Voltage	03	R	-	x	-	6032
Battery Current	04	R	-	x	-	6033
Battery Temperature	05	R	-	x	-	-
Charging System Faulted	01	R	Y	R	-	-

7.19 Electrical Energy Management—(See Table 24.)
Primary ID: Electrical Energy Management
Command ID: $74
Status ID: $75

7.20 Odometer—(See Table 25.)
Primary ID: Odometer
Command ID: $7A
Status ID: $7B

7.21 Fuel System—(See Table 26.)
Primary ID: Fuel System
Command ID: $82
Status ID: $83

7.22 Ignition Switch / Starter—(See Table 27.)
Primary ID: Ignition Switch / Starter
Command ID: $86
Status ID: $87

7.23 Tell Tales—(See Table 28.)
Primary ID: Tell Tales
Command ID: $88
Status ID: $89

TABLE 24—ELECTRICAL ENERGY MANAGEMENT MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q2	Ext Addr	PRN
Delayed Accessory	01	L/R	C	C	-	-
Short Term Storage	02	L/R	C	C	-	-
Long Term Storage	03	L/R	C	C	-	-

TABLE 25—ODOMETER MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q2	Ext Addr	PRN
Vehicle Odometer	01	R	-	x	-	8004
Trip Reset	02	L/R	R	R	-	-
Trip Odometer	04	R	-	x	-	8008
Trip Reset Svc. Active	20	R	Y	R	-	-

TABLE 26—FUEL SYSTEM MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q2	Ext Addr	PRN
Average Fuel Economy	01	R	-	x	-	8009
Instant. Fuel Economy	02	R	-	x	-	800A
Average Fuel Economy Reset	03	L/R	R	R	-	-
Fuel Used - Percent	06	R	-	x	-	800B
Fuel Used - Volume	05	R	-	x	-	800C
Fuel Used Reset	06	L/R	R	R	-	-
Fuel Temperature	10	R	-	x	-	1044
Fuel Pressure	11	R	-	x	-	800A
Fuel Level - Percent	12	R	-	x	-	8005
Fuel Level - Volume	13	R	-	x	-	8006
Fuel Capacity	15	R	-	x	-	8007
Fuel Pump Low Speed	18	L/R	R	R	-	-
Fuel Pump High Speed	19	L/R	R	R	-	-
Fuel Economy Reset Svc. Active	20	R	Y	R	-	-
Fuel Used Reset Svc. Active	25	R	Y	R	-	-
Low Fuel Level	30	R	Y	R	-	-

TABLE 27—IGNITION SWITCH / STARTER MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q2	Ext Addr	PRN
Ignition Switch Position	04	R	-	x	-	1047
Key in Ignition	06	R	Y	R	-	-

TABLE 28—TELL TALES MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q2	Ext Addr	PRN
Seatbelt	01	L/R	Q	Q	-	-
Service Engine Soon	02	L/R	Q	Q	-	-
Check Engine (MIL)	03	L/R	Q	Q	-	-
High Beam Indicator	04	L/R	Q	Q	-	-
Left Turn Indicator	05	L/R	Q	Q	-	-
Right Turn Indicator	06	L/R	Q	Q	-	-
Airbag	07	L/R	Q	Q	-	-
Anti-Lock Brake System Failed	08	L/R	Q	Q	-	-
Traction Control System Failed	09	L/R	Q	Q	-	-
Security	0A	L/R	Q	Q	-	-
Low Fuel	0B	L/R	Q	Q	-	-
Low Coolant	0C	L/R	Q	Q	-	-
Low Oil	0D	L/R	Q	Q	-	-
Low Voltage	0E	L/R	Q	Q	-	-
Ignition	0F	L/R	Q	Q	-	-
Low Washer Fluid	10	L/R	Q	Q	-	-
Traction Control Active	11	L/R	Q	Q	-	-
Alternator Failure	12	L/R	Q	Q	-	-
Low Brake Fluid	13	L/R	Q	Q	-	-
Overdrive	14	L/R	Q	Q	-	-
Traction Control Disabled	15	L/R	Q	Q	-	-
Convertible Latch Warning	21	L/R	Q	Q	-	-
Steer Lock System Warning	22	L/R	Q	Q	-	-
Catalyst Overtemperature	23	L/R	Q	Q	-	-
Vehicle Speed Control	24	L/R	Q	Q	-	-

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7.24 Climate Control (HVAC) —(See Table 29.)
Primary ID: Climate Control (HVAC)
Command ID: $B2
Status ID: $B3

7.25 Window Wiper / Washer —(See Table 30.)
Primary ID: Window Wiper / Washer
Command ID: $B8
Status ID: $B9

7.26 Mirrors—(See Table 31.)
Primary ID: Mirrors
Command ID: $C2
Status ID: $C3

7.27 Door Locks—(See Table 32.)
Primary ID: Door Locks
Command ID: $C4
Status ID: $C5

7.28 External Access—(See Table 33.)
Primary ID: External Access
Command ID: $C6

STATUS ID: $C7

TABLE 29—CLIMATE CONTROL (HVAC) MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q2	Ext Addr	PRN
Blower Fan Speed	02	L / R	–	X	–	–
Multi-Zone Mode	06	L / R	E	D	–	–
Low Refrigerant	07	R	Y	N	–	–
Fluid Life Reset	09	L / R	R	-R	–	–
HVAC Sat Temperature	0A	L / R	–	X	8.3	9B20
		M	Inc	Dec		–
High Side Fluid Temperature	10	R	–	X	–	9B06
High Side Fluid Pressure	11	R	–	X	–	9B13
Fluid Charge - Percent	12	R	–	X	–	9B0B
Fluid Charge - Weight	13	R	–	X	–	9B0C
Fluid Remaining Life	14	R	–	X	–	9B0D
Fluid Capacity - Weight	16	R	–	X	–	9B0E
Low Side Fluid Temperature	20	R	–	X	–	9B0B
Low Side Fluid Pressure	21	R	–	X	–	9B0A
Fan Increment Speed Sw. Active	22	R	Y	N	–	–
Fan Decrement Speed Sw. Active	23	R	Y	N	–	–
Multi-Zone Mode Sw. Active	28	R	Y	N	–	–
Fluid Life Reset Sw. Active	29	R	Y	N	–	–
Increment Temp Sw. Active	2A	R	Y	N	–	–
Decrement Temp Sw. Active	2B	R	Y	N	–	–

TABLE 30—WINDOW WIPER / WASHER MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q2	Ext Addr	PRN
Wiper Mode	01	L / R	–	X	8.3	A003
Washer On / Off	02	L / R	On	Off	8.3	–
Wiper Delay	03	L / R	E	D	8.3	A004
Wiper Pulse	04	L / R	E	D	8.3	–
Fluid Temperature	10	R	–	X	8.3	A006
Fluid Pressure	11	R	–	X	8.3	A007
Fluid Level - Percent	12	R	–	X	8.3	A008
Fluid Level - Volume	13	R	–	X	8.3	A009
Fluid Capacity	16	R	–	X	8.3	A00A
Washer On/Off Sw. Active	22	R	Y	N	8.3	–
Wiper Pulse Sw. Active	24	R	Y	N	8.3	–

TABLE 31—MIRRORS MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q2	Ext Addr	PRN
Up Motion	01	L / R	E	D	8.4	–
Down Motion	02	L / R	E	D	8.4	–
Right Motion	03	L / R	E	D	8.4	–
Left Motion	04	L / R	E	D	8.4	–
Retract Motion	05	L / R	E	D	8.4	–
Extend Motion	06	L / R	E	D	8.4	–
Horizontal Position	10	L / R	–	X	8.4	A00D
Vertical Position	11	L / R	–	X	8.4	A00E
Heater On / Off	17	L / R	On	Off	8.4	–
Nighttime On / Off	18	R	On	Off	8.4	–
Dimming Level	19	L / R	–	X	8.4	A00C
Up Sw. Active	21	R	Y	N	8.4	–
Down Sw. Active	22	R	Y	N	8.4	–
Right Sw. Active	23	R	Y	N	8.4	–
Left Sw. Active	24	R	Y	N	8.4	–
Retract Sw. Active	25	R	Y	N	8.4	–
Extend Sw. Active	26	R	Y	N	8.4	–
Heater Sw. Active	27	R	Y	N	8.4	–

7.29 Seat Motion / Control—(See Table 34.)
Primary ID: Seat Motion / Control
Command ID: $C8
Status ID: $C9
7.30 Windows—(See Table 35.)
Primary ID: Windows
Command ID: $CA
Status ID: $CB
7.31 Steering Column—(See Table 36.)
Primary ID: Steering Column
Command ID: $CC
Status ID: $CD
7.32 Seat Switches—(See Table 37.)
Primary ID: Seat Switches
Command ID: $D0
Status ID: $D1
7.33 Restraints—(See Table 38.)
Primary ID: Restraints
Command ID: $D2
Status ID: $D3

TABLE 33 - DOOR LOCKS MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	PRN
Lock	01	L/R	L	U	8.5	-
Unlock Enable	02	L/R	E	D	8.5	-
Lock Cylinder Secure	03	R	Y	N	8.5	-
Key in Lock Cylinder	04	R	Y	N	8.5	-
Master Controller Lock	05	L/R	L	N	8.5	-
Lock Cylinder State	06	R	-	x	8.5	ADD
Super / Double Lock	07	L/R	L	U	8.5	-
Remote Lock w/ Transmitter ID	08	L/R	L	U	8.5	CDD
Remote Lock	09	L/R	L	U	8.5	-
Lock Svc. Active	20	R	Y	N	8.5	-
Unlock Svc. Active	21	R	Y	N	8.5	-
Unlock Enable Svc. Active	22	R	Y	N	8.5	-
Master Controller Lock Svc. Active	23	R	Y	N	8.5	-
Master Controller Unlock Svc. Active	24	R	Y	N	8.5	-

TABLE 34 - EXTERNAL ACCESS MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	PRN
Open	01	L/R	Y	N	8.5	-
Close	02	L/R	Y	N	8.5	-
Remote Open / Close w/ Transmitter ID	11	L/R	O	C	8.5	CDD
Remote Open / Close	12	L/R	O	C	8.5	-
Ajar Svc. Active	20	R	Y	N	8.5	-
Door Handle Svc. Active	22	R	Y	N	8.5	-
Door Jamb Svc. Active	23	R	Y	N	8.5	-

TABLE 35 - SEAT MOTION / CONTROL MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	PRN
Horiz. Forward Motion	01	L/R	E	D	8.6	-
Horiz. Rearward Motion	02	L/R	E	D	8.6	-
Vert. Up Motion	03	L/R	E	D	8.6	-
Vert. Down Motion	04	L/R	E	D	8.6	-
Front Vert. Up Motion	05	L/R	E	D	8.6	-
Front Vert. Down Motion	06	L/R	E	D	8.6	-
Rear Vert. Up Motion	07	L/R	E	D	8.6	-
Rear Vert. Down Motion	08	L/R	E	D	8.6	-
Recline Forward Motion	09	L/R	E	D	8.6	-
Recline Rearward Motion	0A	L/R	E	D	8.6	-
Lumbar Up Motion	0B	L/R	E	D	8.6	-
Lumbar Down Motion	0C	L/R	E	D	8.6	-
Lumbar In Motion	0D	L/R	E	D	8.6	-
Lumbar Out Motion	0E	L/R	E	D	8.6	-
Headrest Up Motion	0F	L/R	E	D	8.6	-
Headrest Down Motion	10	L/R	E	D	8.6	-
Heater On / Off	11	L/R	O	Off	8.6	-
Heater Temperature	12	L/R	-	x	8.6	ADD
		M	%	Dec		
Occupied	13	R	Y	x	8.6	-
Upper Bolster In Motion	14	L/R	E	D	8.6	-
Upper Bolster Out Motion	15	L/R	E	D	8.6	-
Lower Bolster In Motion	16	L/R	E	D	8.6	-
Lower Bolster Out Motion	17	L/R	E	D	8.6	-

TABLE 36 - WINDOWS MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	PRN
Open	01	L/R	E	D	8.7	-
Close	02	L/R	E	D	8.7	-
Operation Enable	03	L/R	E	D	8.7	-
Master Controller Open	04	L/R	E	D	8.7	-
Master Controller Close	05	L/R	E	D	8.7	-
Position	1A	L/R	-	x	8.7	ADD
Open Svc. Active	21	R	Y	N	8.7	-
Close Svc. Active	22	R	Y	N	8.7	-
Lockout Svc. Active	23	R	Y	N	8.7	-
Master Controller Open Svc. Active	24	R	Y	N	8.7	-
Master Controller Close Svc. Active	25	R	Y	N	8.7	-

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TABLE 36—STEERING COLUMN MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	PRN
Up Motion	01	L / R	E	D	–	–
Down Motion	02	L / R	E	D	–	–
In Motion	03	L / R	E	D	–	–
Out Motion	04	L / R	E	D	–	–
Vertical Position	1A	L / R	–	X	–	A012
Horizontal Position	1B	L / R	–	X	–	A011
Up Sw. Active	21	R	Y	N	–	–
Down Sw. Active	22	R	Y	N	–	–
In Sw. Active	23	R	Y	N	–	–
Out Sw. Active	24	R	Y	N	–	–

TABLE 37—SEAT SWITCHES MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	PRN
Horz. Forward Sw. Active	01	R	Y	N	8.5	–
Horz. Rearward Sw. Active	02	R	Y	N	8.5	–
Vert. Up Sw. Active	03	R	Y	N	8.5	–
Vert. Down Sw. Active	04	R	Y	N	8.5	–
Front Vert. Up Sw. Active	05	R	Y	N	8.5	–
Front Vert. Down Sw. Active	06	R	Y	N	8.5	–
Rear Vert. Up Sw. Active	07	R	Y	N	8.5	–
Rear Vert. Down Sw. Active	08	R	Y	N	8.5	–
Recline Forward Sw. Active	09	R	Y	N	8.5	–
Recline Rearward Sw. Active	0A	R	Y	N	8.5	–
Lumbar Up Sw. Active	0B	R	Y	N	8.5	–
Lumbar Down Sw. Active	0C	R	Y	N	8.5	–
Lumbar In Sw. Active	0D	R	Y	N	8.5	–
Lumbar Out Sw. Active	0E	R	Y	N	8.5	–
Headrest Up Sw. Active	0F	R	Y	N	8.5	–
Headrest Down Sw. Active	10	R	Y	N	8.5	–
Heater On / Off Sw. Active	11	R	Y	N	8.5	–
Increment Temp. Sw. Active	12	R	Y	N	8.5	–
Decrement Temp. Sw. Active	13	R	Y	N	8.5	–
Upper Bolster In Sw. Active	14	R	Y	N	8.5	–
Upper Bolster Out Sw. Active	15	R	Y	N	8.5	–
Lower Bolster In Sw. Active	16	R	Y	N	8.5	–
Lower Bolster Out Sw. Active	17	R	Y	N	8.5	–

TABLE 38—RESTRAINTS MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	PRN
Passive Restraint Engaged	01	L / R	Y	N	8.5	–
Passive Restraint Retracted	02	L / R	Y	N	8.5	–
Passive Restraint Attached	03	R	Y	N	8.5	–
Seatbelt Attached	04	R	Y	N	8.5	–
Shoulder Adjustment Up Motion	05	L / R	E	D	8.5	–
Shoulder Adjustment Down Motion	06	L / R	E	D	8.5	–
Air Bag Deployed	07	R	Y	N	8.5	–
Shoulder Position	1A	L / R	–	X	8.5	0801
Shoulder Adjustment Up Sw. Active	25	R	Y	N	8.5	–
Shoulder Adjustment Down Sw. Active	26	R	Y	N	8.5	–

TABLE 39—EXTERIOR LAMPS OUTAGE MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	PRN
Headlamp OK	01	R	Y	N	8.5	–
Tail Lamp OK	02	R	Y	N	8.5	–
Brake Lamp OK	03	R	Y	N	8.5	–
Park Lamp OK	04	R	Y	N	8.5	–
Turn Lamp OK	05	R	Y	N	8.5	–
High Beam Lamp OK	06	R	Y	N	8.5	–
Hazard Lamp OK	07	R	Y	N	8.5	–
Reverse Lamp OK	08	R	Y	N	8.5	–
Fog Lamp OK	09	R	Y	N	8.5	–
Daytime Running Lamp OK	0A	R	Y	N	8.5	–
Spot Lamp OK	0B	R	Y	N	8.5	–
Cargo Lamp OK	0C	R	Y	N	8.5	–
Cornering Lamp OK	0D	R	Y	N	8.5	–
Driving Lamp OK	0E	R	Y	N	8.5	–
Clutch Lamp OK	0F	R	Y	N	8.5	–

7.34 Exterior Lamps Outage—(See Table 39.)
Primary ID: Exterior Lamps Outage
Command ID: $D8
Status ID: $D9
7.35 Exterior Lamps—(See Table 40.)
Primary ID: Exterior Lamps
Command ID: $DA
Status ID: $DB
7.36 Interior Lamps Outage—(See Table 41.)
Primary ID: Interior Lamps Outage
Command ID: $DC
Status ID: $DD

7.37 Interior Lamps—(See Table 42.)
Primary ID: Interior Lamps
Command ID: $DE
Status ID: $DF
7.38 Tires—(See Table 43.)
Primary ID: Tires
Command ID: $E4
Status ID: $E5

TABLE 40—EXTERIOR LAMPS MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	Proc
Headlamp On / Off	01	L/R	00	00	8.8	-
Tail Lamp On / Off	02	L/R	00	00	8.8	-
Brake Lamp On / Off	03	L/R	00	00	8.8	-
Park Lamp On / Off	04	L/R	00	00	8.8	-
Turn Lamp On / Off	05	L/R	00	00	8.8	-
High Beam Lamp On / Off	06	L/R	00	00	8.8	-
Hazard Lamp On / Off	07	L/R	00	00	8.8	-
Reverse Lamp On / Off	08	L/R	00	00	8.8	-
Fog Lamp On / Off	09	L/R	00	00	8.8	-
Daytime Running Lamp On / Off	0A	L/R	00	00	8.8	-
Spot Lamp On / Off	0B	L/R	00	00	8.8	-
Cargo Lamp On / Off	0C	L/R	00	00	8.8	-
Cornering Lamp On / Off	0D	L/R	00	00	8.8	-
Driving Lamp On / Off	0E	L/R	00	00	8.8	-
Coach Lamp On / Off	0F	L/R	00	00	8.8	-
Autolamp Delay	10	L/R	00	00	8.8	Add
Flash-to-Pass	11	L/R	00	00	8.8	-
Remote Headlamp On / Off w/ Transmitter ID	12	L/R	00	00	8.8	QQQ1
Remote Headlamp On / Off	13	L/R	00	00	8.8	-
Headlamp Svc. Active	21	N	Y	N	8.8	-
Right Turn Svc. Active	22	N	Y	N	8.8	-
Park Lamp Svc. Active	24	N	Y	N	8.8	-
Left Turn Svc. Active	25	N	Y	N	8.8	-
High Beam Svc. Active	26	N	Y	N	8.8	-
Hazard Svc. Active	27	N	Y	N	8.8	-
Fog Lamp Svc. Active	28	N	Y	N	8.8	-
Driving Lamp Svc. Active	29	N	Y	N	8.8	-

TABLE 41—INTERIOR LAMPS OUTAGE MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	Proc
Courtesy Lamp OK	01	N	Y	N	8.8	-
Dome Lamp OK	02	N	Y	N	8.8	-
Puddle Lamp OK	03	N	Y	N	8.8	-
Vanity Mirror Lamp OK	04	N	Y	N	8.8	-
Opera Lamp OK	05	N	Y	N	8.8	-
Reading Lamp OK	06	N	Y	N	8.8	-
Hood Lamp OK	07	N	Y	N	8.8	-
Trunk Lamp OK	08	N	Y	N	8.8	-
Glove Box Lamp OK	09	N	Y	N	8.8	-

TABLE 42—INTERIOR LAMPS MESSAGES

Secondary ID Name	Sec ID	Msg Qty	Q1	Q2	Ext Addr	Proc
Courtesy Lamp On / Off	01	L/R	00	00	8.8	-
Dome Lamp On / Off	02	L/R	00	00	8.8	-
Puddle Lamp On / Off	03	L/R	00	00	8.8	-
Vanity Mirror Lamp On / Off	04	L/R	00	00	8.8	-
Opera Lamp On / Off	05	L/R	00	00	8.8	-
Reading Lamp On / Off	06	L/R	00	00	8.8	-
Hood Lamp On / Off	07	L/R	00	00	8.8	-
Trunk Lamp On / Off	08	L/R	00	00	8.8	-
Glove Box Lamp On / Off	09	L/R	00	00	8.8	-
Illuminated Entry	10	L/R	00	00	8.8	-
Display Brightness & External Lamps On / Off	11	L/R	00	00	-	QQQ0
Courtesy Lamp Svc. Active	21	N	Y	N	8.8	-
Dome Lamp Svc. Active	22	N	Y	N	8.8	-
Puddle Lamp Svc. Active	23	N	Y	N	8.8	-
Vanity Mirror Svc. Active	24	N	Y	N	8.8	-
Opera Lamp Svc. Active	25	N	Y	N	8.8	-
Reading Lamp Svc. Active	26	N	Y	N	8.8	-
Hood Lamp Svc. Active	27	N	Y	N	8.8	-
Trunk Lamp Svc. Active	28	N	Y	N	8.8	-
Glove Box Lamp Svc. Active	29	N	Y	N	8.8	-

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7.39 Defrost—(See Table 44.)
Primary ID: Defrost
Command ID: $E6
Status ID: $E7
7.40 Displays—(See Table 45.)
Primary ID: Displays
Command ID: $EA
Status ID: $EB
7.41 Exterior Environment—(See Table 46.)
Primary ID: Exterior Environment
Command ID: $F2
Status ID: $F3
7.42 Interior Environment—(See Table 47.)
Primary ID: Interior Environment
Command ID: $F4
Status ID: $F5
7.43 Time / Date—(See Table 48.)
Primary ID: Time / Date
Command ID: $F8
Status ID: $F9

TABLE 43--TIMER MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	Page
Temperature	10	R	-	x	8.1	2049
Pressure	11	R	-	x	8.1	2881
Wind Level	14	R	-	x	8.1	2881
Snow Present	15	R	Y	N	-	-

TABLE 44--DEFROST MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	Page
Defrost On / Off	01	L / R	On	Off	8.3	-
Defrost Pending	02	L / R	Y	N	8.3	-
Defrost Switch	03	R	Y	N	8.3	-

TABLE 45--DISPLAYS MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	Page
Metric Display	08	L / R	Y	N	-	-

TABLE 46--EXTERIOR ENVIRONMENT MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	Page
Outside Air Temperature	10	R	-	x	-	9020
Barometric Pressure	11	R	-	x	-	1009
Sun Load	13	R	-	x	8.3	9017
Photo Cell Dark	15	R	Y	N	8.3	-

TABLE 47--INTERIOR ENVIRONMENT MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	Page
Air Filtration On / Off	03	L / R	On	Off	8.2	-
Interior Air Temperature	10	L / R	-	x	8.2	9030
Humidity Level	12	R	-	x	-	9018
Air Filter Remaining Life	14	R	-	x	-	9018

TABLE 48--TIME / DATE MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	Page
Alarm Time	33	R	-	x	-	9047
				x		9047
Time of Day	00	R	-	x	-	9016
				x		9016
				x		9017
Hour of Day	06	R	-	x	-	9017
				x		9017
			Dec	-		-
Minute of Hour	07	R	-	x	-	9018
				x		9018
			Dec	-		-
Second of Minute	08	R	-	x	-	9019
				x		9019
			Dec	-		-
Date	10	R	-	x	-	9020
				x		9020
Day of Week	11	R	-	x	-	9021
				x		9021
			Dec	-		-
Day of Month	12	R	-	x	-	9022
				x		9022
			Dec	-		-
Month of Year	13	R	-	x	-	9023
				x		9023
			Dec	-		-
Year	14	R	-	x	-	9024
				x		9024
			Dec	-		-
Set Time Sw Active	05	R	Y	N	-	-

7.44 Vehicle Identification—(See Table 49.)
Primary ID: Vehicle Identification
Command ID: $FA
Status ID: $FB

7.45 Network Control—(See Table 50.)
Primary ID: Network Control
Command ID: $FE
Status ID: $FF

TABLE 49—VEHICLE IDENTIFICATION MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	PRN
VIN Packet 1 (First digit)	01	R	–	x	–	E001
VIN Packet 2 (digits 2 - 5)	02	R	–	x	–	E002
VIN Packet 3 (digits 6 - 8)	03	R	–	x	–	E003
VIN Packet 4 (digits 10 - 12)	04	R	–	x	–	E004
VIN Packet 5 (digits 14 - 17)	05	R	–	x	–	E005
VIN Packet 6 (reserved for future)	06	R	–	x	–	E006
VIN Packet 7 (reserved for future)	07	R	–	x	–	E007

TABLE 50—NETWORK CONTROL MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q0	Ext Addr	PRN
Bus Wake-up	02	L / R	Y	N	–	–
Node Alive	03	R	Y	N	–	–
Node Sleep	04	L / R	Y	N	–	–

8 *Extended Address Assignments*—The following tables contain the extended address assignments categorized by function. These table are referenced by paragraph number in the message tables on the previous pages.

8.1 Brakes, Tires, and Wheels—The extended address assignments for brakes, tires, and wheels are in Table 51.

TABLE 51—EXTENDED ADDRESS ASSIGNMENTS FOR BRAKES, TIRES, AND WHEELS

Address	Description
00	ALL
10	All Front
11	Left Front
12	Right Front
20	All Rear
21	Left Rear
22	Right Rear
30	Spare Tire

8.2 HVAC Zones—The extended address assignments for HVAC zones are in Table 52.

TABLE 52—EXTENDED ADDRESS ASSIGNMENTS FOR HVAC ZONES

Address	Description
00	ALL
20	All Front
22	Driver Side Front
23	Passenger Side Front
28	All Rear
2A	Driver Side Rear
2B	Passenger Side Rear

8.3 Window Wiper/Washer, Defrost, and Photocell—The extended address assignments for window wiper/washer, defrost, and photocell are in Table 53.

TABLE 53—EXTENDED ADDRESS ASSIGNMENTS FOR WINDOW WIPER/WASHER, DEFROST, AND PHOTOCELL

Address	Description
00	All
10	Front
34	Rear

8.4 Mirrors—The extended address assignments for mirrors are in Table 54.

TABLE 54—EXTENDED ADDRESS ASSIGNMENTS FOR MIRRORS

Address	Description
00	ALL
1A	Driver Side
1C	Rear View
1E	Passenger Side

8.5 Doors and Door Locks—The extended address assignments for doors and door locks are in Table 55.

TABLE 55—EXTENDED ADDRESS ASSIGNMENTS FOR DOORS AND DOOR LOCKS

Address	Description
00	ALL
14	Hood
1E	Passenger Side Glove Box
20	All Front
22	Driver Side Front
24	Convertible Top
26	Passenger Side Front
28	All Rear
2A	Driver Side Rear
2E	Passenger Side Rear
31	Left Side Fuel Door
34	Trunk
37	Right Side Fuel Door
3C	Only or Rear Center Fuel Door

8.6 Seats and Restraints—The extended address assignments for seats and restraints are in Table 56.

TABLE 56—EXTENDED ADDRESS ASSIGNMENTS FOR SEATS AND RESTRAINTS

Address	Description
00	ALL
20	All Front
22	Driver Side Front
24	Front Center
26	Passenger Side Front
28	All Rear
2A	Driver Side Rear
2C	Rear Center
2E	Passenger Side Rear
30	All Rear - Rear (Van)
32	Driver Side Rear - Rear (Van)
38	Passenger Side Rear - Rear (Van)

8.7 Windows—The extended address assignments for windows are in Table 57.

TABLE 57—EXTENDED ADDRESS ASSIGNMENTS FOR WINDOWS

Address	Description
00	ALL
20	All Front
22	Driver Side Front
24	Front Sun Roof
26	Passenger Side Front
28	All Rear
2A	Driver Side Rear
2C	Rear Sun Roof
2E	Passenger Side Rear
34	Rear Windshield

7.44 Vehicle Identification—(See Table 49.)
Primary ID: Vehicle Identification
Command ID: $FA
Status ID: $FB

7.45 Network Control—(See Table 50.)
Primary ID: Network Control
Command ID: $FE
Status ID: $FF

TABLE 49—VEHICLE IDENTIFICATION MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q5	Ext Addr	PNN
VIN Packet 1 (First digit)	01	R	–	x	–	E001
VIN Packet 2 (digits 2 - 5)	02	R	–	x	–	E002
VIN Packet 3 (digits 6 - 9)	03	R	–	x	–	E003
VIN Packet 4 (digits 10 - 13)	04	R	–	x	–	E004
VIN Packet 5 (digits 14 - 17)	05	R	–	x	–	E005
VIN Packet 6 (reserved for future)	06	R	–	x	–	F006
VIN Packet 7 (reserved for future)	07	R	–	x	–	E007

TABLE 50—NETWORK CONTROL MESSAGES

Secondary ID Name	Sec ID	Msg Op	Q1	Q5	Ext Addr	PNN
Bus Wake-up	02	L/R	Y	N	–	–
Node Alive	03	R	Y	N	–	–
Node Sleep	04	L/R	Y	N	–	–

8. Extended Address Assignments—The following tables contain the extended address assignments categorized by function. These table are referenced by paragraph number in the message tables on the previous pages.

8.1 Brakes, Tires, and Wheels—The extended address assignments for brakes, tires, and wheels are in Table 51.

TABLE 51—EXTENDED ADDRESS ASSIGNMENTS FOR BRAKES, TIRES, AND WHEELS

Address	Description
00	ALL
10	All Front
11	Left Front
17	Right Front
30	All Rear
31	Left Rear
37	Right Rear
3C	Spare Tire

8.2 HVAC Zones—The extended address assignments for HVAC zones are in Table 52.

TABLE 52—EXTENDED ADDRESS ASSIGNMENTS FOR HVAC ZONES

Address	Description
00	ALL
20	All Front
22	Driver Side Front
26	Passenger Side Front
28	All Rear
2A	Driver Side Rear
2E	Passenger Side Rear

8.3 Window Wiper/Washer, Defrost, and Photocell—The extended address assignments for window wiper/washer, defrost, and photocell are in Table 53.

TABLE 53—EXTENDED ADDRESS ASSIGNMENTS FOR WINDOW WIPER/WASHER, DEFROST, AND PHOTOCELL

Address	Description
00	All
1C	Front
34	Rear

8.4 Mirrors—The extended address assignments for mirrors are in Table 54.

TABLE 54—EXTENDED ADDRESS ASSIGNMENTS FOR MIRRORS

Address	Description
00	ALL
1A	Driver Side
1C	Rear View
1E	Passenger Side

8.5 Doors and Door Locks—The extended address assignments for doors and door locks are in Table 55.

TABLE 55—EXTENDED ADDRESS ASSIGNMENTS FOR DOORS AND DOOR LOCKS

Address	Description
00	ALL
14	Hood
1E	Passenger Side Glove Box
20	All Front
22	Driver Side Front
24	Convertible Top
26	Passenger Side Front
28	All Rear
2A	Driver Side Rear
2E	Passenger Side Rear
31	Left Side Fuel Door
34	Trunk
37	Right Side Fuel Door
3C	Only or Rear Center Fuel Door

8.6 Seats and Restraints—The extended address assignments for seats and restraints are in Table 56.

TABLE 56—EXTENDED ADDRESS ASSIGNMENTS FOR SEATS AND RESTRAINTS

Address	Description
00	ALL
20	All Front
22	Driver Side Front
24	Front Center
26	Passenger Side Front
28	All Rear
2A	Driver Side Rear
2C	Rear Center
2E	Passenger Side Rear
30	All Rear - Rear (Van)
32	Driver Side Rear - Rear (Van)
36	Passenger Side Rear - Rear (Van)

8.7 Windows—The extended address assignments for windows are in Table 57.

TABLE 57—EXTENDED ADDRESS ASSIGNMENTS FOR WINDOWS

Address	Description
00	ALL
20	All Front
22	Driver Side Front
24	Front Sun Roof
26	Passenger Side Front
28	All Rear
2A	Driver Side Rear
2C	Rear Sun Roof
2E	Passenger Side Rear
34	Rear Windshield

1.504

8.8 External Lamps—The extended address assignments for external lamps are in Table 58.

TABLE 58—EXTENDED ADDRESS ASSIGNMENTS FOR EXTERNAL LAMPS

Address	Description
00	ALL
01	Left Side (Turn Signal)
02	Right Side (Turn Signal)
08	All Front
09	Left Front
0A	Right Front
10	All Rear
11	Left Rear
12	CHMSL
13	Right Rear

8.9 Internal Lamps—The extended address assignments for internal lamps are in Table 59.

TABLE 59—EXTENDED ADDRESS ASSIGNMENTS FOR INTERNAL LAMPS

Address	Description
00	ALL
20	All Front
22	Driver Side Front
24	Passenger Side Front
28	All Rear
2A	Driver Side Rear
2C	Dome Lamp
2E	Passenger Side Rear

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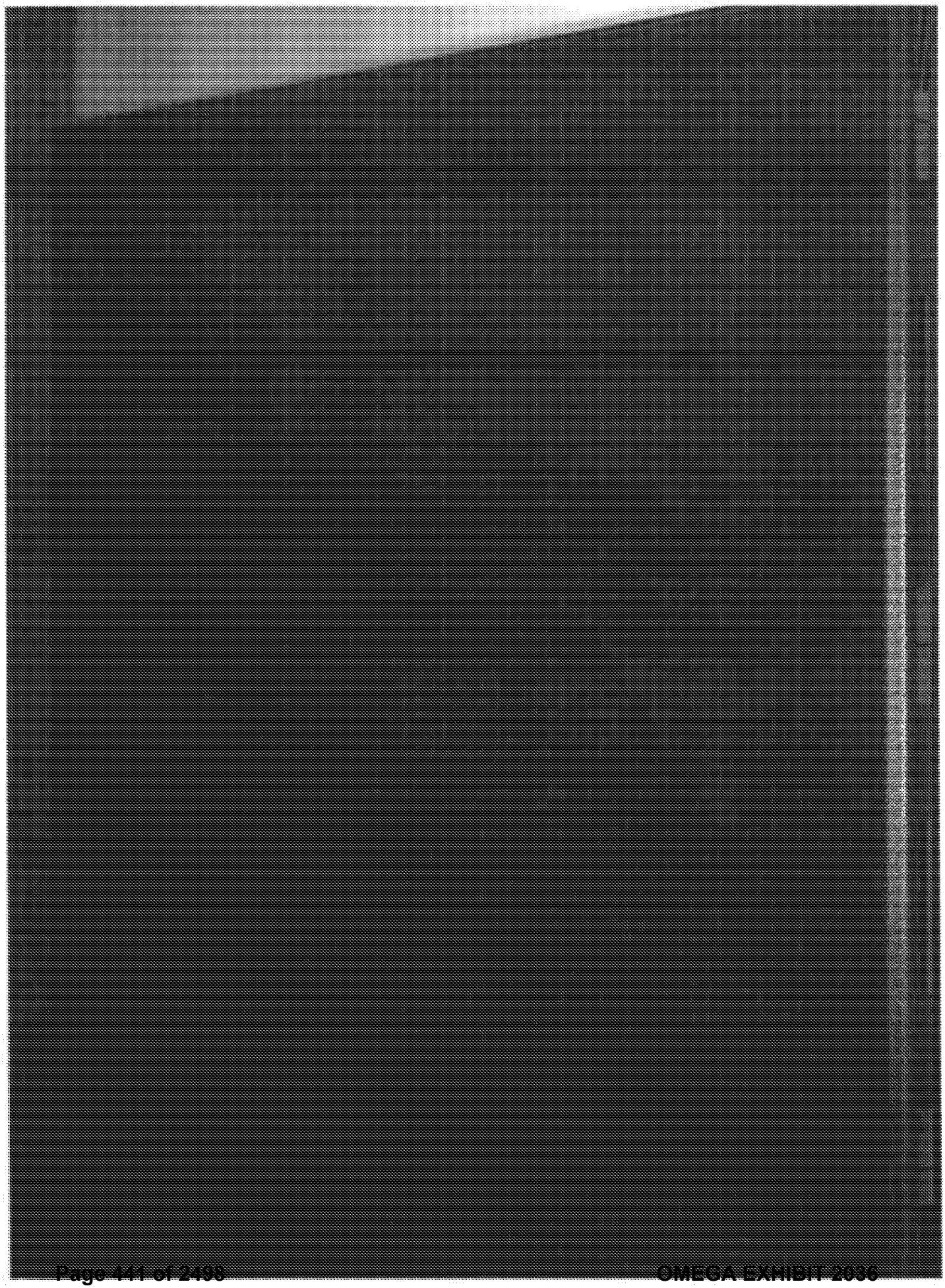

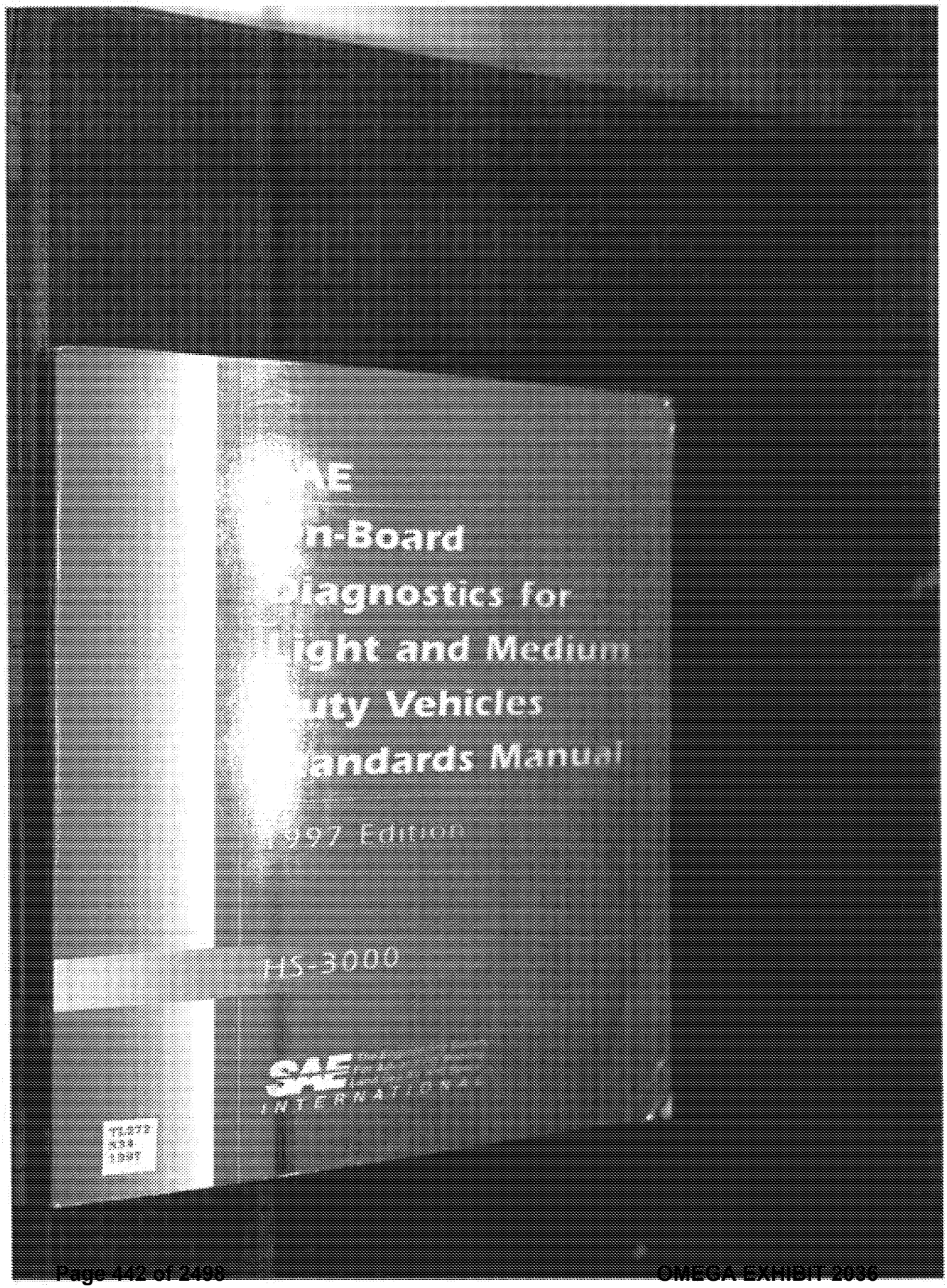
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US005732074A

United States Patent [19]

Spaur et al.

[11] Patent Number: 5,732,074

[45] Date of Patent: Mar. 24, 1998

[54] **MOBILE PORTABLE WIRELESS COMMUNICATION SYSTEM**

[75] Inventors: **Charles W. Spaur; Michael F. Braitberg; Patrick J. Kennedy; Lester B. Hatcher**, all of Boulder, Colo.

[73] Assignee: **CellPort Labs, Inc.**, Boulder, Colo.

[21] Appl. No.: **586,602**

[22] Filed: **Jan. 16, 1996**

[51] **Int. Cl.**[6] **H04M 11/00**

[52] **U.S. Cl.** **370/313**; 370/401; 455/457

[58] **Field of Search** 370/310, 313, 370/328, 401; 455/33.1, 49.1, 53.1, 54.1, 99, 457, 404, 577, 563; 379/58, 59, 63

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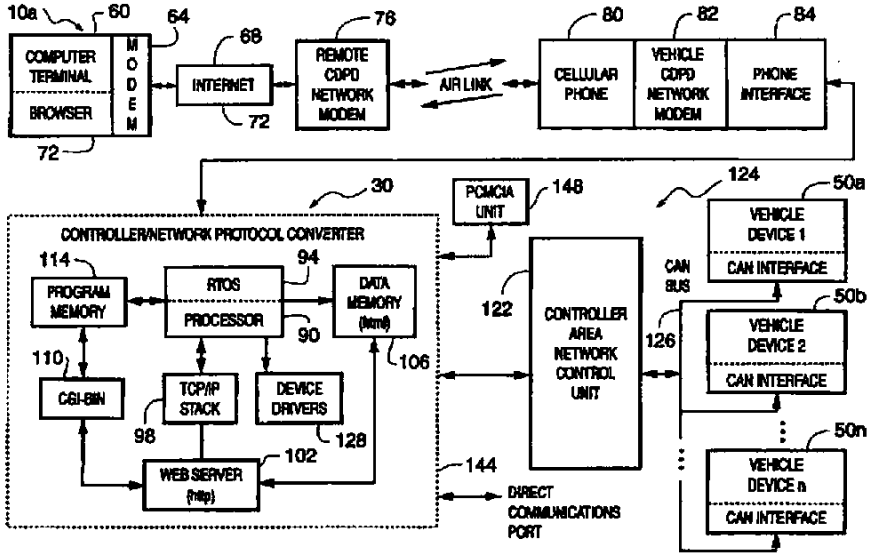
Primary Examiner—Chau Nguyen

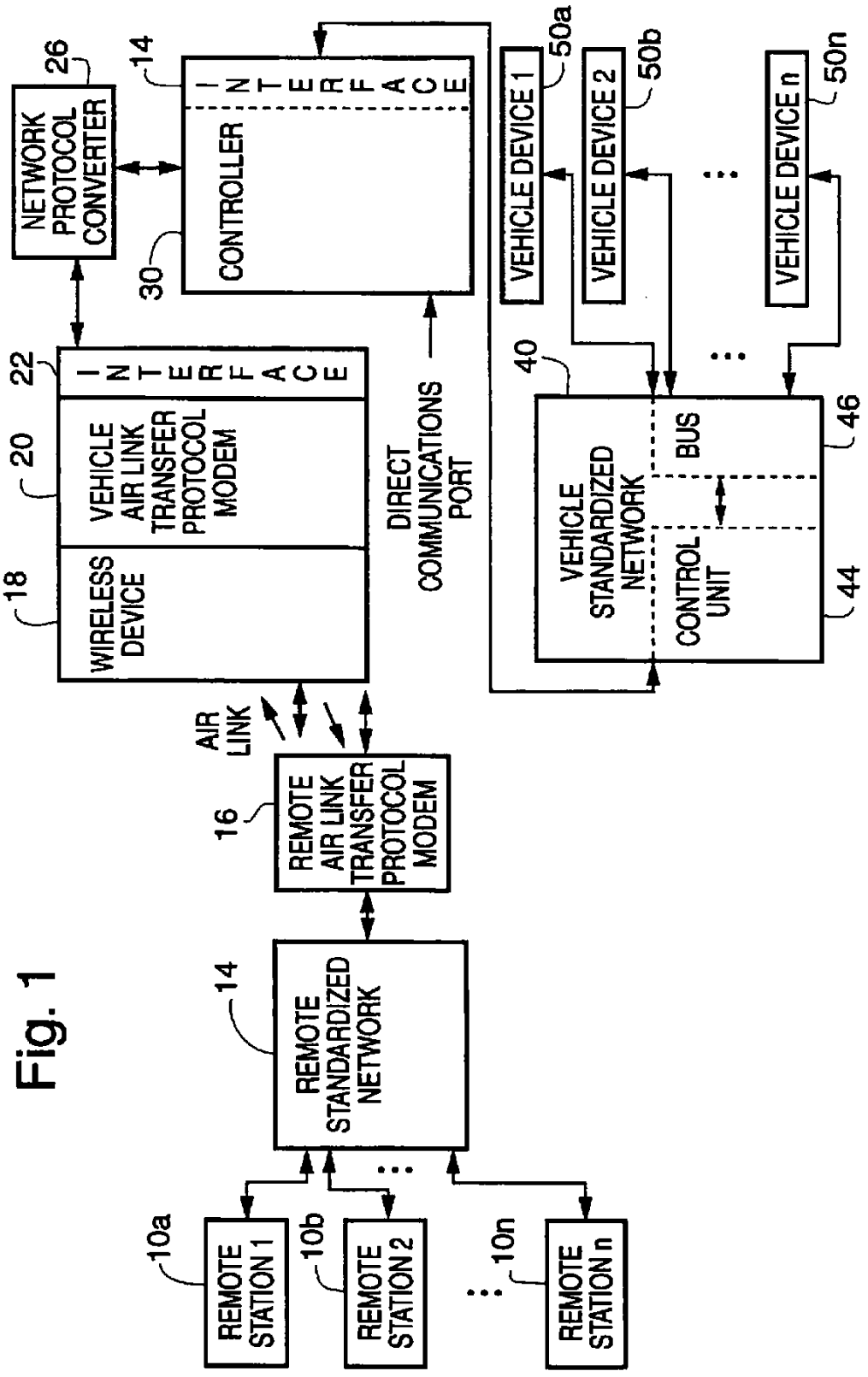
Attorney, Agent, or Firm—Sheridan Ross P.C.

[57] **ABSTRACT**

Communication of information including data between a remote computer and a vehicle is managed and facilitated using an apparatus compatible with standardized network communication links. In one embodiment, the standardized network communication links include the Internet and a controller area network used in vehicles. The apparatus preferably includes a controller contained in the vehicle. The controller is comprised of a number of hardware and software elements including a processor. A TCP/IP stack is part of the controller for providing the necessary control in checking for communicating information, such as requests and data, over the Internet. A web server communicates with the TCP/IP stack for servicing information related requests in http format including obtaining or sending information in operative communication with the TCP/IP stack. A CGI-bin (common gateway interface-binary) communicates with the web server and acts as a link to executable software stored in program memory that is responsive to user requests. A data memory is also available for storing data in html that is accessible by the web server. A real time operating system (RTOS) is involved in task and memory management as part of the responding to requests for information. The controller is able to receive requests using a wireless device when it is in the vehicle and through a communications port when the wireless device is not in the vehicle. In another embodiment, each of the plurality of vehicle devices has an Internet address or designation associated with it.

21 Claims, 4 Drawing Sheets

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VEHICLE DEVICE 2
50b
VEHICLE DEVICE n
50n
22
INTERFACE
20
VEHICLE AIR LINK TRANSFER PROTOCOL MODEM
18
WIRELESS DEVICE
DIRECT COMMUNICATIONS PORT
40
VEHICLE STANDARDIZED NETWORK
BUS
CONTROL UNIT
46
44
AIR LINK
16
REMOTE AIR LINK TRANSFER PROTOCOL MODEM
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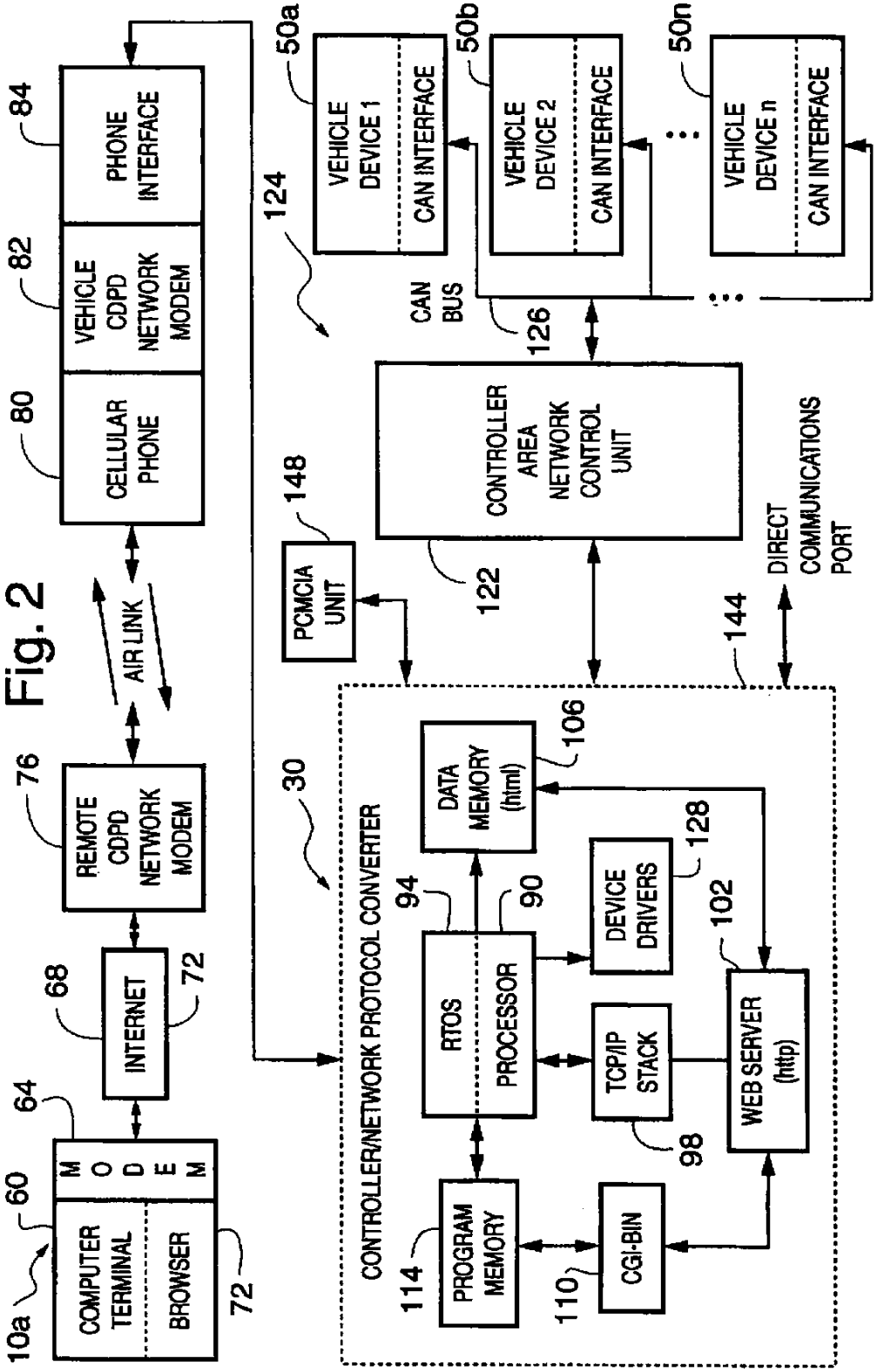
REMOTE STANDARDIZED NETWORK
10a
REMOTE STATION 1
10b
REMOTE STATION 2
10n
REMOTE STATION n

Fig. 1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MODEM
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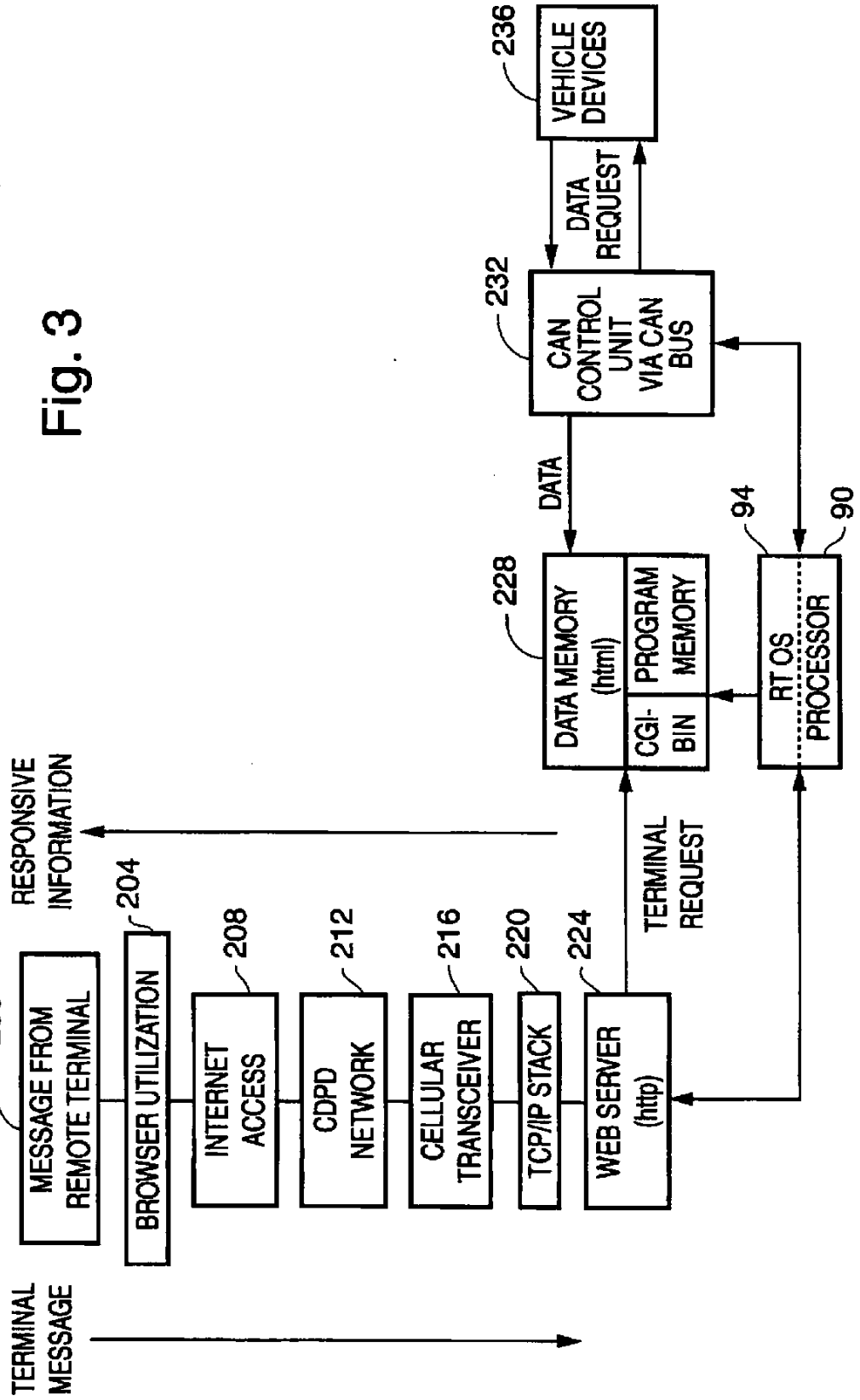
AIR LINK
CELLULAR PHONE
80
VEHICLE CDPD NETWORK MODEM
82
PHONE INTERFACE
84
30
CONTROLLER/NETWORK PROTOCOL CONVERTER
PROGRAM MEMORY
114
CGI-BIN
110
RTOS
PROCESSOR
94
90
TCP/IP STACK
98
DEVICE DRIVERS
128
DATA MEMORY (html)
106
WEB SERVER (http)
102
PCMCIA UNIT
148
CONTROLLER AREA NETWORK CONTROL UNIT
122
144
DIRECT COMMUNICATIONS PORT
CAN BUS
126
124
VEHICLE DEVICE 1
CAN INTERFACE
50a
VEHICLE DEVICE 2
CAN INTERFACE
50b
VEHICLE DEVICE n
CAN INTERFACE
50n

Fig. 2

Fig. 3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VEHICLE DEVICES
DATA REQUEST
232
CAN CONTROL UNIT VIA CAN BUS
DATA
228
DATA MEMORY (html)
PROGRAM MEMORY
CGI-BIN
94
90
RT OS PROCESSOR
RESPONSIVE INFORMATION
204
208
212
216
220
224
TERMINAL REQUEST
200
MESSAGE FROM REMOTE TERMINAL
BROWSER UTILIZATION
INTERNET ACCESS
CDPD NETWORK
CELLULAR TRANSCEIVER
TCP/IP STACK
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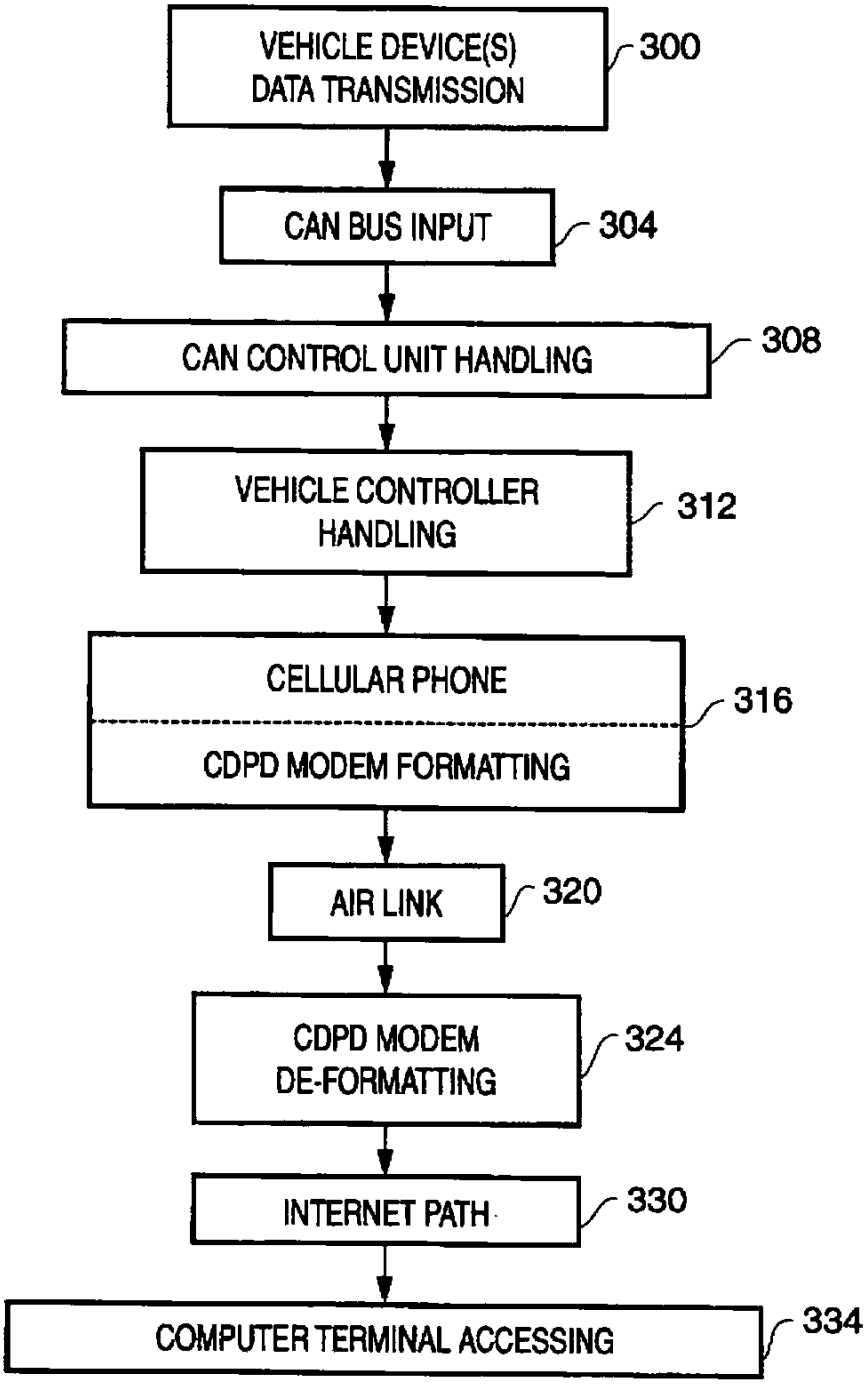
TERMINAL MESSAGE

Fig. 4


VEHICLE DEVICE(S) DATA TRANSMISSION
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CAN BUS INPUT
304
CAN CONTROL UNIT HANDLING
308
VEHICLE CONTROLLER HANDLING
312
CELLULAR PHONE
CDPD MODEM FORMATTING
316
AIR LINK
320
CDPD MODEM DE-FORMATTING
324
INTERNET PATH
330
COMPUTER TERMINAL ACCESSING
334

MOBILE PORTABLE WIRELESS COMMUNICATION SYSTEM

FIELD OF THE INVENTION

The present invention relates to bi-directional communications over an airlink and, in particular, information transfers between a vehicle and one or more remote stations using an established network, such as the Internet.

BACKGROUND OF THE INVENTION

Establishing communications with vehicles that are commonly found at different locations or are in transit between locations has become increasingly more important. It is often desirable to know the location of a particular vehicle at a given time. Such a vehicle may be transporting goods that the recipient is waiting for and wishes to know the current location of the vehicle transporting the goods. It may also be useful to monitor conditions of the goods, such as the temperature of refrigerated loads. In addition to goods carried by the vehicles, the vehicles themselves can be monitored for certain conditions, such as engine or other parameters. Such information can be utilized in insuring that the vehicles are properly maintained to avoid vehicle downtime or the necessity of road service. Other applications involving communications with vehicles might involve safety and security considerations. A monitored vehicle can include an emergency vehicle that transports a patient who is connected to monitoring equipment in the vehicle that continuously or periodically gathers patient data. During transport of the patient, such patient data can be communicated to medical personnel at a remote location, such as a hospital, to prepare for the arrival of the patient. When the patient arrives, this data has been evaluated and decisions reached as to how best to care for the patient. Other security or safety checks might include: whether a vehicle door was unlocked, initiation of an alarm by activating a switch, automatic indication of an airbag detonation and automatic generation of a signal when an expected input has not been received for a certain amount of time.

With regard to requesting and obtaining such data from vehicles in connection with different vehicle related applications, substantial impediments are encountered. Specifically, no universal system or package is available that is configured to operate with vehicles from which information may be sought by multiple users having different objectives or applications. Typically, users have different computer hardware and telecommunications equipment, as well as software for their particular jobs or applications. With respect to the vehicle itself, and depending upon the desired applications of a particular user, data to be gathered has to be obtainable from a potentially large number of physical devices. Given such a broad spectrum of actual and potential applications and available devices and equipment, an appropriate and effective linkage must be provided to enable accurate and efficient communication to occur between the remote station and the vehicle. In light of the mobile nature of the vehicle, part of the communication must occur wirelessly over an airlink. Achieving desired communications with vehicles also requires the flexibility to adapt to changing applications associated with vehicle related information being sought, including physical devices that might be modified or added at later times, as well as accommodating new users with different physical devices that may have different information gathering requirements and parameters. Relatedly, multiple users must be able to simultaneously access different information that may require

multiple tasks to be performed in the vehicle before such information can be gathered and sent to the remote site. With all these requirements and objectives, the implementation of such a communication system cannot be burdensome, nor be prohibitively costly. Importantly, the communications system and processing capability must be portable and practical for the vehicle environment, as well as involving protocols that a variety and large number of users are familiar with.

SUMMARY OF THE INVENTION

In accordance with the present invention, a system is provided in which communication of information, including requests, commands and data, is achieved between vehicle having physical vehicle devices and one or more sites that are remote from the vehicle. The information communication is implemented using certain standardized network communication links that enable multiple users, either simultaneously or at separate times, with different communications and processing hardware, software and different applications and requiring information from different vehicle devices, to obtain the desired information while avoiding design complexities in interfacing the remote site with the vehicle devices.

The system includes, at the remote site, a computer terminal which can be a conventional PC with a modem. The computer terminal is able to communicate with a first standard communications network link, such as the Internet, through its modem. An internet or a world wide web browser, for example, that is available to the computer terminal is accessed. The computer terminal supplies the browser with an IP (Internet protocol) address. This IP address is associated with a particular vehicle including communications related hardware contained in the vehicle. Typically, the IP address is accompanied by a request or command for information or data that is available from the particular vehicle. In addition to this first standardized communications network, since bi-directional communications involving a vehicle are conducted wirelessly for at least a portion of the communications link, it is necessary for the Internet to communicate with an appropriate interface or network that wirelessly links with the vehicle. In one embodiment, the cellular digitized packet data (CDPD) network provides the desired link including arrangement of information being communicated and where the destination site, namely the particular vehicle, is found in the network. If a channel is available to the particular vehicle, the CDPD link can proceed to transmit the Internet packets to the vehicle of interest. Instead of the CDPD network as the link, a communications interface could be employed that involves data only, such as a two way paging interface with the vehicle.

With respect to handling requests, commands and information including data transfers relative to the vehicle, particularly involving data from vehicle devices, certain hardware and software is contained in the vehicle. For receiving information from the Internet, a wireless device, such as a cellular phone, having the appropriate hardware and channels acts as a receiver for such information in combination with an appropriate airlink modem, such as a CDPD network modem. The wireless device is contained within the vehicle and communicates with a controller through a phone interface. The phone interface provides the necessary electrical signal connections between the output lines or channels from the wireless device and the controller inputs.

The controller is also found in the vehicle and is a key unit of the apparatus and includes a number of hardware and

software elements. Specifically, a TCP/IP (transmission control protocol/Internet protocol) stack acts on a received request or command by performing a number of functions. The received request has a IP address associated with it and a check is made as to whether or not the request has the correct address. Further, the formatted data is checked for accuracy. The TCP is responsible for controlling the structure and flow of the received information. In that regard, the TCP/IP stack is associated with a number of sockets that it communicates with or links to, with the selected socket being dependent upon the content of the received information. In that regard, among the sockets available to the TCP/IP stack is a server. In conjunction with effectively communicating over the Internet, an http (hypertext transmission protocol) web server is utilized. The web server operates in accordance with world wide web protocol and services information related requests in http format including obtaining or getting information based on a received request or command and sending or posting information in response to received requests or commands. The controller also includes data memory for storing data in html (hypertext markup language) format, with such data being frequently previously collected from vehicle devices and stored in the data memory. In response to a request, for example, the web server accesses the data memory to obtain desired data and encapsulates it in accordance with http format for transmission from the controller through the wireless device using an appropriate airlink modem to a destination site (remote station).

The web server also communicates with a CGI-bin (common gateway interface-binary), which is also part of the controller. The CGI-bin is useful in linking the web server with a number of executable programs stored in a program memory. These executable programs can be utilized in obtaining or providing data or other information associated with the vehicle devices. In one embodiment, one or more executable programs are run to obtain data which is then stored in data memory in html format for later access and use, including transmitting such data to a remote site. The controller also has a real time operating system (RTOS) that typically is involved with managing a number of services associated with conducting one or more applications oriented tasks. For example, the RTOS works with the applications software during execution for managing tasks that are run by the applications software and management of data stored in the file memory. Especially in the context of a vehicle, the executable software might include a variety of applications including: the present location of the vehicle; vehicle maintenance monitoring parameters, such as status conditions associated with the engine, coolant status, oil pressure and battery life; cargo conditions including status of delivery of cargo and relevant cargo conditions, such as temperature; alarm conditions that apprise others of certain predetermined events associated with the vehicle, such as airbag detonation; and, in the case of a vehicle transporting a patient, monitoring data associated with patient vital signs.

With regard to obtaining information or data from these vehicle devices for appropriate processing using, for example, one or more executable programs in the program memory, the controller communicates with a second standardized network in the form of a network that is commercially available and used in vehicles, such as the previously devised controller area network (CAN). The CAN is operatively connected to each of a plurality of vehicle devices that transmit, receive, or both transmit and receive desired data. For example, the vehicle devices include transducers or other physical devices that detect and provide information useful to applications software for processing to obtain information that is then transmitted, for storing in memory for later transmission, or even for immediate transmission without processing, upon receipt of the proper request or command. Other available networks could be utilized, instead of the CAN, such as Arcnet, which has a protocol similar to CAN.

More specifically, with respect to transmission of information from the controller through the wireless device to a remote site, after receipt of a request as previously described and in accordance with one procedure, the web server interprets the transmitted request and determines that certain data stored in the data memory is being requested by a user at the remote site. The stored data is accessed and prepared by the web server in accordance with http format for transmission over the Internet. The http formatted information is subject to the operation of the TCP/IP stack for regulating the transmission of the requested information including associating a destination IP address with the information being sent. Once the information is properly prepared using the TCP/IP stack, it can be sent over the airlink via the wireless device to the Internet connection using appropriate airlink modems.

In a variation of this operation, instead of a request starting from the remote station, the sending of information including data might be initiated in the vehicle. By way of example, it may be necessary or desirable that certain data parameters be periodically transmitted to a remote station for analysis or other considerations. In still another operation variation, an additional information transmission can be received from another user located at a different remote site during the time that a first request for information is being processed by the controller. In such a case, the TCP/IP stack, in conjunction with the operating system, enables multiple tasks to be performed in a controlled manner so that more than one user is able to communicate with the controller at the same time.

Preferably, the controller in the vehicle is also associated with an interface for communication with one or more available systems, such as an RS232 connection, an Ethernet connection and/or a PCMCIA unit. In a related embodiment, the controller includes a direct communications port for receiving and sending information without requiring the wireless device and the Internet connection to the wireless device. In this embodiment, the direct communications port receives information or data using another source contained in the vehicle, such as the vehicle's radio. Subcarrier information is transmitted to the radio and decoded for input to the direct communications port for subsequent analysis or use by the CAN. In yet a further variation of controller operation, each vehicle device on the CAN has its own IP designation or address so that the remote user can utilize this designation or address for communication with the selected vehicle device having that designation or address. The controller uses the received IP address or designation for the particular device and acts as a link or bridge for the remote user to the particular device.

Based on the foregoing summary, a number of salient features of the present invention can be readily identified including the substantial elimination or avoidance of numerous, different and complex hardware and software for communicating information involving physical devices located in a vehicle and one or more computers located at one or more remote sites. A combination of controller related components are containable in a vehicle for responding to requests from remote sites, obtaining and storing information associated with vehicle devices and running executable

software that may be available in the program memory of the controller or downloaded from the remote site, while handling and configuring information including data that is communicative with the remote site over an established network, such as the Internet. Furthermore, the controller efficiently communicates with another standard network found in a vehicle, such as the controller area network, to obtain data from the vehicle devices and, when appropriate, send messages or information to the vehicle devices. The controller elements are important in communicatively linking together previously incompatible remote and vehicle networks to achieve a functional mobile communication system. The overall system including the standardized networks effectively enables, either substantially simultaneously or separately, a variety of applications to be performed by multiple users and which applications utilize one or more of a large number of selectable and different vehicle devices, while not requiring substantial allocated memory in the vehicle.

Additional advantages of the present invention will be readily understood from the following discussion, particularly when taken together with the accompanying drawing figures.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram illustrating the general components of the apparatus for information communication between one or more remote stations and a vehicle;

FIG. **2** is a more detailed block diagram illustrating major elements of the controller;

FIG. **3** is a flow diagram illustrating major steps that are involved in the bi-directional communications between one or more remote stations and a vehicle having the controller in which a message is initiated from the remote station; and

FIG. **4** is a flow diagram illustrating major steps that are involved in a communication initiated by the vehicle to a remote station.

DETAILED DESCRIPTION

With reference to FIG. **1**, an apparatus is illustrated in the block diagram for hi-directional communication between one or more remote stations **10***a*–**10***n* and a vehicle. The bi-directional communication has the capability of involving multiple users and a number and variety of applications that are germane to the vehicle. Each remote station can include communications and processing related hardware and software that is different from that of the other remote stations. To avoid extensive and customized hardware and software in order to achieve the desired bi-directional communications, a standardized remote network communications link **14** is utilized. That is, each user who wishes to communicate with the vehicle, need not develop and establish the necessary interfacing networks and protocols for communication with the vehicle. Each user, including users who operate independently of other users, is able to access the vehicle through the same standardized remote network communications link **14**, regardless of the particular application or applications that the user has for implementation or operation in conjunction with hardware and software associated with the vehicle. In a preferred embodiment, the remote network communications link **14** is the Internet. With respect to communication with a vehicle, the information being communicated must be configured or formatted in a way that achieves proper communication over an airlink to the vehicle. This is accomplished using a suitable switching station identified generally as a remote airlink transfer protocol modem **16**. In one embodiment, the communication information is formatted in accordance with a CDPD (cellular digitized packet data) configuration. At the vehicle, this information is received by a wireless device **18** that is able to transmit and receive information via the airlink. The wireless device **18** is operatively associated with a vehicle airlink transfer protocol modem **20** for the proper handling of the airlink formatted transmission. In one embodiment, the wireless device **18** includes a cellular phone that is selected from a plurality of conventional or commercially available cellular phones. The wireless device **18** bi-directionally communicates with a controller **30** contained in the vehicle through a network protocol converter **26** using a wireless device interface **22**. The wireless device interface **22** establishes the necessary signal compatibilities and connections from the wireless device **18**. The network protocol converter **26** removes or otherwise converts the inputted information to a form that is acceptable to the controller **30** or, alternatively, information is made compatible with the remote airlink transfer protocol modem **16** when such information is sent through the airlink using the network protocol converter **26**. In conjunction with the FIG. **1** illustration, the network protocol converter **26** is essentially part of the wireless device **18** and physically separated from the controller **30** but electrically connected thereto so that no network protocol converter is required in the controller **30**. In the embodiment to be described in greater detail herein, the network protocol converter **26** includes a TCP/IP stack which can be part of the controller **30** so that the controller **30** is also definable or can be referred to as a controller/network protocol converter **30**. The controller **30** is responsible for a number of functions related to understanding and acting on information received from one or more remote stations **10**, obtaining and responding to requested information and operatively functioning with information including data available from other elements in the vehicle. In that regard, the controller **30** communicates with a controller interface **34** that electrically links the controller **30** with a vehicle standardized network **40**. The vehicle standardized network **40** includes a controller unit **44** that provides appropriate message and data handling functions associated with sending and receiving information including data from each of a plurality of physical vehicle devices **50** that are operatively connected to a bus **46** of the vehicle standardized network **40**. Like the remote standardized network **14**, the vehicle standardized network **40** is an established and previously developed network that interfaces with components in a vehicle, such as engine related components in order to provide desired or requested data concerning the operations or status of these components. An important aspect of the apparatus of the present invention involves the enabling of communications between two mutually incompatible and highly dissimilar standardized networks. More specifically, full communication capabilities are achieved among numerous remote stations via a global or remote standardized network and vehicle devices via a localized standardized network, either at different or at the same times, using the apparatus even though the global and localized networks are configured substantially differently and involve significant protocol and environmental differences. That is, the remote standardized network **14**, such as the Internet, is configured as an information communications system having no geographic boundaries. The vehicle or localized standardized network **40** is designed to function properly in the electrically noisy and otherwise hostile vehicle environment. The diverse design objectives and problems faced by these two different standardized networks

therefore requires a communications related apparatus that is able to effectively enable these two networks to bi-directionally communicate with each other, as well as other hardware and software that is operably connected to the two standardized networks. In accordance with the present invention, the vehicle devices **50** might include a large number of diverse devices, including common vehicle parts or components, for providing and receiving information including data, as well as, in some cases, acting on such information by analyzing or processing such information. With regard to providing information to a remote station **10**, a substantially symmetrical relationship exists among the elements of FIG. **1**. That is, the controller **30** is able to prepare information for sending to a remote station **10**, including data or other information available from one or more of the vehicle devices **50** using the vehicle standardized network **40**. Such information is sent to the wireless device **18** through its interface **22** for transmission using the vehicle airlink transfer protocol modem **20** over the airlink to the remote station **10** by way of the remote standardized network **14** in combination with the remote airlink transfer protocol modem **16**.

With reference now to FIG. **2**, greater details of the apparatus of FIG. **1** are illustrated, particularly key elements of the controller **30** contained in the vehicle. As shown in FIG. **2**, remote station **10***a* is illustrated and it includes a computer terminal **60**. In one embodiment, the computer terminal **60** is a conventional PC having the usual hardware and software components and capabilities including input and output devices, such as a keyboard, mouse and terminal display screen. The computer terminal **60** communicates with a modem **64** in order that the information from and to the computer terminal **60** can be sent over conventional communication lines, such as telephone lines. In the preferred embodiment, the modem **64** enables the computer terminal **60** to communicate with Internet **68**. In one embodiment, the computer terminal **60** has one or more browsers **72** available to it, which is used in requesting or responding to information communications involving a particular vehicle. The Internet **68** operatively communicates with a standardized network transmission protocol that permits information to be bi-directionally communicated over the airlink and, in one embodiment, includes a remote CDPD network modem **76** which prepares the information in a conventionally acceptable manner for transmission and communication with a cellular phone **80** which is contained in the vehicle. The cellular phone **80** can be any selected one of a number of conventional cellular phones that have the capability of properly communicating with the desired formatted or arranged information. In the illustrated embodiment of FIG. **2**, the cellular phone **80** is operatively associated with a vehicle CDPD network modem **82** that demodulates the received information so that it is acceptable for further handling or processing. A phone interface **84** links the cellular phone **80** with the controller **30** and is, preferably, configured to work with a variety of cellular phones having differing output connections and/or arrangements of output connections. In that regard, the phone interface **84** is useful in providing a proper battery charging function for the cellular phone **80**, assisting in the identification of the particular cellular phone **80** that is being utilized, and establishing the correct electrical connections for passage or communication of the signals between the cellular phone **80** and the controller **30**. An appropriate phone interface **84**, or at least portions thereof, is disclosed in U.S. Pat. No. 5,333,177 issued Jul. 26, 1994 and entitled "Universal Connection for Cellular Telephone Interface."

As also seen in FIG. **2**, the controller **30** includes a number of elements for handling the functions and responsibilities associated with responding to messages, such as requests or commands, from one or more of the remote stations **10**, running executable software and obtaining data, as well as achieving the necessary communications protocols with the Internet **68**. The controller **30** includes a processor **90** for performing processing operations including running of executable program code, including in the context of utilizing or incorporating data that the controller **30** has access to. Preferably, the processor **90** is a single microprocessor that performs multiple tasks, in conjunction with a real time operating system (RTOS) **94**. That is, the RTOS **94** manages a number of services associated with conducting one or more applications oriented tasks. Preferably, the RTOS **94** includes a kernel that is involved in performing real time multi-tasking including: task management, intertask communication, memory management, message management, timing, I/O management and error management. In the context of applications associated with the vehicle, the RTOS **94** works with applications software in a multi-task scheme to respond to requests for vehicle related information including data.

The controller **30** also includes a TCP/IP (transmission control protocol/internet protocol) stack **98** for providing necessary communication protocols in association with the Internet. The TCP regulates the flow and structure of data or other information including an operative communication with a web server **102**. The IP is responsible for recognizing source and destination addresses in connection with insuring receipt at the proper location, as well as checking for the accuracy of data packets received from the airlink. The TCP/IP stack **98** is invoked initially when information is received by the controller **30** and is invoked when information including data is to be outputted from the controller **30** to the phone interface **84**. Preferably, the TCP/IP stack **98** is a commercially available portable unit for an embedded system that provides a single threaded stack for supporting multiple sockets including sockets associated with the web server **102**. The web server **102** services information related requests in http (hyper text transmission protocol) format. These requests include obtaining or getting information, as requested, and the sending or posting of information, as requested. The web server **102** is also a commercially available Internet related product. With respect to getting information, the controller **30** further includes a data storage unit or data memory **106**. Generally, the data memory **106** stores data that has been generated and is expected to be useful in handling requests or commands. Such data may be data obtained from monitoring a physical device associated with a vehicle and/or may include data useful in running executable software that is intended to provide further information or data useful to a requestor. The data in the data memory **106** is preferably configured in html (hyper text markup language). In this configuration, the web server **102** is able to access the data memory **106** and obtain such configured data for encapsulation or incorporation in the http format for communication over the Internet **68**. In addition to communication with the data memory **106**, the web server **102** is operatively linked to a CGI-bin (common gateway interface-binary) **110**. The CGI-bin **110** acts as a link or a gate to a number of typically short executable programs stored in program memory **114**. Such stored executable software may encompass a variety of applications associated with the vehicle. Generally, such software is useful in processing, analyzing or otherwise acting on data available in the vehicle, including acting on the data in real time, such

as acting on available data in real time that is used for transmission to a remote station, where such transmission is initiated in the vehicle. A representative listing of applications is as follows:

(a) monitoring of vehicle locations and status;

(b) tracking of deliveries of packages by the vehicle;

(c) monitoring cargo conditions in the vehicle, such as the temperature of the cargo and checking equipment related to maintaining a desired temperature;

(d) vehicle parameter monitoring for maintaining the vehicle such as checking engine conditions including possibility of overheating and operating mileage (odometer reading);

(e) displaying of directions and/or dispatch instructions; and

(f) communication of short messages between a user at the remote site and the operator of the vehicle.

In addition to application software that might be involved with such functions, the short programs in the program memory **114** may include software related to safety and security considerations, including:

(a) monitoring a patient's vital signs who is being transported by the vehicle;

(b) providing information as to whether or not a roving security vehicle has periodically checked in with a home base; and

(c) providing an indication of key or alarm related events, such as when roadside assistance is required, the vehicle or the driver of the vehicle faces a threatening situation, an unauthorized vehicle door unlocking and/or initiating an automatic call for assistance in light of an airbag detonation.

With regard to representative operations, the data memory **106** may store page information that is accessible by the web server **102**. Upon receipt of a command or request, this page information may be accessed and updated with current data or other information for transmission to a user at a remote station **10**. For example, page information may require that data, which is collected from the vehicle devices **50**, be inserted or be included therein. In a variation of this operation, all or substantially all of the page information is generated after receiving a request for information that is associated with the page. In generating the page information, data already stored in the data memory **106** may be utilized or, alternatively, data may be obtained upon receipt of the request from the physical devices associated with the vehicle. In a further and related variation, information or executable software may be downloaded from the remote station to the controller **30** for execution as part of responding to an accompanying or future request, which software may be executed in conjunction with the operation of an applet that is stored as part of the controller **30**. In such a variation or with other variations, it may be appropriate to maintain memory storage space at a reduced level in the controller **30** so as to keep within defined vehicle cost and space requirements. In a related embodiment, the appropriate information or executable software is already part of the controller **30** and is part of the short programs accessible using the CGI-bin **110**.

With continued reference to FIG. **2**, a more detailed discussion related to the vehicle devices **50** is provided. Each of the vehicle devices **50***a*–**50***n* is able to receive information such as data, send information, or is able to both receive and send information. Generally, the vehicle devices **50** can include a variety of monitoring, detecting, inputting or other information communication related devices. In conjunction with the aforedescribed short executable programs that might be available in or to the controller **30**, such vehicle devices **50** can include sensors, transducers or other equipment for providing or receiving information. By way of example only, the vehicle devices **50***a*–**50***n* can include one or more of the following: GPS (global positioning system), dead reckoning sensors, facsimile machine, PDA (personal digital assistant), laptop computer, printer, display unit, modem, CD-ROM unit, storage device, medical condition sensors, vehicle condition sensors, vehicle cargo sensors, airbag sensor and general alarm sensors related to unlocking the vehicle or unwanted intrusion into the vehicle.

In order to provide the necessary communications protocol between the controller **30** and the vehicle devices **50***a*–**50***n*, another standardized network communications link is provided, which is different from the first standardized network communications link, such as the Internet **68**. This further standardized communications network is responsible for handling the communication exchange functions associated with sending and receiving information relative to the vehicle devices **50**. In a preferred embodiment, this further standardized network is a network that has been previously devised and is commonly used in a number of makes and models of vehicles. This communications network is defined as the controller area network (CAN) **124**. Although the CAN **124** has previously commonly been used in operative association with automotive electronics including engine control elements, sensors, lamps, electric windows etc., the present invention also enables the CAN **124** to be used with a variety of other devices contained in the vehicle, such as the previously described devices. An apparatus that utilizes processing capability in a vehicle with a number of peripheral devices in communication therewith over a common bus is disclosed in U.S. Pat. No. 5,479,479 issued Dec. 26, 1995 and entitled "Method and Apparatus for Transmission of and Receiving Signals Having Digital Information Using an Air Link," and which is assigned to the same assignee as the present application.

Generally, the CAN**124** is definable as being comprised of an object layer and a transfer layer that constitute a CAN control unit **122**, and a physical layer. The object layer is responsible for message filtering, and message and status handling. The transfer layer is responsible for confinement of faults, error detection and signaling, message validation, acknowledgements, bus contention, arbitration among information, message framing and transfer rate and timing. The physical layer is the transmission medium itself as well as the signal level and bit representations that are transmitted along the transmission medium. The transmission medium is essentially a multi-conductor bus **126** that has electrical conductors electrically connected to each of the vehicle devices **50** that are on the CAN **124**. In operatively connecting the CAN bus **126** to each vehicle device **50***a*–**50***n*, each of these vehicle devices is operatively associated with a CAN interface. In one embodiment, each of the CAN interfaces is connected in "daisy-chain" fashion as part of the bus **126** configuration. In interfacing with the CAN **124**, the controller **30** also has device drivers **128** that are useful in achieving desired communications in both directions between the CAN **124** and the controller **30**. For example, the processor **90** is able to obtain data or other information from the vehicle devices **50***a*–**50***n* using the device drivers **128** and which information can be used by the processor **90** including, for example, storing data in the data memory **106** for subsequent access and transmission to a remote station **10**.

As also illustrated in FIG. **2**, information can be communicated to the apparatus without passing through the cellular phone **80**. A direct communications port **144** is operatively

associated with the device driver assembly **128** for communication through the CAN **124** to one or more of the vehicle devices **50***a*–**50***n*. The direct communications port **144** has particular utility when the cellular phone **80** or other wireless device is not in the vehicle. In that situation, information is communicated using another device or unit in the vehicle. For example, the vehicle radio receives a transmission having a subcarrier signal that conveys information useful to and understood by the hardware associated with the direct communications port **144**. The data stream that is inputted to the port **144** was previously obtained or decoded to provide the information in a format compatible with the port **144**. Conversely, the port **144** enables information carrying signals to be outputted therefrom for transmission outside of the vehicle, such as again using the vehicle's radio.

In addition to vehicle devices **50** that communicate through the CAN **124**, further peripheral devices can be connected directly to the controller **30**, instead of communicating through the CAN **124**. For example, a PCMCIA (personal computer memory card interface association) unit **148** is electrically connected to the device driver assembly **128**. The unit **148** might include a storage device with a disk drive for storing desired information or data. Another such unit **148** might include a modem for providing communication capability directly between the controller **30** and another device or unit in the vehicle.

The description so far has been directed to an embodiment in which the vehicle or the controller **30** is associated with an address that the Internet **68** utilizes in connection with sending information to the vehicle. In another embodiment, each of the vehicle devices **50***a*–**50***n* has its own IP (internet protocol) address or designation. A user at a remote station **10** that wishes to send or receive information relative to a particular vehicle device **50***a*–**50***n*, utilizes the IP address or designation of the vehicle device in order to achieve the information transfer relative to the particular vehicle device **50**. In this case, the controller **30** and its operation are essentially transparent to a user at a remote site and each vehicle device **50** appears or acts as if it is a TCP/IP device. An example of operation, in accordance with this embodiment, might involve a vehicle device **50**, such as a CD-ROM unit. Specifically, the user or accessor of the CD-ROM unit provides an IP address for this device and it is received by the vehicle having the CD-ROM unit. The controller **30** recognizes this IP address and is able to provide the requested link to the CD-ROM unit through the CAN **124**. As a possible variation or addition to such an operation, the controller **30** can include an applet that is associated with this IP address. When this IP address for the CD-ROM unit is recognized by the controller **30**, the controller **30** sends the applet to the user accessing the Internet **68**, where the applet is received by the browser **72**. The browser **72** uses the applet to bring up a display using the computer terminal **60**. The display might include, for example, buttons that represent CD-ROM unit controls that the user can "click on" to cause certain operations associated with the CD-ROM unit.

In further related methods of operation when an http request is received by the web server **102**, the controller **30** is able to respond in a dynamic manner to reflect the current status or conditions of vehicle devices **50**. By way of example, as just noted, when all vehicle devices are properly functioning and providing data, an html page including one or applets could be downloaded to handle such data from the controller **30**. However, if one or more vehicle devices are not producing accurate data, a determination might be made to modify the content or number of applets that are usually downloaded in connection with such data when it is accurate. This reduces the magnitude and time of transmission, which results in a decrease in the cost of the wireless transmission, especially where there is a substantial amount of data, a large number of vehicles and/or an expected transmission on a very regular basis. As an additional example, the controller **30** might utilize information including data from a group of vehicle devices that is to be served to an applet embedded in a page. In a case in which one or more vehicle devices are not properly functioning or not functioning at all, the quality of information produced by the embedded application varies and is not reliable. Thus, it would be useful to be able to alter the presentation of this information in a dynamic manner. That is, such a presentation should reflect accurate data and the controller **30** is able to make a determination as to what information or data should be presented when such situations arise.

In yet a further related method of operation, the controller **30** is able to provide information by way of one or more notifications to one or more stations when a particular event or condition occurs such as at a predetermined time interval after the event or condition arises. In one embodiment, a worldwide web browser operably connected to the web server **102** selects the events or conditions to which the predetermined actions are to be taken by the web server **102**. For example, a user may request a notification message when the vehicle reaches a certain location, when a sensor in the vehicle measures a value relative to a predetermined threshold value and upon the occurrence of other predetermined events or conditions. Such request for notifications may be formulated via a point-and-click worldwide web browser interface and notifications can be made to frames on a web page, or other appropriate ways specified by the user. The user could also specify in the request that the notifications are to be sent to a third party by way of E-mail or http/html messages. By such techniques, notifications can be sent to a list of locations in electronic format suited for each individual location.

With reference to FIG. **3**, the operation of the present invention is further described in the context of a flow diagram illustrating steps for transmitting and receiving information between a computer terminal **60** and a vehicle of interest. In particular, the user inputs a message at the computer terminal **60**, in accordance with block **200**. The message includes at least an IP address and a request for information that is obtainable from the subject vehicle. The message is transmitted via the modem **64** connected to the computer terminal **60** utilizing the browser **72** at block **204** to direct or route the host message in accordance with the IP address. At block **208** the Internet **68** is accessed for carrying the message. As part of the message transmission, the remote CDPD network modem **76** is employed at block **212** to packetize the data message so that it can be properly transmitted over the airlink. At block **216**, the CDPD transmitted message is received by the cellular phone **80** or other transceiver and the output thereof is gated to the controller **30** having the TCP/IP stack **98** at block **220** after the message is demodulated by the vehicle CDPD network modem **82**. The IP checks the accuracy of the identified address and other information in the message. The TCP coordinates the flow of the message and prepares it for transmission to the http web server **102** at block **224**. The web server **102** under the control and process functioning of the RTOS **94**/processor **90**, services the information related request in http format. In accordance with one example, the message includes a request for vehicle information related to engine and/or other vehicle component operations or con-

ditions. In one application, for example, the requested vehicle conditions might have to be obtained from data that is processed or analyzed using executable software or a program stored in the program memory **114**. In such a case, a request based on the message is applied to the CGI-bin **110** at block **228**. This link enables the desired program to be selected and run under the processing/control of the processor **90**/RTOS **94**. As part of that execution, it may be necessary to obtain previously stored information including data from the data memory **106** Additionally, or alternatively, it may be necessary to obtain current or other data that is available from a particular vehicle device itself. In that context, the processor **90**/RTOS **94** obtains such information through the CAN controller unit **122** via the CAN bus **126** at block **232**. The CAN protocol is utilized to request and obtain the data from the selected vehicle device at block **236**. The data obtained by the CAN **124** is utilized by the processor **90** in connection with the execution of the selected program that is being executed. In one embodiment, with the requested data related to the vehicle component conditions having been obtained by processing, or from one or more vehicle devices **50**, or by both methods, such data can then be included in page information. Portions of the page information could be stored in the data memory **106**, with the obtained data being included in the appropriate parts of the page. Once this is completed, the page information is handled by the web server **102** for sending the page information in http format. The TCP/IP stack **98** is involved in the control of the transmission of this page information, as well as checking the destination address. The page information is transmitted through the cellular phone **80** including being packeted for a CDPD network transmission, using the vehicle CDPD network modem **82** for transmission over the Internet **68** to the requesting computer terminal **60**. The page information can then be displayed on the display unit of the computer terminal **60**.

With regard to operation variations, with respect to one or more alarm conditions, when a particular vehicle device **50** detects or is involved with an alarm event, this is reported by the CAN **124** to the processor **90** using the device drivers **128**. The processor **90** and the TCP/IP stack **98** cooperate to send a signal through the cellular phone **80** indicative of this alarm condition, without the need to utilize the web server **102**. The signal representative of the alarm condition is properly directed to a predetermined IP address over the Internet **68**. Relatedly, the processor **90** is able to execute an appropriate interrupt routine in order to delay or interrupt a response that is being performed due to a currently existing request to the controller **30** in order to process the detected alarm condition. After such processing, the processor **90** can continue with responding to the request that was present prior to the interrupt. Additionally, the controller **30** is able to be responsive to more than one request from different users at different remote stations. The processor **90** and the RTOS **94** cooperate to perform multiple tasks in a coordinated fashion in response to requests from multiple users.

Previous discussions of the operation of the apparatus have primarily been directed to operations in which the sending of information is initiated by a remote computer terminal **60**. With reference to the flow diagram of FIG. **4**, a further related description of the operation of the present invention involves a case in which information is transmitted upon initiation of the controller **30** in the vehicle. In accordance with such an operation, data or other information from one or more vehicle devices **50***a*–**50***n* is provided over the airlink to one or more remote stations **10***a*–**10***n* on a predetermined or determinable time basis. For example, each vehicle in a fleet of vehicles might be required to report its location on a periodic basis to a remote station **10**. The steps of FIG. **4** are next described in the context of such an example. At block **300**, vehicle positioning data is available from one of the vehicle devices **50**, which might be a GPS. On a requested or regular input scheme, such vehicle device data is sent to the CAN bus **126** at block **304**. The CAN controller **122** is responsible for controlling the receipt and transmitting of such data to the controller **30** at block **308**. The vehicle data that is to be transmitted over the wire link, in accordance with the predetermined or determinable procedure, is appropriately processed, analyzed or otherwise acted on using the controller **30** at block **312**. In one embodiment, vehicle device data, such as GPS data, do not rely on the web server **102** but may utilize a different communications pathway, such as E-mail. In any event, the controller **30** gates the vehicle location data to the cellular phone having the vehicle airlink transfer protocol modem **20**, such as a CDPD network modem **82**, at block **316**. The vehicle location data is properly formatted and transmitted through the cellular phone over the airlink at block **320**. In receiving such data from the airlink, a remote airlink transfer protocol modem **16**, such as a remote CDPD network modem **76**, collects such data at block **324** and subsequently passes the vehicle data to the Internet **68** at block **330**. The desired computer terminal **60** receives the vehicle positioning data from the Internet **68** at block **334**. In accordance with desired embodiments, such data can be further processed by the computer terminal **60**, displayed on a display unit thereof in a pre-established way, or otherwise handled to achieved desired use of the received data. In a related variation of this embodiment, after processing such data, the computer terminal **60** may initiate further actions in the way of sending information to the vehicle for adjusting or otherwise affecting the vehicle device that provided the data for analysis. That is, based on the data received and analyzed by the computer terminal **60**, a determination is made that a desired or feedback input needs to be provided in real time to this vehicle device.

The foregoing discussion of the invention has been presented for purposes of illustration and description. Further, the description is not intended to limit the invention to the form disclosed herein. Consequently, variations and modifications commensurate with the above teachings, within the skill and knowledge of the relevant art, are within the scope of the present invention. The embodiments discussed herein above are further intended to explain the best mode known of practicing the invention and to enable others skilled in the art to utilize the invention in such, or in other, embodiments and with the various modifications required by their particular application or uses of the invention. It is intended that the appended claims be construed to include alternative embodiments to the extent permitted by the prior art.

What is claimed is:

1. An apparatus for information transmission involving one or more remote stations and a vehicle, comprising:

at least a first remote station including computer means located at a distance from a vehicle;

a wireless device for location in the vehicle for use in sending and receiving information including data relative to said first remote station over an airlink;

a plurality of different vehicle devices associated with the vehicle and with each of said vehicle devices for at least one of receiving and sending said information;

controller means including processing means in the vehicle for controlling the sending and receiving of said information using said wireless device between said

first remote station and the vehicle, said controller means further including first standard network communication means for use in presenting information for transmission over the airlink in a first format that is acceptable to a first standardized network that includes the airlink, wherein said first network communication means enables said information to be provided to multiple users that utilize different makes of communication equipment, different processing hardware and different applications software executable by said processing means of said controller means, said first standard network communication means including a web server in the vehicle for responding to a plurality of service related requests and providing said information in said first format for transmission to said computer means at said first remote station using said wireless device; and

a second standard network communication means, different from said first standard network communication means, in communication with said controller means for presenting information in a second format that is acceptable to a second standardized network, with said second standardized network communication means communicating with said vehicle devices for sending and receiving said information relative thereto and in which said controller means enables said information to be properly communicated between said first and second standardized networks.

2. An apparatus, as claimed in claim 1, wherein:

said first standard network communication means includes first means for communicating with said wireless device for receiving a request for said information obtainable from at least one of said vehicle devices, said first means including means for checking source address information associated with said request in determining that said request is to be responded to by said controller means.

3. An apparatus for information transmission involving one or more remote stations in a vehicle, comprising:

at least a first remote station including computer means located at a distance from a vehicle:

a wireless device for location in the vehicle for use in sending and receiving information including data relative to said first remote station over an airlink;

a plurality of different vehicle devices associated with the vehicle and with each of said vehicle devices for at least one of receiving and sending said information;

controller means including processing means in the vehicle for controlling the sending and receiving of said information using said wireless device between said first remote station and the vehicle, said controller means further including first standard network communication means for use in presenting said information for transmission over the airlink in a first format that is acceptable to a first standardized network that includes the airlink, wherein said first network communication means enables said information to be provided to multiple users that utilize different makes of communication equipment, different processing hardware and different applications software executable by said processing means of said controller means, said first standard network communication means including a web server in the vehicle for responding to a plurality of service related requests and also including transmission control protocol means in communication with said web server for regulating flow and ordering of said information related to said vehicle devices to said web server; and

a second standard network communication means, different from said first standard network communication means, in communication with said controller means for presenting information in a second format that is acceptable to a second standardized network, with said second standardized network communication means communicating with said vehicle devices for sending and receiving said information relative thereto and in which said controller means enables said information to be properly communicated between said first and second standardized networks.

4. An apparatus for information transmission involving one or more remote stations in a vehicle, comprising:

at least a first remote station including computer means located at a distance from a vehicle;

a wireless device for location in the vehicle for use in sending and receiving said information including data relative to said first remote station over an airlink;

a plurality of different vehicle devices associated with the vehicle and with each of said vehicle devices for at least one of receiving and sending said information;

controller means including processing means in the vehicle for controlling the sending and receiving of said information using said wireless device between said first remote station and the vehicle, said controller means further including first standard network communication means for use in presenting said information for transmission over the airlink in a first format that is acceptable to a first standardized network that includes the airlink, wherein said first network communication means enables said information to be provided to multiple users that utilize different makes of communication equipment, different processing hardware and different applications software executable by said processing means of said controller means, said first standard network communication means including a web server in the vehicle for responding to a plurality of service related requests and also including a CGI-bin communicating with said web server and in which said CGI-bin links said web server with a number of executable programs useful in obtaining said information related to said vehicle devices; and

a second standard network communication means, different from said first standard network communication means, in communication with said controller means for presenting information in a second format that is acceptable to a second standardized network, with said second standardized network communication means communicating with said vehicle devices for sending and receiving said information relative thereto and in which said controller means enables said information to be properly communicated between said first and second standardized networks.

5. An apparatus for information transmission involving one or more remote stations in a vehicle, comprising:

at least a first remote station including computer means located at a distance from a vehicle;

a wireless device for location in the vehicle for use in sending and receiving information including data relative to said first remote station over an airlink;

a plurality of different vehicle devices associated with the vehicle and with each of said vehicle devices for at least one of receiving and sending said information;

controller means including processing means in the vehicle for controlling the sending and receiving of said information using said wireless device between said

remote station and the vehicle, said controller means further including first standard network communication means for use in presenting said information for transmission over the airlink in a first format that is acceptable to a first standardized network that includes the airlink, wherein said first network communication means enables said information to be provided to multiple users that utilize different makes of communication equipment, different processing hardware and different applications software executable by said processing means of said controller means, said first standard network communication means including a web server in the vehicle for responding to a plurality of service related requests received using said wireless device, with said web server in communication with program memory for storing said executable software in connection with obtaining said information from said vehicle devices and in which said first standard network communication means further includes an operating system for managing a number of services associated with conducting applications oriented tasks in conjunction with said executable software; and

a second standard network communication means, different from said first standard network communication means in communication with said controller means for presenting information in any second format that is acceptable to a second standardized network, with said second standardized network communication means communicating with said vehicle devices for sending and receiving said information relative thereto and in which said controller means enables said information to be properly communicated between said first and second standardized networks.

6. An apparatus, as claimed in claim 1, wherein:

said first standardized network communication means includes the Internet and said second standardized network includes a bus having predetermined protocol that permits controlled communications relative to said vehicle devices and in which said executable software includes a plurality of the following: software for providing the location of the vehicle; software for providing data related to the vehicle conditions; software for providing data related to conditions of cargo contained in the vehicle; software for providing data related to medical conditions of a patient carried by the vehicle; and software for providing predetermined alarm conditions and in which said software utilizes said information from said vehicle devices.

7. An apparatus for information transmission involving one or more remote stations in a vehicle, comprising:

at least a first remote station including computer means located at a distance from a vehicle

a wireless device for location in the vehicle for use in sending and receiving information including data relative to said first remote station over an airlink:

a plurality of different vehicle devices associated with the vehicle and which each of said vehicle devices for at least one of receiving and sending said information;

controller means including processing means in the vehicle for controlling the sending and receiving of said information using said wireless device between said first remote station and the vehicle, said controller means further including first standard network communication means for use in presenting said information for transmission over the airlink in a first format that is acceptable to a first standardized network that includes the airlink, wherein said first network communication means enables said information to be provided to multiple users that utilize different makes of communication equipment, different processing hardware and different applications software executable by said processing means of said controller means, said first standard network communication means including a web server in the vehicle that responds to a plurality of service related requests and provides said information in said first format and a data memory that communicates with said web server for storing data in html that is obtainable using said web server and in which said web server provides said data in said first format, with said first format being http; and

a second standard network communication means, different from said first standard network communication means, in communication with said controller means for presenting said information in a second format that is acceptable to a second standardized network, with said second standardized network communication means communicating with said vehicle devices for sending and receiving said information relative thereto and in which said controller means enables said information to be properly communicated between said first and second standardized networks.

8. An apparatus as claimed in claim 1, wherein:

said controller means includes a communications port for receiving communications port information separately from said wireless device, with said communications port information being useful in providing an input to one of said plurality of vehicle devices through said second standard network communication means.

9. An apparatus, as claimed in claim 1, wherein:

each of said plurality of vehicle devices has a separate designation known to said controller means, with information being requested from a first vehicle device by said computer means by selecting a designation associated with said first vehicle device and said first vehicle device designation being acceptable to said first standardized network.

10. An apparatus, as claimed in claim 1, wherein:

said computer means includes display means and said controller means responds to a request from said computer means by controlling the sending of software to said computer means for use in displaying information on said display means, with said software being related to operation of one of said vehicle devices.

11. An apparatus, as claimed in claim 1, wherein:

said controller means initiates a transfer of information to said first remote station based on occurrence of at least one predetermined event.

12. A method for using at least a first standardized network for communicating information between a remote station and a vehicle, comprising:

providing a wireless device in the vehicle;

sending a message including a request for information and an address using a computer at the remote station;

formatting said message so that it is acceptable to the first standardized network;

configuring said message to communicate said message over an airlink;

receiving said message in the vehicle using said wireless device;

coordinating said request for information including checking for an address;

sending said request for information to a server;

obtaining information based on management by said server of said request for information, said obtained information being provided in accordance with a predetermined language arrangement, said obtaining step including accessing data memory for storing data defined in html using said server;

formatting said obtained information using said server;

transmitting said obtained information over said airlink using said wireless device; and receiving said information by said computer.

13. A method, as claimed in claim 12, wherein:

said obtaining step includes using a second standardized network that communicates with a number of vehicle devices, each of said vehicle devices for at least one of sending and receiving data and in which said data is sent in response to said request for information.

14. A method, as claimed in claim 13, further including:

initiating a signal by a first of said vehicle devices in response to detection of a first condition and in which responding to said request for information is delayed while sending data related to said first condition.

15. A method, as claimed in claim 13, wherein:

said obtaining step includes receiving said request for information separately from said wireless device using a communications port associated with controller means that communicates with said wireless device when said wireless device is not in the vehicle.

16. A method for using at least a first standardized network for communicating information between a remote station and a vehicle, comprising:

providing a wireless device in the vehicle;

sending a message including a request for information and an address using a computer at the remote station;

formatting said message so that it is acceptable to the first standardized network;

configuring said message to communicate said message over an airlink;

receiving said message in the vehicle using said wireless device;

coordinating said request for information including checking for an address;

sending said request for information to a server;

obtaining information based on management by said server of said request for information; said obtained information being provided in accordance with a predetermined language format, said obtaining step includes invoking an applications program using a CGI-bin in communication with said server and subsequently executing said applications program using processing means in the vehicle;

formatting said obtained information using said server;

transmitting said obtained information over said airlink using said wireless device; and

receiving said information by said computer.

17. A method, as claimed in claim 16, wherein:

said executing step includes using data obtained from at least one of said plurality of vehicle devices.

18. A method, as claimed in claim 17, wherein:

said executing step includes using operating system software for managing a number of services associated with conducting one or more applications-oriented tasks and in which said operating system is involved in interrupting said request for information when a predetermined alarm condition is detected by a predetermined one of said vehicle devices.

19. A method, as claimed in claim 18, wherein:

said executing step includes performing multiple tasks using said operating system.

20. A method, as claimed in claim 12, further including:

initiating a transfer of information by controller means contained in the vehicle based on the occurrence of a predetermined condition.

21. A method for communicating information between a computer at a remote site and a vehicle having a plurality of vehicle devices for sending and receiving information including data, comprising:

providing a wireless device in the vehicle;

requesting data from a first of said vehicle devices using said computer;

formatting said request so that it is acceptable to a first standardized network, with said request including a first address associated with said first vehicle device, said step of formatting said request includes using a http web server and said first standardized network includes the Internet;

configuring said request to communicate said request over an airlink;

receiving said request in the vehicle using said wireless device;

managing said request including where said data is to be obtained with reliance on said first address of said first vehicle device;

obtaining said data after said managing step using a second standardized network, different from said first standardized network, said second standardized network includes a controller area network for providing communications protocol for a number of different vehicle devices;

formatting said data so that it is acceptable to said first standardized network;

transmitting said data over said airlink using said wireless device; and

receiving said data associated with said first vehicle device by said computer.

* * * * *

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United States Patent [19]

Beckert et al.

[11] Patent Number: 5,794,164

[45] Date of Patent: Aug. 11, 1998

[54] **VEHICLE COMPUTER SYSTEM**

[75] Inventors: **Richard D. Beckert**, Lake Stevens; **Mark M. Moeller**, Des Moines; **William Wong**, Redmond, all of Wash.

[73] Assignee: **Microsoft Corporation**, Redmond, Wash.

[21] Appl. No.: **564,586**

[22] Filed: **Nov. 29, 1995**

[51] **Int. Cl.**[6] **G06F 19/00**

[52] **U.S. Cl.** **701/1**; 701/36

[58] **Field of Search** 364/424.045, 423.098; 455/345, 346; 701/36, 1

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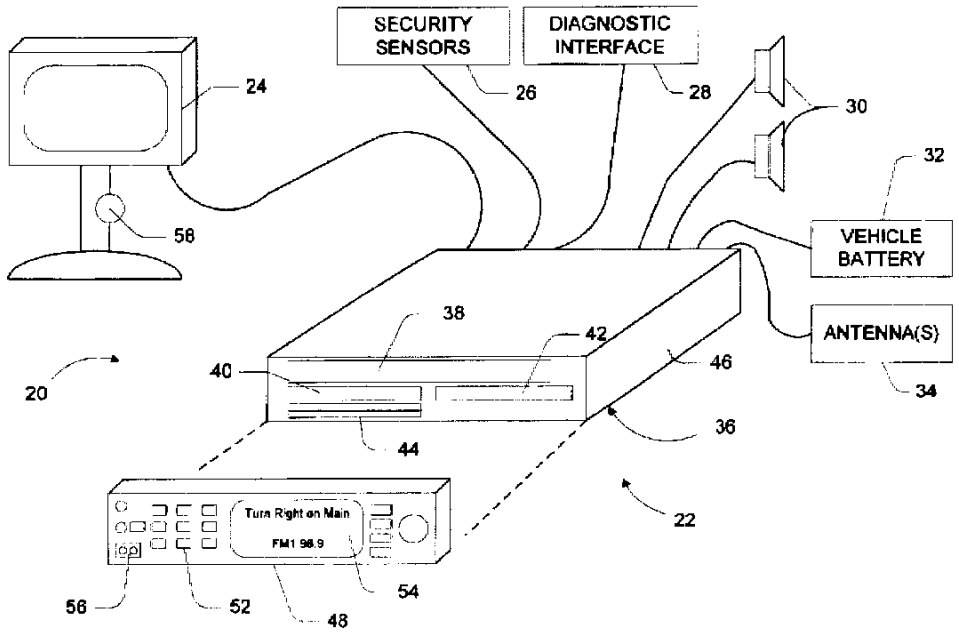
Primary Examiner—Michael Zanelli

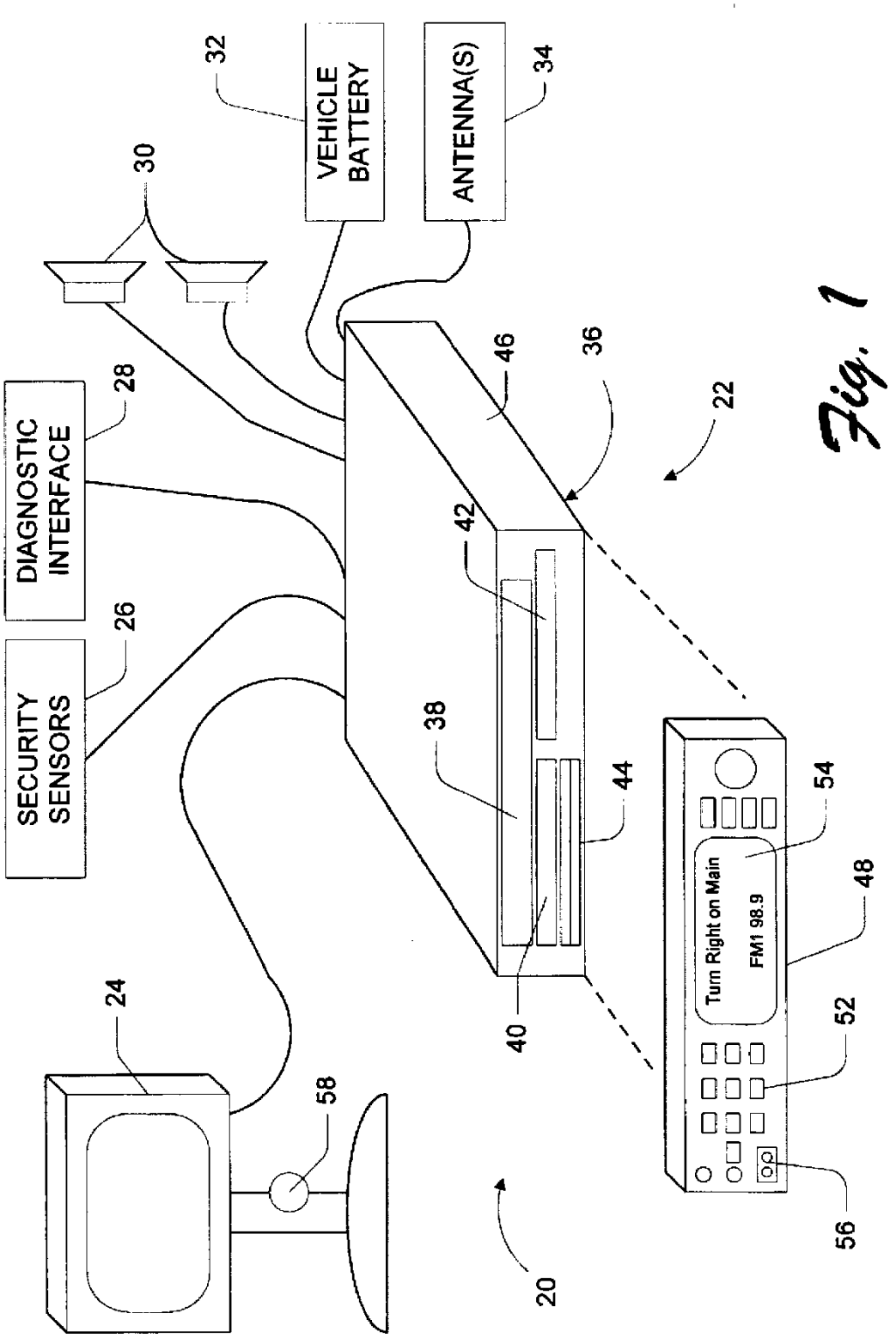
Attorney, Agent, or Firm—Lee & Hayes, PLLC

[57] **ABSTRACT**

A vehicle computer system has a housing sized to be mounted in a vehicle dashboard or other appropriate location, a computer mounted within the housing, and an open platform operating system which executes on an open hardware architecture computer. The open platform operating system supports multiple different applications that can be supplied by a vehicle user. For instance, the operating system can support applications pertaining to entertainment, navigation, communications, security, diagnostics, and others. The computer has one or more storage drive (e.g., CD drive, floppy disk drive, cassette player, or hard disk drive) which permits the vehicle user to download programs from a storage medium (e.g., CD, diskette, cassette, or hard disk) to the computer. In the described implementation, the computer has two independent processors. One processor, which runs the operating system, is mounted in a stationary base unit of the housing and the other processor is mounted to a faceplate which is detachable from the base unit. When the faceplate is attached, the first processor provides the primary control over all operating systems (i.e., entertainment, navigation, communications, security, diagnostics, and others) and the faceplate processor is subservient. When the faceplate is detached, it forms a portable RF device with the faceplate processor providing radio and communications capabilities.

46 Claims, 7 Drawing Sheets




VEHICLE BATTERY
ANTENNA(S)
DIAGNOSTIC INTERFACE
SECURITY SENSORS
Turn Right on Main
FM1 98.9
20
22
24
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30
32
34
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42
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46
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Fig. 1

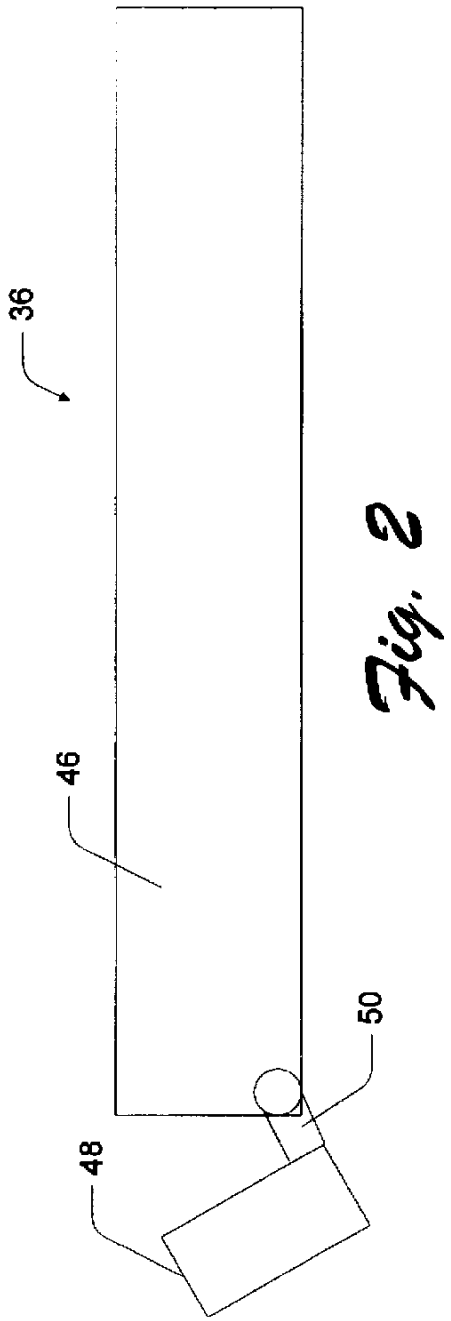


Fig. 2

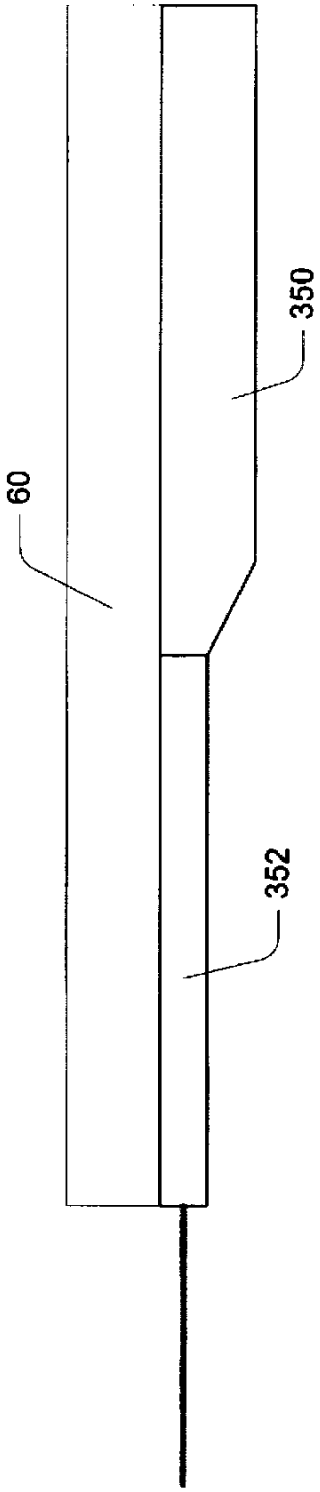
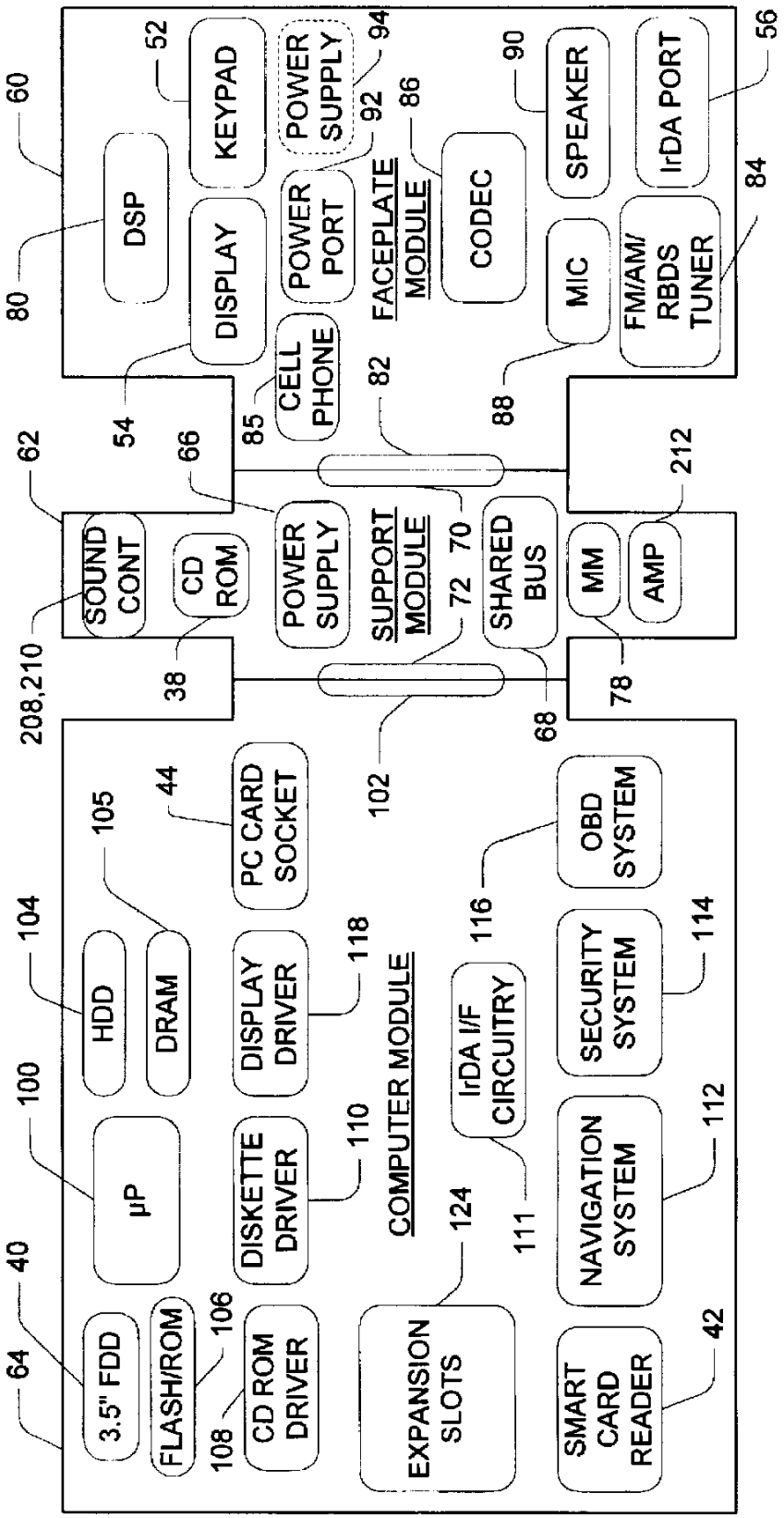


Fig. 6


DSP
KEYPAD
POWER SUPPLY
DISPLAY
POWER PORT
FACEPLATE MODULE
CODEC
SPEAKER
IrDA PORT
MIC
FM/AM/ RBDS TUNER
CELL PHONE
SOUND CONT
CD ROM
POWER SUPPLY
SUPPORT MODULE
SHARED BUS
MM
AMP
PC CARD SOCKET
HDD
DRAM
DISPLAY DRIVER
COMPUTER MODULE
IrDA I/F CIRCUITRY
OBD SYSTEM
SECURITY SYSTEM
µP
DISKETTE DRIVER
NAVIGATION SYSTEM
3.5" FDD
FLASH/ROM
CD ROM DRIVER
EXPANSION SLOTS
SMART CARD READER
60
80
52
94
92
86
90
56
84
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85
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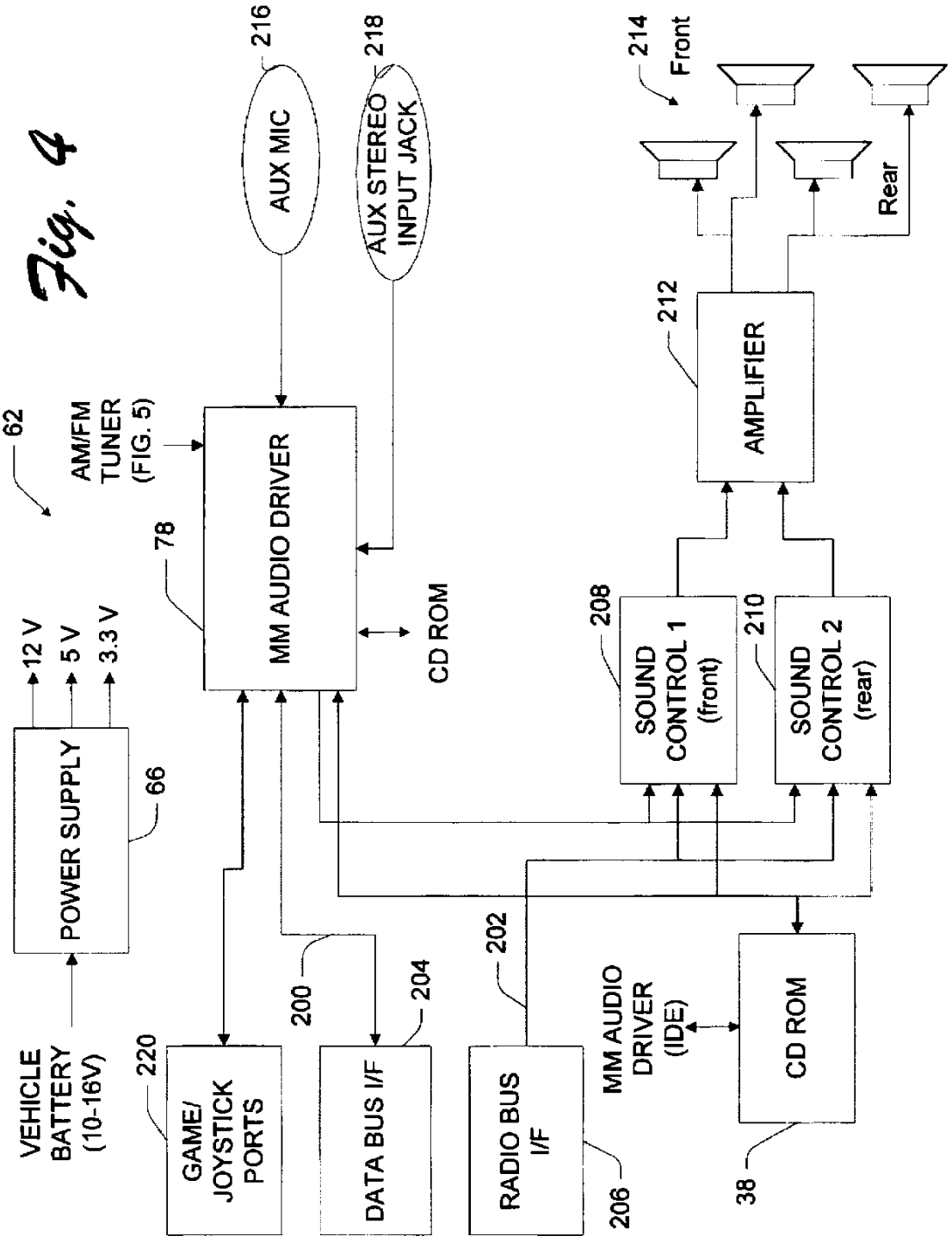
106
108
42

Fig. 3

Fig. 4


62
AM/FM TUNER (FIG. 5)
78
MM AUDIO DRIVER
216
AUX MIC
218
AUX STEREO INPUT JACK
CD ROM
214
Front
Rear
212
AMPLIFIER
208
SOUND CONTROL 1 (front)
210
SOUND CONTROL 2 (rear)
12 V
5 V
3.3 V
POWER SUPPLY
66
VEHICLE BATTERY (10-16V)
220
GAME/ JOYSTICK PORTS
200
204
DATA BUS I/F
202
RADIO BUS I/F
206
MM AUDIO DRIVER (IDE)
CD ROM
38

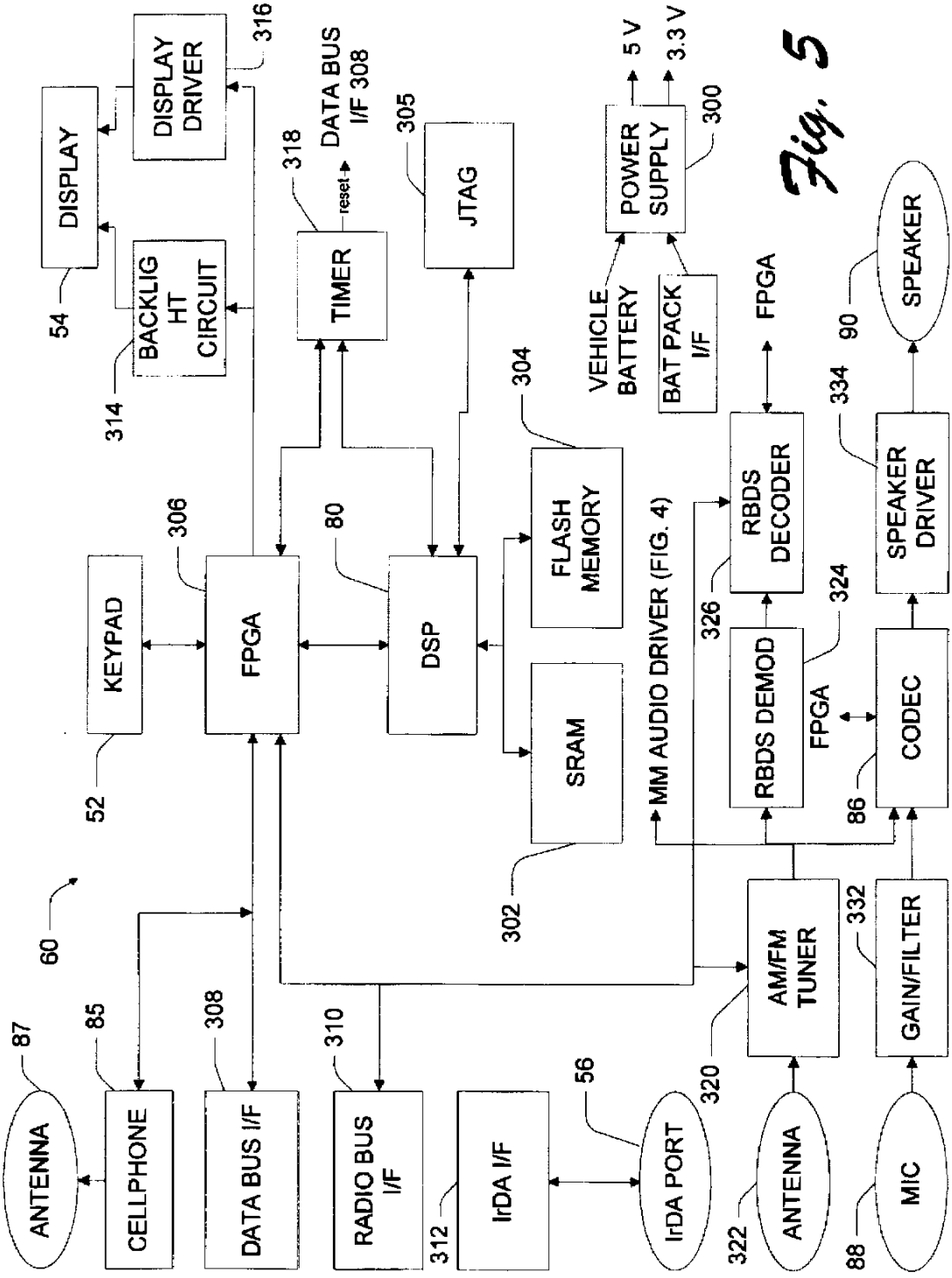

DISPLAY
DISPLAY DRIVER
BACKLIG HT CIRCUIT
TIMER
reset
DATA BUS I/F 308
JTAG
POWER SUPPLY
5 V
3.3 V
VEHICLE BATTERY
BAT PACK I/F
FPGA
SPEAKER
KEYPAD
FPGA
DSP
FLASH MEMORY
SRAM
MM AUDIO DRIVER (FIG. 4)
RBDS DECODER
RBDS DEMOD
FPGA
SPEAKER DRIVER
CODEC
AM/FM TUNER
GAIN/FILTER
ANTENNA
CELLPHONE
DATA BUS I/F
RADIO BUS I/F
IrDA I/F
IrDA PORT
ANTENNA
MIC
60
54
314
316
318
305
300
52
306
80
304
302
326
324
334
90
86
87
85
308
310
312
56
320
322
332
88

Fig. 5

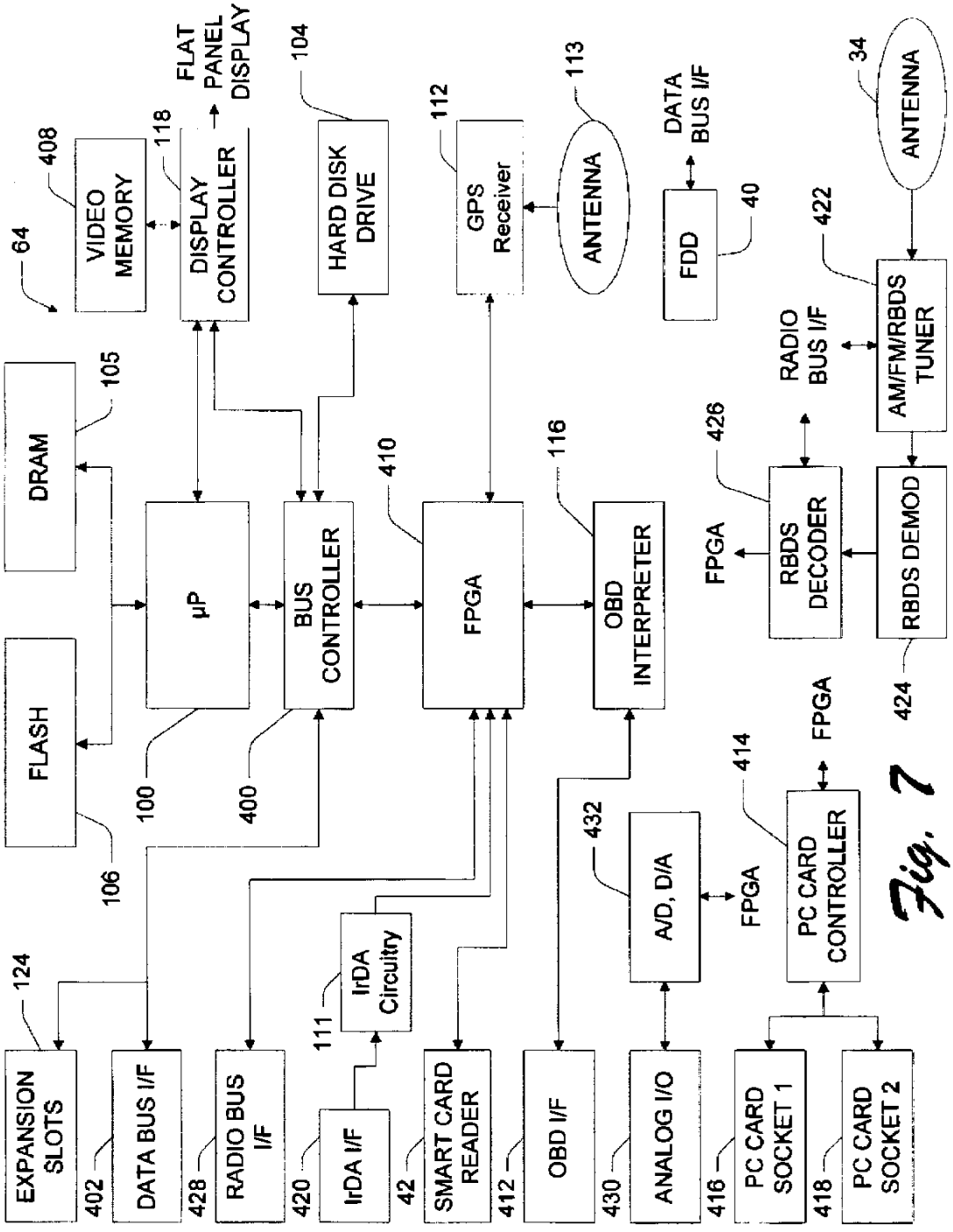

64
408
VIDEO MEMORY
118
DISPLAY CONTROLLER
FLAT PANEL DISPLAY
104
HARD DISK DRIVE
112
GPS Receiver
113
ANTENNA
DATA BUS I/F
FDD
40
34
ANTENNA
422
RADIO BUS I/F
AM/FM/RBDS TUNER
DRAM
105
FLASH
106
µP
100
BUS CONTROLLER
400
410
FPGA
116
OBD INTERPRETER
426
FPGA
RBDS DECODER
RBDS DEMOD
424
124
EXPANSION SLOTS
402
DATA BUS I/F
428
RADIO BUS I/F
420
IrDA I/F
111
IrDA Circuitry
42
SMART CARD READER
412
OBD I/F
432
A/D, D/A
FPGA
414
FPGA
PC CARD CONTROLLER
430
ANALOG I/O
416
PC CARD SOCKET 1
418
PC CARD SOCKET 2

Fig. 7

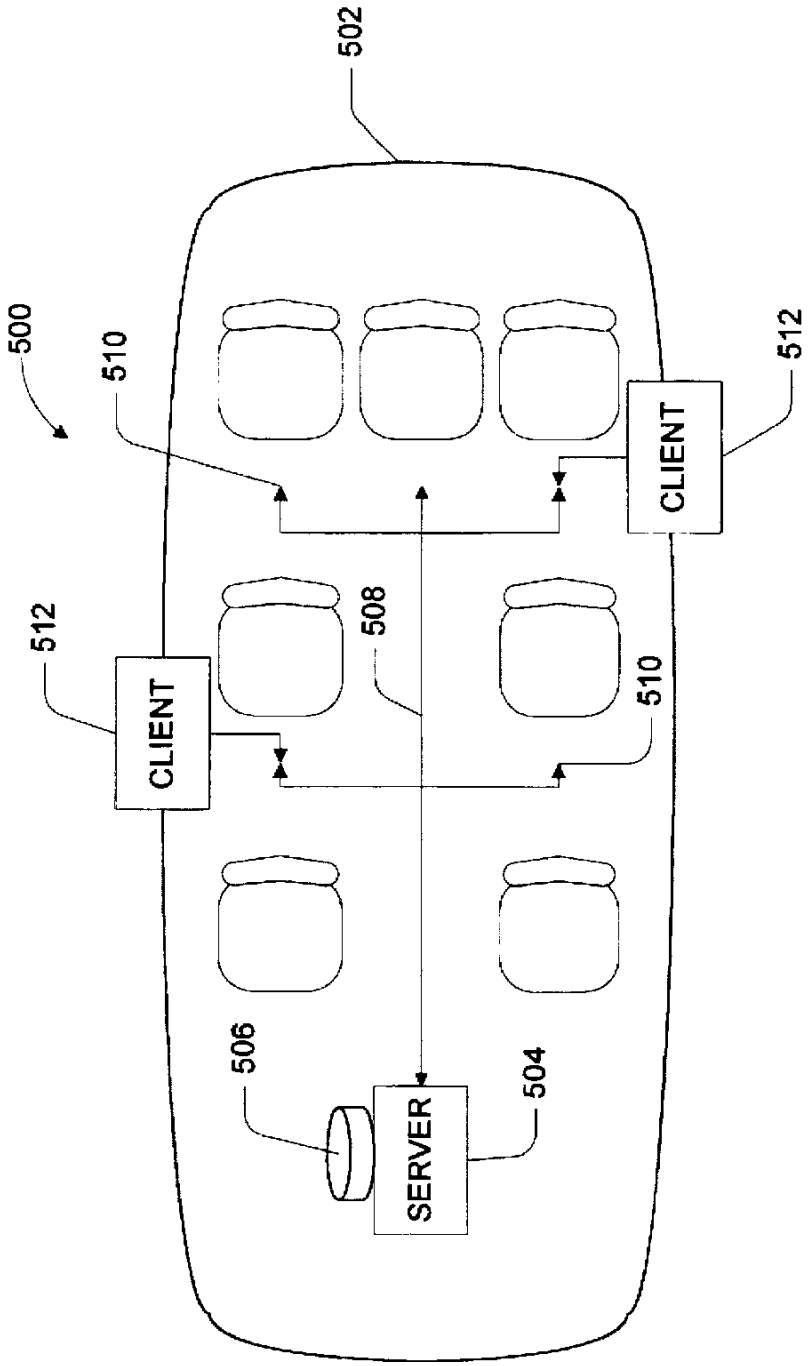


Fig. 8

VEHICLE COMPUTER SYSTEM

TECHNICAL FIELD

This invention relates to computer systems for vehicles.

BACKGROUND OF THE INVENTION

Modern vehicles are typically equipped with several independent electronic systems. For instance, most modern vehicles have a sound system and a security system. The sound system usually consists of an AM/FM radio, a cassette or CD (compact disk) player, an equalizer/amplifier, and speakers. The radio and player are arranged in a metal casing or housing that is mounted in a dashboard of the vehicle. The housing has a standardized size, often expressed in terms of DINs (Deutsche Industry Normen), to ensure that the sound system is compatible with and can be retrofit into most vehicle dashboards.

The security system is entirely separate from the sound system. The security system generally consists of security sensors placed throughout the vehicle, and a central application-specific integrated circuit (ASIC) to monitor the sensors and determine whether security is being jeopardized. Security System also controls actuators to lock/unlock doors or windows, and an alarm or siren.

Most late model (1996 or later for OBD II, 1993 or later for OBD I) vehicles are also constructed with a diagnostic system that analyzes performance of the vehicle's engine, transmission and fuel system, and other components. The diagnostic system can be coupled to an external computer to download or monitor diagnostic information that is useful to a vehicle mechanic during servicing of the vehicle. Additionally, the diagnostic system might include dashboard displays that inform the driver of various operating conditions.

In some recent models, vehicles are being equipped with a navigation system that incorporates a global positioning system (GPS) receiver. The GPS receiver has an antenna to receive signals from a satellite network. The vehicle navigation system uses the satellite positioning signals to compute coordinates that locate the vehicle over the surface of the earth with regard to longitude, latitude, and altitude. Also, with the appropriate map software, the vehicle's location can then be shown on a map.

Cellular communications systems have also been added to vehicles. These communications systems enable the vehicle driver or occupant to transact telephone calls from their vehicle. Some of the more sophisticated systems are voice controlled which permit the driver to initiate or receive calls while traveling without removing a hand from the driving wheel, or diverting his/her eyes from the navigation of the vehicle.

While these various electronics systems have proven useful to vehicle users, there is a drawback in that the systems are unrelated and incompatible. Each system employs separate proprietary dedicated processors or ASICs which execute incompatible proprietary software. If a vehicle owner would like to add a security system to his/her vehicle, the owner must purchase an entire security system from one of the vendors and have it customarily installed. There is no way to add security functionality to an existing electronics system, such as the navigation system or the sound system.

SUMMARY OF THE INVENTION

This invention concerns a vehicle computer system that is capable of integrating these diverse and separate systems as well as offering a general purpose computing platform that allows for easy expandability. The vehicle computer system has a housing sized to be mounted in a vehicle dashboard. This system provides an open hardware architecture and supports an open platform operating system. The open platform operating system supports multiple different applications that can be supplied by a software vendor. For instance, the operating system can support applications pertaining to entertainment, navigation, communications, security, diagnostics, and others In the preferred implementation, the operating system is a multitasking operating system capable of concurrently running multiple applications. The computer has one or more storage devices (e.g., hard disk drive, CD drive, floppy disk drive, cassette player, or smart card reader) which permits the user to download programs from a storage medium (e.g., hard disk, CD, diskette, cassette, or smart card) to the computer. Also, the user can write data to writeable medium (e.g., hard disk, diskette, cassette, or smart card). In this manner, the vehicle owner can easily add new systems to his/her vehicle by installing additional programs.

In one implementation, the vehicle computer system has two independent processors. One processor (e.g., an Intel® based microprocessor) is provided on a computer module which mounts to a stationary base unit of the housing that resides in the vehicle dashboard or other location. The operating system runs on this processor to support the vehicle-related applications and to additionally provide all of the functionality typically afforded by a personal computer. Another processor (e.g., a digital signal processor) is provided on a faceplate module that detachably connects to the base unit. The faceplate module has an AM/FM tuner, display, keypad, and a CODEC which are controlled by the second processor. A third module, known as the support module, resides in the stationary base unit. The support module contains a storage drive (which also functions as an entertainment player), power supply, multimedia audio driver for the entertainment system, and a communications bus.

The three modules operate cooperatively, or independently, of one another except that the support module can not operate by itself. The faceplate module can be detached from the base unit and operate independently as a portable radio with mono-audio sound. By use of the CODEC with built in speaker and microphone, the faceplate module can further function as a portable phone or a handset unit that can communicate with the base unit in the vehicle. The portable faceplate module can also be used to receive paging information, take voice notes, and to remotely operate the security system. While detached, the faceplate module is powered by an independent source, such as batteries.

The faceplate module and support module can operate independently of the computer module. The faceplate module is physically connected to the front of the base unit and electronically interfaced with the support module. When connected and the computer module is not connected, the faceplate module totally controls the entertainment system of the vehicle. The faceplate processor controls the multimedia audio driver and the CD player in the support module. The faceplate module derives its power from the vehicle batteries via the power supply in the faceplate module.

When the computer module is also present, the faceplate module is controlled as a hot pluggable peripheral device. The processor on the computer module has full control of the communications bus and is master to the faceplate processor. The computer module processor controls systems not contained in the faceplate and can indirectly control

resources contained in the faceplate. Also, the faceplate module processor lends signal processing resources to enhance the entertainment services and directly controls the resources contained in the faceplate.

The modular computer system affords tremendous flexibility when installing the system in a vehicle. As a low cost base model, the support module and faceplate module are installed in place of the conventional sound system. The housing is sized to the standard DIN form factor, so that the low cost base model can be substituted directly for the present sound system. This low cost model gives the owner an enhanced sound system with multimedia capabilities, plus a portable radio/phone system. The computer module can be installed as an upgrade feature to provide full computer system functionality. For instance, the computer module supports the navigation, security, diagnostics, communications, and entertainment systems, as well as any other application that the vehicle owner would like to subsequently install; a standard expansion bus is part of the computer module. The expansion bus can be used for adding additional peripherals.

In another implementation, the vehicle computer system includes a centralized server located in the dashboard or elsewhere in the vehicle and remote client computers located at the passengers of the vehicle. The server is connected to retrieve data or programs from the storage device, such as the CD player, floppy diskette, or hard drive, and to download such information to the client computers over a data network arranged in the vehicle. In this manner, a passenger can operate a game application or watch a video from their seat in the car without interrupting the driver or other occupants.

In yet another application, a single computer module could drive two or more graphic displays using separate graphic controllers; thus displaying separate images such as a moving map for the driver on one display and entertainment or TV for the passenger on another display.

BRIEF DESCRIPTION OF THE DRAWINGS

The same reference numerals are used throughout the drawings to reference like components and features.

FIG. **1** is a diagrammatic illustration of a vehicle computer system.

FIG. **2** is a diagrammatic side view of a base unit and detachable faceplate employed in the vehicle computer system.

FIG. **3** is a block diagram of the vehicle computer system according to one implementation having a faceplate module, a support module, and a computer module.

FIG. **4** is a functional block diagram of the support module.

FIG. **5** is a functional block diagram of the faceplate module.

FIG. **6** is a diagrammatic side view of the faceplate operating as a communications device while detached from the base unit of the vehicle computer system.

FIG. **7** is a functional block diagram of the computer module.

FIG. **8** is a diagrammatic illustration of the vehicle computer system according to another embodiment having a centralized server computing unit and one or more client computing units distributed on a data network in a vehicle.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** shows a vehicle computer system **20** according to one implementation of this invention. Vehicle computer system **20** has a centralized computer **22** coupled to various peripheral devices, including a monitor **24**, security sensors **26**, a vehicle diagnostic interface **28**, speakers **30**, vehicle battery **32**, and antenna(s) **34**. The computer **22** is assembled in a housing **36** that is sized to be mounted in a vehicle dashboard, similar to a conventional car stereo. Preferably, the housing **36** has a form factor of a single DIN (Deutsche Industry Normen). But, it possibly could be housed in a 2 DIN unit or other special form factor for an OEM.

The computer **22** runs an open platform operating system which supports multiple applications. Using an open platform operating system and an open computer system architecture, various software applications and hardware peripherals can be produced by independent vendors and subsequently installed by the vehicle user after purchase of the vehicle. This is advantageous in that the software applications do not need to be dedicated to specially designed embedded systems. The open hardware architecture is preferably running a multitasking operating system that employs a graphical user interface. One preferred operating system is a Windows® brand operating system sold by Microsoft Corporation, such as Windows 95® or Windows NT® or other derivative versions of Windows®. A multitasking operating system allows simultaneous execution of multiple applications.

The computer **22** includes at least one storage drive which permits the vehicle user to download programs and data from storage medium. In the illustrated implementation, the computer **22** has a CD ROM drive **38** which reads application-related CDs, as well as musical, video, game, or other types of entertainment CDs. In this manner, the CD ROM drive **38** performs a dual role of storage drive and entertainment player. Also, a hard disk drive (not shown in FIG. **1**) is included on the computer module which can be used for storing both application programs and user data. The computer **22** has an optional 3.5" floppy diskette drive **40**, a smart card reader **42**, and dual PCMCIA card sockets **44** which accept PCMCIA card types II and III. Hereinafter, the acronym "PC-Card" will be used in place of the acronym "PCMCIA."

The storage drives are mounted in a stationary base unit **46** of housing **36**. The base unit **46** is constructed and sized to be fixedly mounted in the dashboard. The housing **36** also has a faceplate **48** which is pivotally mounted to the front of the base unit **46**. The faceplate can be rotated to permit easy and convenient access to the storage drives.

FIG. **2** shows the housing **36** in more detail. Faceplate **48** has a physical coupling assembly **50** which enables the pivotal movement to alternately cover or expose the storage drives within the base unit **46**. Additionally, the physical coupling assembly **50** enables the faceplate **48** to be attached to or detached from the base unit **46**. This is represented in FIG. **1** in which the faceplate **48** is entirely detached from the base unit **46**.

With reference again to FIG. **1**, the computer **22** has a keypad **52** and a display **54** on the faceplate **48**. The display **54** is preferably a back lit LCD. The operating system executing on the computer **22** controls the faceplate keys **52** and the faceplate display **54** as peripheral devices when the faceplate is attached to the base unit. Additionally, as will be described below in more detail, the computer has a voice recognition device situated on the faceplate to permit the user to verbally enter commands in a hands-free, eyes-free environment. These voice commands can be used for controlling most operating modes of the vehicle computing platform. The computer **22** is also equipped with an IrDA

(infrared developers association) transceiver port **56** mounted on the faceplate **48** to transmit and receive data and programs using infrared signals. The entire faceplate unit **48** behaves as a multifunction peripheral to the computing platform.

To load an application or data onto the computer **22**, the vehicle user inserts a CD or diskette, if the application is not already contained on the hard disk, into the appropriate drive and the operating system downloads the application or data therefrom. The installation process can be automatically handled by the operating system, or with the assistance of commands input from the user in the form of keyed sequences on the keypad **52** or verbal instructions using the voice recognition device. Another technique to load data or applications or transfer data with other computing devices is through the use of the IrDA transceiver port **56**.

The computer **22** can output visual data to the LCD **54** at the faceplate, or to the standalone monitor **24**. The monitor **24** is preferably a small flat panel display (e.g., 6.4" screen) that is movably mounted on a stand or yoke and remotely located from the computer. The monitor **24** is fully adjustable to different viewing positions that can be seen by the driver or other passengers in the vehicle. The type of data displayed on the monitor can range widely from word instructions concerning the vehicle's performance, to diagrammatic directions used by the navigation system, to video movies for in-car entertainment. The monitor **24** is equipped with an automatic override switch **58** which automatically disables the display of any non-driving related data when being viewed by the driver. In the event that the monitor is positioned for driver viewing, only information supportive and helpful to driving (e.g., diagnostics, navigation directions) is displayed on the monitor, while distracting information (e.g., video movies, games) are blocked from display. In one implementation, the switch is an electrical cylindrical switch which closes when the display is capable of being viewed by the driver; thus, the software can sense the display position and only allow permitted information to be displayed.

In general, the vehicle computer system **20** can be used to integrate multiple vehicle-related systems onto one open platform hardware and software architecture. For instance, the vehicle computer system **20** can serve as a multimedia entertainment system, a navigation system, a communications system, a security system, and a diagnostics system. Moreover, the vehicle computer system **20** provides additional functionality traditionally associated with desk-top and laptop personal computers. For instance, vehicle computer system **20** can support word processing applications, spreadsheet applications, database applications, and appointment/schedule applications. Furthermore, the vehicle computer system **20** can be configured to operate as a server to other computing units in the vehicle to distribute games, video movies, and the like to passengers.

FIG. **3** shows the computer **22** according to one implementation of the invention. Computer **22** has three primary modules: a faceplate module **60**, a support module **62**, and a computer module **64**.

Support Module **62**

The support module **62** resides in the stationary base unit **46** (FIG. 1) that is mounted in the vehicle dashboard. The support module **62** includes a power supply subsystem **66** and an internal bus **68** for the computer **22**. The internal bus **68** has a first interfacing slot **70** and a second interfacing slot **72** which provide shared access to the bus from the faceplate module **60** and the computer module **64**. The support module **62** also has the CD ROM player **38**, a multimedia audio driver **78**, audio amplifier, and sound control circuitry.

FIG. **4** shows the support module in more detail. The power supply subsystem **66** derives power from the vehicle battery, and transforms the battery voltage level (e.g., 10–16 volts) to appropriate chip voltage levels (e.g., 3.3–5 volts) or to a voltage sufficient to run the CD player **38**, diskette memory drive **40**, hard disk drive, and other devices possibly requiring 12 volts. The internal bus **68** preferably comprises two separate buses: an data-related bus **200** (e.g., a PCI bus) and a radio-related bus **202** (e.g., an I^2C bus). The first and second interfacing slots **70**, **72** include the data bus interface **204** for bus **200** and the radio bus interface **206** for bus **202**. The second interfacing slot also includes a power interface to supply power to the CPU module. For the faceplate module, however, vehicle power is taken directly from the vehicle battery and passed to the faceplate module, which has its own power regulation circuitry.

The multimedia audio driver **78** controls the audio sound system of the vehicle. It is coupled to control the CD ROM **76**, and parallel sound controllers **208** and **210**. The audio data coming out of the CD-ROM drive can be selected to feed the parallel sound controllers which control the volume, treble, bass, and balance for the front and rear speakers, respectively. The use of two sound control chips enables different audio sources to be selected and played in the front and rear of the vehicle. For example, the vehicle driver can listen to navigation instructions while the rear seat passengers can listen to their favorite tunes.

The audio signals are amplified by power amplifier **212** and converted to stereo sound by quad-speaker system **214**. The multimedia audio drive **78** also supports an auxiliary microphone input **216**, and an auxiliary stereo jack input **218** for attaching an external tape drive, portable tape player or some other external sound sources. A game/joystick port **220** is also provided in the support module **62** and coupled to the multimedia driver **78**.

Faceplate Module **60**

With reference to FIG. **3**, the faceplate module **60** resides on the detachable faceplate **48** (FIG. 1). The faceplate module **60** includes a first processor in the form of a digital signal processor (DSP) **80**, although other types of processors may be employed. The faceplate module **60** further includes an electrical interface **82** which compatibly couples to the first interfacing slot **70** on support module **62** to permit data communication between the faceplate module and the support module.

The faceplate module **60** is primarily dedicated to entertainment and communications. When the faceplate module is coupled to the support module, the DSP **80** uses the internal shared bus **68** on the support module **62** to control the CD player **38** via the multimedia audio chip **78** when playing musical or video CDs and the multimedia audio driver **78** to optimize sound and video quality. It should be noted that analog or digital cassette players, or other entertainment players, can be substituted for the CD player or added to the system.

The faceplate module **60** is also equipped with a radio tuner **84** which supports radio functionality. The radio tuner **84** includes an AM/FM tuner, RBDS demodulator, and decoder to recover information transmitted on the FM subcarrier programming. Additionally, a cellular telephone **85** or an RF transceiver can optionally be attached to the faceplate. The faceplate module **60** includes an audio analog to digital converter and digital to analog converter (or "CODEC") **86** that converts analog voice signals into data

that can be sampled by the DSP **80**. Also, the CODEC converts DSP sample data into analog signals that can drive a small loud speaker. The CODEC **86** in conjunction with the cellular phone **85** can be configured to provide full cellular phone functionality, independent of the computer module **64**, or to operate as a remote handset that communicates with the computer module **64** or other phone. The CODEC **86** controls a microphone **88** to receive verbal input, and a speaker **90** to output voice. A power port **92** is also provided on the faceplate module **60** to enable use of an external power source (e.g., cellular battery pack **94**) when the faceplate module is physically detached from the base unit or to regulate the vehicle battery voltage when attached to the base unit.

FIG. **5** shows the faceplate module **60** in more detail. It has its own power supply subsystem **300** which receives power from either the vehicle battery or from a battery pack in the event that the faceplate module is detached from the base unit. The faceplate power supply subsystem **300** transforms the input voltage level to a suitable chip voltage level of 3.3 volts or 5 volts.

The DSP **80** has an SRAM **302** for data storage and buffering and a flash memory **304** for program and voice template storage. This flash memory can be updated via the data bus and JTAG (Joint Test Action Group) port **305**. Using the voice template in the flash memory **304**, the DSP **80** operates in conjunction with the CODEC **86** as a voice recognition device that records and analyzes voice commands in relation to the stored voice template to determine and execute verbal instructions. In some cases the request will need to be sent to the CPU module if present.

The DSP **80** is coupled to a field programmable gate array (FPGA) **306** which coordinates data flow on the faceplate module. The FPGA **306** is coupled to the data bus interface **308** and the radio bus interface **310** which form part of the electrical interface **82** that connects to the first interfacing slot **70** of the support module **62**. The data bus interface **308** also provides connection to any internal components embedded in the faceplate module **60**, such as the cellphone chipset **85**. The faceplate module **60** also has an IrDA interface port **312** coupled to the IrDA port **56** to convey the data to the computer module **64**, as described below. This IrDA interface **312** is also part of the electrical interface **82**.

The DSP **80** further controls the keypad **52** and display **54** via the FPGA **306**. The DSP **80** scans and interprets inputs from the keypad **52**. The input data can be acted upon by the DSP **80** or sent to the computer module **64** via the data bus interface **308**. The display **54** is preferably a back lit LCD, driven by a backlight circuit **314** and a display driver **316**. The display is memory mapped to an I/O space in the DSP **80** for direct control by the DSP. Additionally, the computer module **64** can send commands to the DSP to indirectly control the display resources and other DSP controlled resources. A watchdog timer **318** is contained on the faceplate module gets periodically reset by the DSP. If the DSP fails to reset this timer, then something is hung and all resources on all three modules are reset and the unit recovers to a default state.

The faceplate module has an AM/FM tuner **320** connected to receive an RF signal from an antenna **322**. The antenna **322** can be the vehicle antenna, or a separate remote antenna that is used by the faceplate module when detached from the base unit. The RF signal received at the tuner **320** is demodulated by a demodulator **324** to retrieve the information signal from the carrier signal. The information signal is then decoded by a decoder **326** and passed to the DSP **80** via the FPGA **306**. It is noted that the decoding function performed by decoder **326** can alternatively be performed by logic contained in the FPGA **306**. The DSP passes the radio signal over the data bus interface **308** to the multimedia audio driver in the support module **62** to be played over the sound system in high quality, stereo sound.

A separate mono CODEC **86** is also coupled to receive analog sound signals from the microphone **322** or tuner **320**. The CODEC **86** in conjunction with the microphone **88**, speaker **90**, and cellphone or RF transceiver provides telecommunications functionality in the faceplate module. A gain/filter **332** and a speaker driver **334** associated with the CODEC **86** are optimized to provide premium voice recognition and playback for use against vehicle and environmental noise. The CODEC **86** can also be used to supply voice commands to the DSP **80** via FPGA **306**. The DSP **80** is programmed to recognize certain voice commands using a voice template stored in the flash memory **304**.

The faceplate module **60** can be disconnected from the base unit and employed as a portable RF device for both radio reception and telecommunications with the optional cellphone module or RF transceiver module. As shown in FIG. **5**, the cellphone module **85** is connected to the data bus I/F **308** and to an antenna **87** to provide telecommunications. FIG. **6** shows the faceplate module **60** detached from the base unit and coupled to a conventional cellular battery pack **350** and a cellular phone RF transceiver and antenna unit **352**. The faceplate module **60** can play monosound radio using the speaker **90**, and provide telecommunications directly to a cellular network, or indirectly through the base unit. Additionally, the portable RF device can provide support for features like paging, voice recording, and voice dialing.

Computer Module **64**

The computer module **64** may reside in the dashboard-mounted base unit **46** or in a separate location and includes a second processor in the form of a microprocessor **100**, such as an Intel® 486 microprocessor. The computer module **64** is configured as a plug-in motherboard having an electrical interface **402**, which compatibly couples to the second interfacing slot **72** on support module **62**. When plugged in, the computer module **64** has access to the internal shared bus **68**. In this manner, the faceplate module **60**, support module **62**, and computer module **64** all share the same internal bus **68** to communicate with one another. The computer module **64** derives power from power supply subsystem **66** on the support module **62**.

The microprocessor **100** runs an open platform operating system, such Windows 95® or Windows NT® or other Windows® derivative operating systems from Microsoft Corporation. The operating system is stored in a hard disk drive **104** (e.g., >200 Mbytes). The computer module **64** supports any variety of applications that the vehicle user might desire. These applications can also be stored on the hard disk drive **104** or on a removable storage medium, such as a CD ROM, cassette, CD changer, or floppy diskette. A DRAM **105** (e.g., 8 Mbytes) and flash memory **106** (e.g., 512 Kbytes) are employed in the computer module to support the microprocessor **100** in running the operating system and loaded applications.

When the user wishes to install a program on the computer module **64**, he/she inserts a floppy diskette into the floppy disk drive **40** or a CD ROM into the CD drive **38**. The operating system senses the new storage device and initiates the install procedures. BIOS extensions are stored with the operating system to enable booting from the CD ROM or

floppy disk drive (FDD). The computer module **64** has a CD ROM driver **108** and diskette driver **110** to control the CD player **38** or diskette drive **40**, respectively, during this read operation. If contained on the CD, the program data is transferred from the CD ROM drive **38** through the MM chip **78** to bus **68** on the support module **62**, and then over the interface coupling **72/102** to the microprocessor **100** and RAM **106** on the computer module **64**. If the data is contained on the floppy disk, then the data is transferred directly through the FDD interface contained on the computer module. As noted above, data can also be input via the IrDA port **56** on the faceplate. Such data is transferred via the faceplate/support coupling **70/82**, the shared bus **68** (or separate conductor), and the support/computer coupling **72/102** to the IrDA interface circuitry **111** contained on the computer module.

The computer module **64** has a navigation system **112** which includes both a GPS (global positioning system) receiver and a map application, such as Automap™, a program produced by Microsoft Corporation. A security system **114** is provided in the computer module **64** to manage vehicle security. The security system **114** monitors the security sensors **26** (FIG. **1**) for any potential threat of theft or vandalism. The security system **114** is connected to actuators which lock/unlock doors and windows, and to an alarm which can be activated upon detection of unwanted tampering.

An OBD (On Board Diagnostic) interpreter **116** is provided in the computer module to communicate with the OBD system built into the vehicle by the manufacturer. The OBD interpreter **116** interprets the status data received and provides performance related information from the vehicle's OBD system to the microprocessor **100**. Also, commands can be provided to the interpreter which allows non-critical car systems to be controlled.

The computer module **64** also includes at least one flat panel display controller **118** to control the flat panel monitor **24**. A dual PC card socket **44** is provided to support 2-type II or 1-type III PC cards. Such cards might be configured as extra memory, moderns, network adapters, or other components. The computer module **64** also has a smart card reader **42** which accepts smart cards (i.e., plastic cards with an integrated circuit mounted thereon). The smart cards can be programmed as a key to the vehicle, to contain encrypted driver identification that the security system uses to authenticate the driver before the vehicle can be started, and be programmed to remember vehicle driver configuration profiles. In the event the microprocessor does not recognize the identification on the smart card, the security system can activate the alarm or take other precautionary measures to prevent theft by unauthorized users. For added security, a driver might also be asked to input a PIN (personal identification number) using the keypad **52** on the faceplate.

The computer module also includes expansion slots **124** to support a variety of peripheral devices. For instance, the computer module **64** can support additional peripherals via the expansion slots such as a universal serial bus, analog I/O, an RF transceiver, a cellular phone/modem, a display, a tape player, an MPEG video/audio decoder, a TV tuner, a gyroscope, a keyboard, a mouse, a joystick, and a docking station.

FIG. **7** shows the computer module **64** in more detail. The microprocessor **100** is coupled to a bus controller **400**, such as an PCI bus controller. The bus controller **400** is attached to the data bus interface **402** and the expansion slots **124**. Additionally, the bus controller **400** directly supports the hard disk drive **104**. A DRAM **105** (e.g., 8 Mbytes) and a flash memory **106** (e.g., 512 Kbytes) provide data and caching storage for the microprocessor. The microprocessor **100** manages the flat panel display controller **118** with video memory **408** (e.g., 512 Kbytes) to output visual display data received from bus controller **400** to the flat panel display **24** (FIG. **1**).

An FPGA **410** is connected to the bus controller **400** and is controlled by the microprocessor **100**. The FPGA **410** is connected to the navigation system **112** and the OBD interpreter **116**. The GPS receiver **112** is connected to GPS antenna **113** to receive RF signals from the satellite-based GPS. The GPS antenna **113** is separate from the AM/FM antenna **322** (FIG. **5**) and the cellphone antenna **87** (FIG. **5**) because of the different wavelengths. However, in another implementation, the GPS antenna **113** and the cellphone antenna **87** can be packaged as two antenna elements in one enclosure. The navigation system **112** can be implemented using a GPS chipset manufactured by Trimble Navigation, Rockwell International, Phillips Semiconductor or others. The OBD interpreter **116** is connected to an OBD interface **412** that interconnects to the vehicle manufacturer's diagnostic system.

The bus controller **400** supports a PC card controller **414** which manages two PC card sockets **416** and **418**. The first PC card socket **416** accepts a type II PC card when no type III card is present in the second slot, and the second PC card socket **418** accepts either a type II or type III PC card. The FPGA **410** is further connected to a smart card reader **42**, and to an IrDA interface **420** via IrDA circuitry **111**. The IrDA interface **420** is coupled to receive or transmit data via infrared signals using the IrDA port **56** on the faceplate. The FPGA has a DUART or other serial-to-parallel converter to perform rudimentary conversion of the serial data stream received from the smart card or infrared carrier signal to a data set usable by the microprocessor.

The computer module **64** is equipped with a second radio receiver unit consisting of an AM/FM tuner **422** connected to receive an RF signal from antenna **34**, a demodulator **424**, and a decoder **426**. The second radio receiver unit can be used to receive radio signals for timed recording of radio programming for later playback. Additionally, the second radio receiver can be tuned to receive both the FM subcarrier and audio programming of the primary FM channel. Such FM subcarrier might carry weather, news, sports, financial, traffic, paging, or other information. With two radio receiver units (i.e., one in the faceplate module and one in the computer module), the computer system can receive both the primary channel and the subchannels concurrently. A radio bus interface **428** is used to connect the second radio receiver unit to the FPGA (**410**) which then converts the data to digital data to be transmitted over the data bus (e.g., PCI bus) to the multimedia audio driver and sound system on the support module **62**.

An analog I/O **430** and converters **432** are optionally provided on the computer module **64** to provide an analog input port to the computer and are used to interface to the security system. The security sensors **26** (FIG. **1**) are connected to analog inputs **430**, while the actuators which lock/unlock doors and windows and an alarm are driven by analog outputs **430**.

The modular vehicle computer system described herein offers a unique flexibility to be customarily configured according to the tastes and preferences of each vehicle owner. There are three primary configurations of the modular vehicle computer system: a portable RF device, an

entertainment/communication system, and a fully operable computer system that supports communications and entertainment.

Configuration 1: Portable RF Device

In this first configuration, the faceplate module **60** is physically detached from the base unit and electrically disconnected from the support module interface slot **70** to operate as a portable RF electronics device. In this mode, the faceplate module **60** functions as a portable radio unit with monosound via the single speaker **90**. The faceplate module **60** can also function as a portable telecommunications device using the CODEC **86**, microphone **88**, and speaker **90** for voice input/output, and the keypad **52** or voice to dial numbers. Additionally, by virtue of the RF receiver and using the RBDS information over the FM subcarrier, the faceplate module can function as a pager to receive messages that can be stored as voice notes, or displayed on the LCD **54**. Also, voice can be recorded by the user and stored in the flash memory of the faceplate.

Configuration 2: Vehicle Entertainment/Communication System

In this second configuration, the faceplate module **60** is attached to the base unit and electrically connected to the interface slot **70** to communicate with the support module **62**. However, the computer module is removed from the base unit. In this arrangement, the double module unit functions as an entertainment/communications system in that it provides all of the functionality of conventional car stereo systems while optionally integrating telecommunication functionality. The DSP **80** in the faceplate module **60** controls the AM/FM radio, the CD ROM drive, and the multimedia audio drive. The vehicle user can play CDs or tune to a favorite radio station and listen to high quality, stereo sound. Additionally, the user can receive and initiate telephone calls, receive pages, or record voice notes in the same manner as the portable faceplate module. One added convenience is that all of these features are voice activated to maintain a hands-free, eyes-free driving environment.

Configuration 3: Full Computer System

In the third configuration, both the faceplate module **60** and the computer module **64** are coupled to the support module. The triple module arrangement forms the full computer system capable of supporting a wide range of applications (e.g., navigation, security, diagnostics) as well as communications. Additionally, the tri-module configuration provides an enhanced entertainment system that offers both audio and video, as well as a second tuner to receive financial, weather, and other news in the FM sub carriers via RBDS.

When both processing modules are connected to the support module, the microprocessor **100** on the computer module **64** operates as the master processor with full control of the shared bus **68** and resources. The DSP **80** in the faceplate module functions as a slave processor. This hierarchy is established simply by plugging the computer module into the support module which places the DSP in a slave mode. The DSP is relegated to audio signal processing for enhanced stereo sound, scanning the keypad **52**, exporting visual data to the LCD **54**, controlling the faceplate tuner and performing voice recognition. As a result, the faceplate module **60** is treated as a peripheral device on the shared bus **68** that is controlled by the computer module **64**, whereby the keypad **52**, LCD **54**, communications CODEC **86**, and faceplate tuner serve as I/O peripherals accessed via registers in the faceplate FPGA.

The faceplate module **60** can be removed while the computer module **64** is powered up. With the loss of these peripherals, the computer module **64** loses some functionality and some DSP enhanced audio qualities. However, the computer module **64** still supports many applications, including security, diagnostics, navigation, paging, and others.

It is further noted that the complete vehicle computer system can be removed from the base unit for security reasons, or to plug the computer into a docking station at the user's residence or office. With a docking station, the user can install or configure various programs for vehicle usage, or simply use the computer module as a portable computer.

System Software

As noted above, the vehicle computer system runs an open platform operating system, such as Windows 95®, Windows NT®, or Windows® derivative. There are several applications that are supported by the operating system. These applications include a navigation application, a security application, a radio-on-demand application (program recording and playback based on radio program attribute such as time or content), a paging application, and a faceplate user interface. The applications can be stored on the hard disk drive, or on CD ROMs that are inserted into the CD ROM drive.

The vehicle computer system also implements several application program interfaces (APIs) that offer specific functionality to support the various applications. Example APIs include a position and navigation API, a smart card and cryptography API, a diagnostics API, radio/TV tuner API, and analog I/O API.

These applications and APIs are vehicle related. Other applications which are unrelated to vehicles can also be loaded onto the computer. Such applications might include a banking/financial application, such as Money™ from Microsoft Corporation, to assist the user in banking while on the road. There might also be video applications that facilitate display of in-car video movies or games. Essentially, the vehicle computer system can support any applications that run on the open platform operating system, which are many and varied.

Vehicle Network

FIG. **8** shows a vehicle computer network system **500** designed for a vehicle **502**. In this example illustration, the vehicle **502** is a minivan or sport utility vehicle which seats seven occupants. The system **500** has a server computing unit **504** which is mounted in a first location of the vehicle **502**. Preferably, this server computing unit **504** is implemented as computer **22** described above and mounted in the vehicle dashboard or other suitable location. The server computing unit **504** runs a server operating system, such as Windows NT®.

A mass storage device or database **506** is provided at the server computing unit **504** to store data. In one implementation, the storage device **506** comprises data and programs stored on a CD that can be read using the CD ROM drive of the server computing unit. Alternatively, the storage device **504** can be implemented as a hard disk drive or a tape storage.

A data network **508** is arranged throughout the vehicle **502** to provide connection ports at various locations remote from the server computing unit **504**. Here, connection ports **510** are provided at each of the rear five passenger seats.

The vehicle computer network system **500** has one or more client processing units **512** equipped with a compatible interface adapter for the network connection port **510**. Once connected to the network, the client processing unit **512** can

receive data and programs from the central storage device **506** via server computing unit **504**. The client processing unit **512** preferably has a visual display screen and audio sound card to provide multimedia entertainment.

According to this arrangement, the server computing unit **504** can provide in-car entertainment to passengers. For instance, a movie can be shown to a passenger by inserting a video disk into the CD ROM drive **506** at the server computing unit **504**. The central computing unit becomes a video server distributing video over the data network **508** to the client processing units **512**. Other types of entertainment include games and music.

The network system can be configured to be interactive in which the client computing units **512** can request certain entertainment from the server computing unit **504**. For example, suppose a game CD having multiple games is loaded in the CD ROM drive. One passenger wants to play an combat video game, while another passenger wishes to play computer chess. Each client computing unit can request the appropriate game from the server computing unit **504**, which retrieves the games and distributes them to the requesting client computing units.

In compliance with the statute, the invention has been described in language more or less specific as to structure and method features. It is to be understood, however, that the invention is not limited to the specific features described, since the means herein disclosed comprise exemplary forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents and other applicable judicial doctrines.

We claim:

1. A vehicle computer system comprising:

a housing of a size suitable to be mounted in a vehicle dashboard;

a computer mounted within the housing;

an open platform operating system executing on the computer, the operating system being configured to support multiple applications that are supplied by a vehicle user;

a faceplate attached to the housing; and

a peripheral device contained in the faceplate and compatibly connected to the computer, the operating system managing the peripheral device.

2. A vehicle computer system as recited in claim **4** further comprising:

a removable storage medium that stores individual ones of the applications; and

the computer having a storage drive that compatibly reads the storage medium to load the individual applications from the storage medium to the computer.

3. A vehicle computer system as recited in claim **4** wherein the operating system is a multitasking operating system that is capable of concurrently running the multiple applications.

4. A vehicle computer system as recited in claim **1** wherein the peripheral device is a display.

5. A vehicle computer system as recited in claim **1** wherein the peripheral device is an input mechanism.

6. A vehicle computer system as recited in claim **1** wherein the applications supported by the operating system are selected from a group comprising a navigational application, an entertainment application, a communications application, a vehicle security application, and a vehicle diagnostics application.

7. A vehicle computer system as recited in claim **1** wherein the housing has a form factor of a single DIN.

8. A vehicle computer system as recited in claim **1** further comprising a data network connected to the computer, the data network having at least one connection interface provided at a location remote from the vehicle dashboard.

9. A vehicle computer system as recited in claim **8** further comprising at least one client processing unit having a network port to compatibly couple to the connection interface of the data network.

10. A vehicle computer system comprising:

a housing of a size suitable to be mounted in a vehicle dashboard, the housing having first and second support structures that can be physically connected to, or separated from, one another;

a first processing unit mounted to the first support structure of the housing to provide first processing and control capabilities;

a second processing unit mounted to the second support structure of the housing to provide second processing and control capabilities;

a busing subsystem to electrically interconnect the first and second processing units when the first and second support structures are physically connected to one another; and

the first processing unit, the second processing unit, and the busing subsystem being arranged within the housing so that the vehicle computer system conforms to a form factor for mounting in the vehicle dashboard.

11. A vehicle computer system as recited in claim **10** wherein

the second support structure is a base unit constructed for physical mounting in the vehicle dashboard; and

the first support structure is a detachable faceplate that can be attached to or detached from the base unit.

12. An vehicle computer system as recited in claim **10** wherein:

the first processing unit is a digital signal processor; and

the second processing unit is microprocessor.

13. A vehicle computer system as recited in claim **10** further comprising a data network connected to the second processing unit, the data network having at least one connection interface provided at a location remote from the vehicle dashboard.

14. A vehicle computer system as recited in claim **13** further comprising at least one client processing unit having a network port to compatibly couple to the connection interface of the data network.

15. An vehicle computer system comprising:

a housing having a base unit and a faceplate;

a support module mounted to the base unit, the support module having a communications bus and first and second interfacing slots to provide access to the communications bus;

a first processor mounted to the faceplate to form a faceplate module, the faceplate module being compatibly connected to the first interfacing slot of the support module;

a computer module having a second processor, the computer module being compatibly connected to the second interfacing slot of the support module; and

the communications bus electronically interconnecting the faceplate module, the computer module, and the support module.

16. A vehicle computer system as recited in claim **15** wherein the housing has a form factor of a single DIN.

17. A vehicle computer system as recited in claim 15 wherein the computer module has an open platform operating system executing on the second processor, the operating system being configured to support multiple applications that are supplied by a vehicle user.

18. A vehicle computer system as recited in claim 15 wherein the faceplate module is controlled as a peripheral device by the computer module.

19. A vehicle computer system as recited in claim 15 further comprising an input device provided on the faceplate module that is electrically coupled as a peripheral to the computer module.

20. A vehicle computer system as recited in claim 15 further comprising an output device provided on the faceplate module that is electrically coupled as a peripheral to the computer module.

21. A vehicle computer system as recited in claim 15 further comprising a storage drive mounted in the housing, the storage drive reading information stored on a compatible storage medium to load the information into the computer module.

22. A vehicle computer system as recited in claim 15 further comprising a graphical display monitor separate and remotely located from the housing, but electrically coupled as a peripheral to the computer module.

23. A vehicle computer system as recited in claim 15 further comprising:

a first radio tuner provided in the faceplate module; and

a second radio turner provided in the computer module.

24. A vehicle computer system as recited in claim 15 wherein the faceplate module includes a voice recognition device to receive verbal commands from a user.

25. A vehicle computer system as recited in claim 15 wherein the faceplate module includes a speech generation device to produce verbal commands.

26. A vehicle computer system as recited in claim 15 wherein the faceplate module is physically detachable from the housing, the faceplate module being disconnected from the first interfacing slot when the faceplate module is physically detached form the housing, the faceplate module having an RF receiver and being operable as a portable RF receiving device to receive RF signals when the faceplate module is detached from the housing.

27. A vehicle computer system as recited in claim 15 wherein the faceplate module includes a microphone and speaker.

28. A vehicle computer system as recited in claim 15 wherein the faceplate module is physically detachable from the housing, the faceplate module being disconnected from the first interfacing slot when the faceplate module is physically detached form the housing, the faceplate module having a communications transceiver and being operable as a portable wireless communications device.

29. A vehicle computer system as recited in claim 15 wherein the computer module can be disconnected from the second interfacing slot and removed from the housing.

30. A vehicle computer system as recited in claim 15 further comprising a data network connected to the computer module, the data network having at least one connection interface provided at a location remote from the vehicle dashboard.

31. A vehicle computer system as recited in claim 30 further comprising at least one client processing unit having a network port to compatibly couple to the connection interface of the data network.

32. A vehicle entertainment/communication system comprising:

a base unit of a size suitable to be mounted in a vehicle dashboard;

a faceplate detachably connected to the base unit;

an entertainment player;

a processor mounted to the faceplate to form a faceplate module, the processor being configured to control the entertainment player when the faceplate module is attached to the base unit; and

an RF receiver provided in the faceplate module and operatively coupled to the processor, the faceplate module being operable as a portable RF receiving device to receive RF signals when the faceplate module is detached from the base unit.

33. A vehicle entertainment/communication system as recited in claim 32 wherein the faceplate module has a power connector to enable use of an external power source when the faceplate module is detached from the base unit.

34. A vehicle entertainment/communication system as recited in claim 32 wherein the faceplate module has a communications transceiver and the faceplate module is operable as a portable wireless communications device when the faceplate module is detached from the base unit.

35. A vehicle entertainment/communication system as recited in claim 32 further comprising first and second compatible transceivers, the first transceiver being located in the base unit and the second transceiver being located in the faceplate module, the faceplate module being operable to communicate with the base unit when the faceplate module is detached from the base unit.

36. A vehicle computer system comprising:

a housing of a size suitable to be mounted in a vehicle dashboard;

a computer mounted within the housing;

a graphical display monitor separate and remotely located from the housing, but electrically coupled as a peripheral to the computer, the computer controlling graphical data output to the graphical display monitor; and

the graphical display monitor having an automatic override switch that is activated when the display is viewable by the driver to prevent display of non-driving related information.

37. A vehicle computer system as recited in claim 36 wherein the graphical display monitor is a flat panel display.

38. A vehicle computer system as recited in claim 36 further comprising an open platform operating system executing on the computer, the operating system being configured to support multiple applications that are supplied by a vehicle user.

39. A vehicle computer system as recited in claim 36 wherein the housing has a form factor of a single DIN.

40. A vehicle computer system as recited in claim 36 further comprising a data network connected to the computer, the data network having at least one connection interface provided at a location remote from the vehicle dashboard.

41. A vehicle computer system as recited in claim 40 further comprising at least one client processing unit having a network port to compatibly couple to the connection interface of the data network.

42. A portable RF electronics device for use in conjunction with a vehicle entertainment system, the vehicle entertainment system having a base unit sized to be mounted in a vehicle dashboard and a player mounted in the base unit, the portable RF electronics device comprising:

a faceplate having a physical coupling assembly which enables the faceplate to be attached to or detached from the base unit of the vehicle entertainment system;

a processor mounted to the faceplate to form a faceplate module, the faceplate module having an electrical interface which compatibly couples to an interface on the base unit to permit data communication from the faceplate module to the player, the processor being configured to control the player device when the faceplate module is electrically coupled to the base unit; and

an RF receiver provided in the faceplate module and operatively coupled to the processor, the faceplate module being operable as a portable RF receiving device to receive RF signals when the faceplate module is physically detached from the base unit.

43. A portable RF electronics device as recited in claim **42** further comprising a power connector to enable use of an external power source when the faceplate module is physically detached from the base unit.

44. A portable RF electronics device as recited in claim **42** further comprising a CODEC provided in the faceplate module to enable portable wireless communications when the faceplate module is physically detached from the base unit.

45. A portable RF electronics device as recited in claim **42** further comprising a voice recognition device provided in the faceplate module to receive verbal commands from a user.

46. A portable RF electronics device as recited in claim **42** further comprising an AM/FM/RBDS tuner provided in the faceplate module.

* * * * *

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United States Patent [19]

Beckert et al.

[11] Patent Number: 6,009,363

[45] Date of Patent: Dec. 28, 1999

[54] **VEHICLE COMPUTER SYSTEM WITH HIGH SPEED DATA BUFFER AND SERIAL INTERCONNECT**

[75] Inventors: **Richard D. Beckert**, Lake Stevens; **Mark M. Moeller**, Des Moines; **Ron Randall**, Snohomish; **William Wong**, Redmond, all of Wash.

[73] Assignee: **Microsoft Corporation**, Redmond, Wash.

[21] Appl. No.: **08/668,781**

[22] Filed: **Jun. 24, 1996**

Related U.S. Application Data

[63] Continuation-in-part of application No. 08/564,586, Nov. 29, 1995, Pat. No. 5,794,164.

[51] **Int. Cl.**[6] **H04B 1/03**

[52] **U.S. Cl.** **701/33**; 370/522; 340/825.25; 361/814; 455/345; 307/10.7

[58] **Field of Search** 701/29–33, 24, 701/35; 364/551.01; 340/439, 426, 691, 825.5, 310.1, 538, 825.25, 815.69; 361/686, 683, 680, 814, 679; 395/281, 290; 370/522, 476, 537; 455/345, 346, 349, 348; 307/10.7, 10.1

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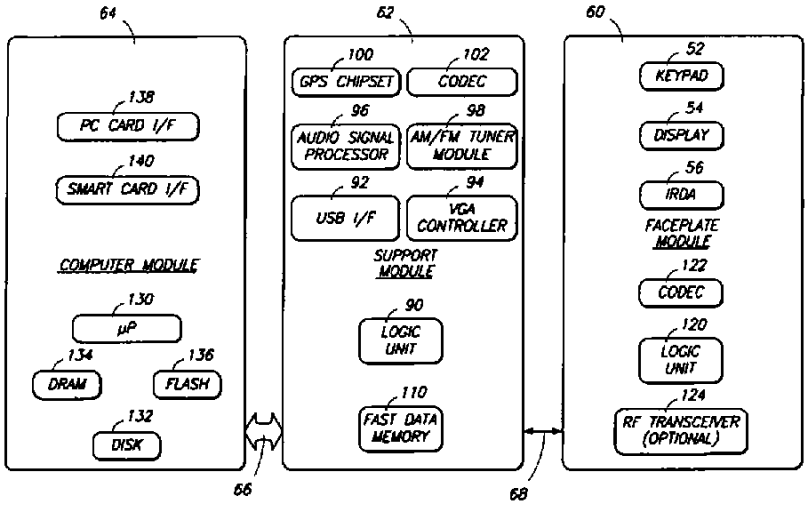
Primary Examiner—Jacques H. Louis-Jacques
Attorney, Agent, or Firm—Lee & Hayes, PLLC

[57] **ABSTRACT**

A vehicle computer system has a housing sized to be mounted in a vehicle dashboard or other appropriate location. The housing includes a base unit and a faceplate. A first logic unit is mounted to the base unit to form a support module. The support module has two interfacing slots and can support connections to multiple peripheral devices. The support module facilitates high speed data exchange between the peripheral devices for streaming continuous audio or video data. The support module has a fast data memory to temporarily hold data being communicated between the peripheral devices. The support module also has a memory access circuit associated with each of the peripheral devices which designates at least one storage area within the fast data memory to hold data received from, or to be sent to, the associated peripheral device. The vehicle computer has a computer module which can be connected to or removed from one interfacing slot of the support module. A multi-bit bus (e.g., PCI bus) interfaces the computer module and the support module. The vehicle computer system also has a logic unit mounted to the faceplate to form a faceplate module. This module is detachably connected to the other interfacing slot of the support module. When the faceplate module is attached, a high speed serial interface electronically couples the support module to the faceplate module. The high speed serial interface enables the logic units on the support and faceplate modules to exchange a high speed, synchronized, serial bit stream. This data stream is organized into multiple frames, with each frame having multiple data bits and at least one valid bit to indicate whether the data bits are valid.

31 Claims, 9 Drawing Sheets



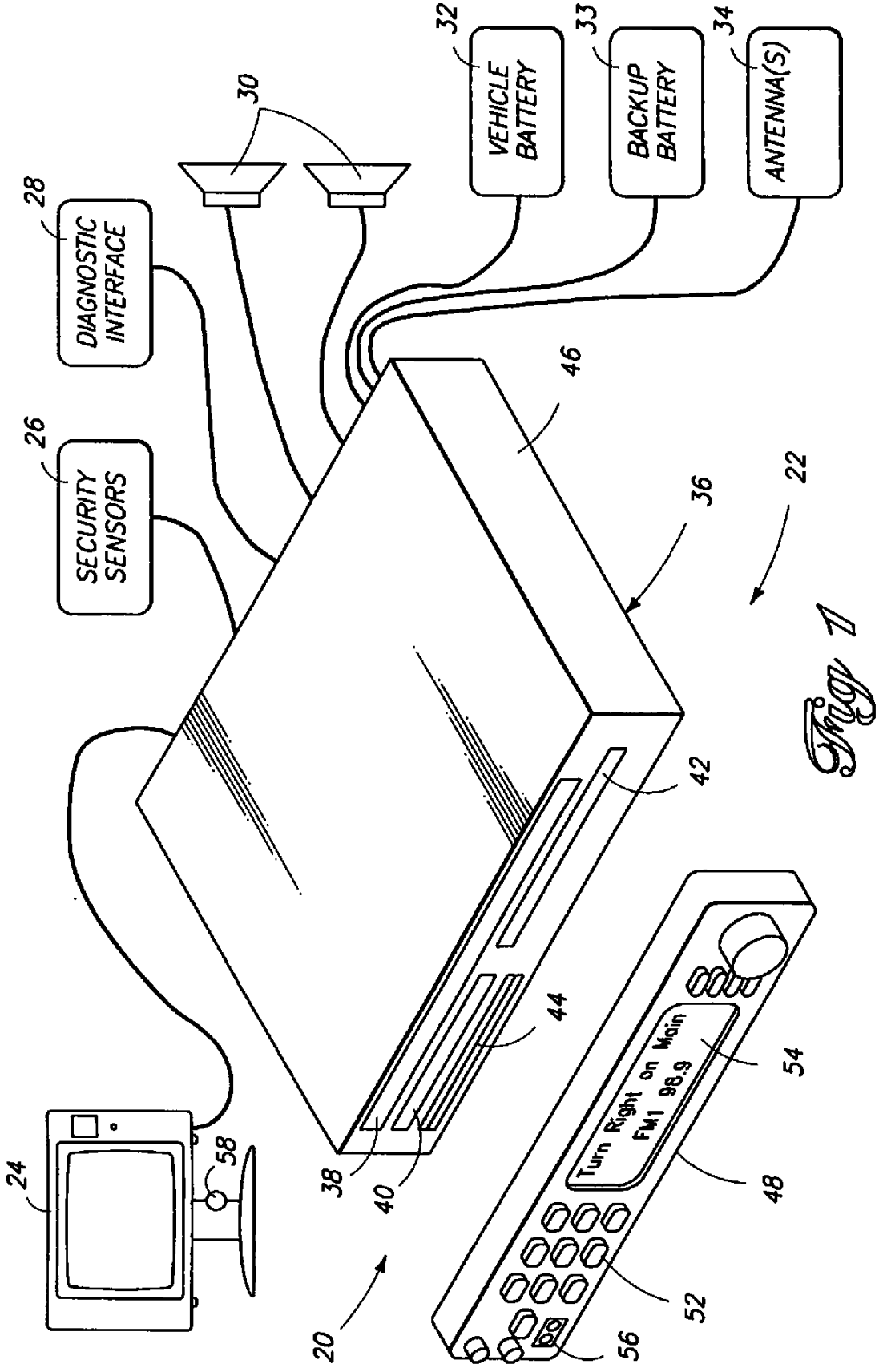
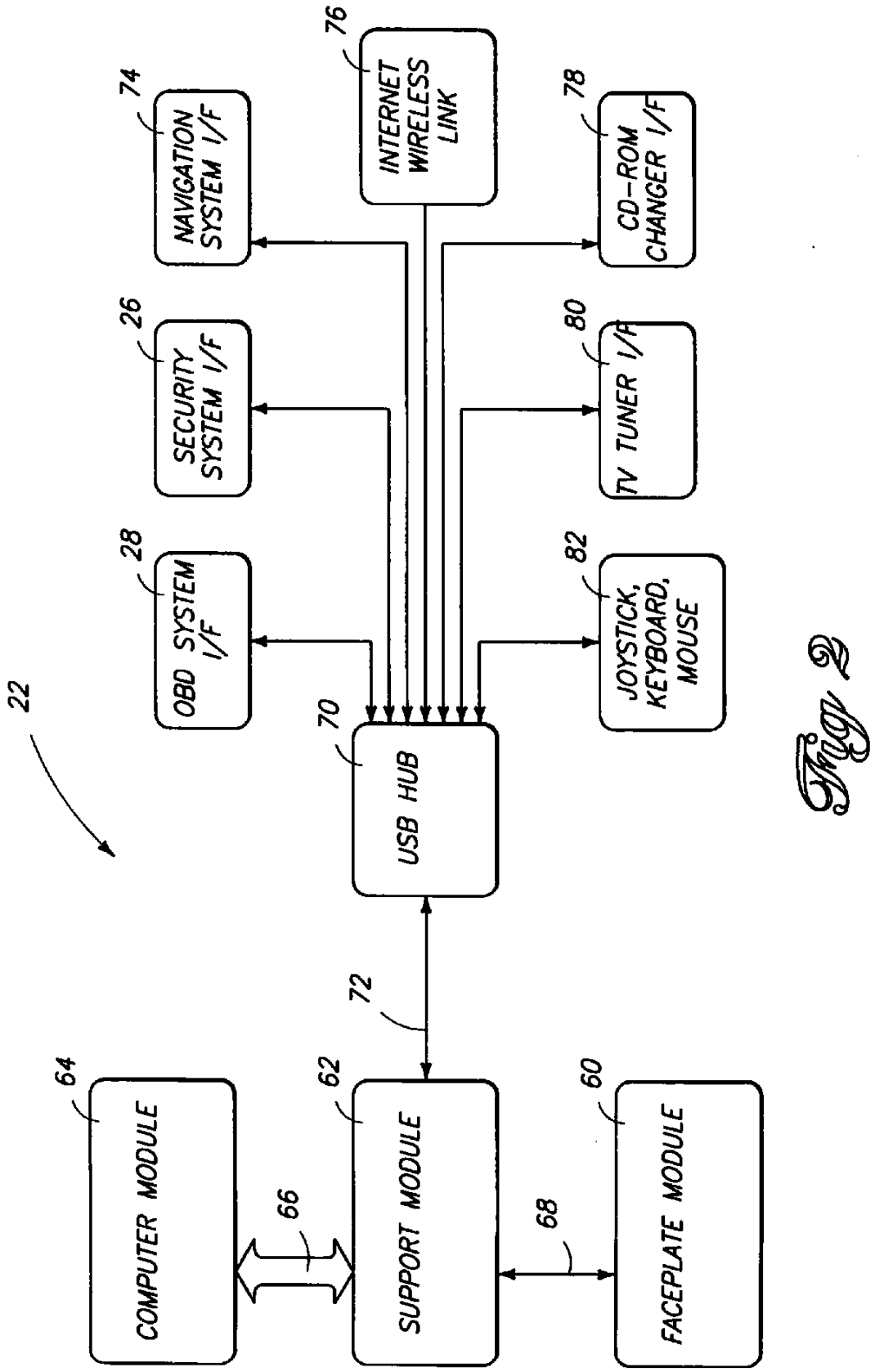

32
VEHICLE BATTERY
33
BACKUP BATTERY
34
ANTENNA(S)
30
28
DIAGNOSTIC INTERFACE
26
SECURITY SENSORS
46
36
22
42
44
38
40
54
Turn Right on Main
FM1 98.9
48
52
56
20
24
58

Fig 1


22
COMPUTER MODULE
64
66
SUPPORT MODULE
62
68
FACEPLATE MODULE
60
72
USB HUB
70
OBD SYSTEM I/F
28
SECURITY SYSTEM I/F
26
NAVIGATION SYSTEM I/F
74
INTERNET WIRELESS LINK
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CD-ROM CHANGER I/F
78
TV TUNER I/F
80
JOYSTICK, KEYBOARD, MOUSE
82

Fig. 2

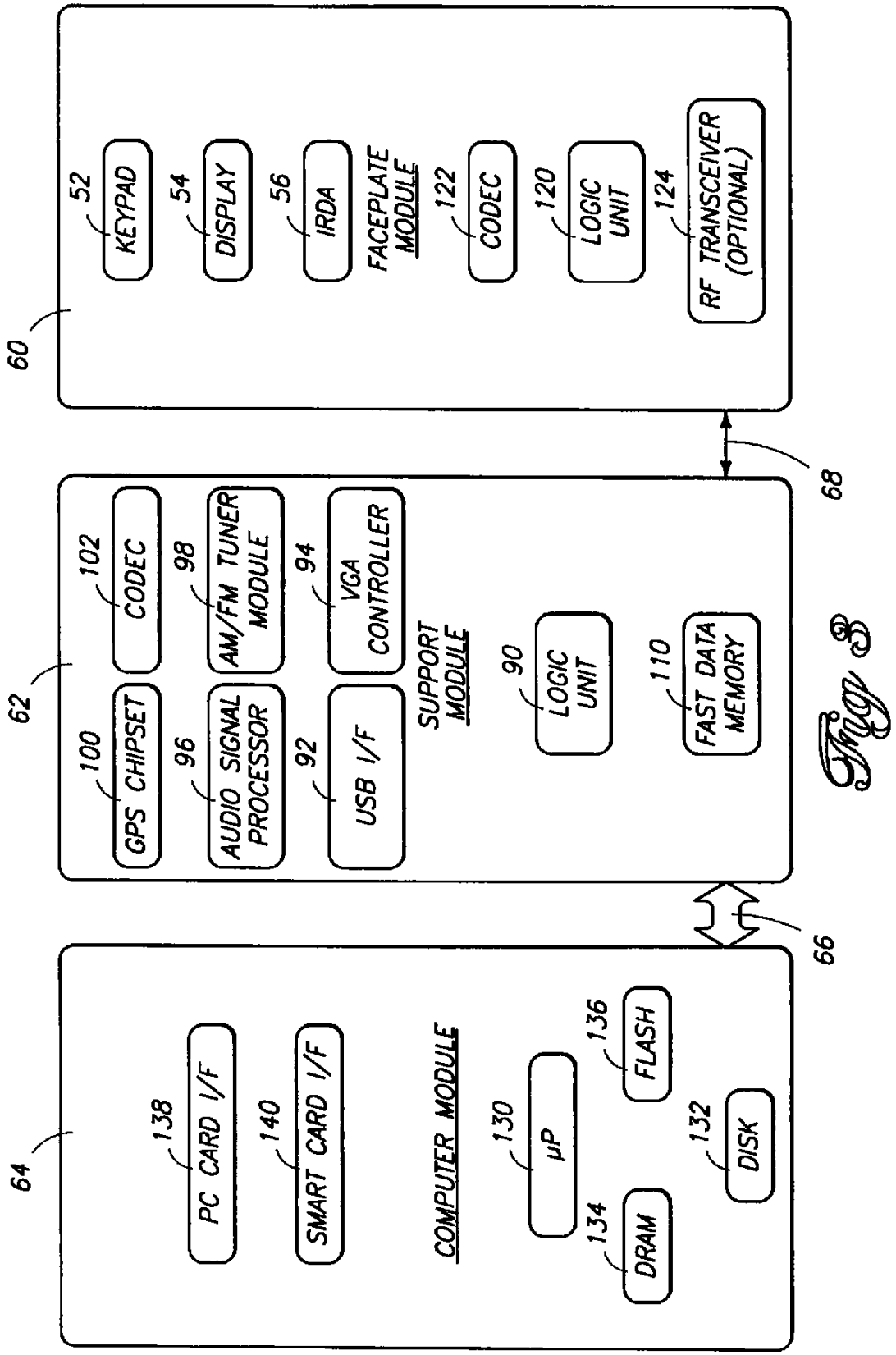
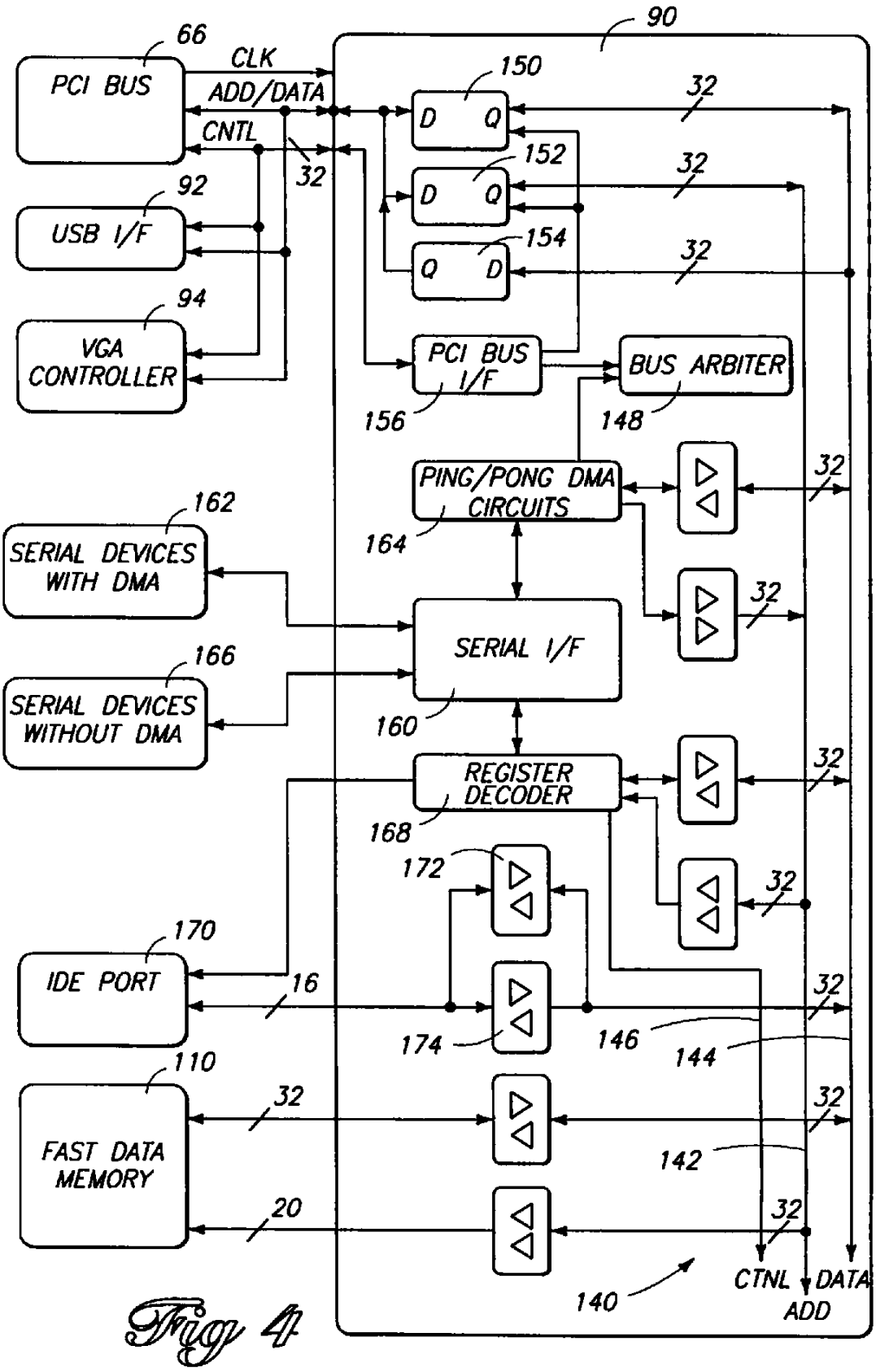

60
52
KEYPAD
54
DISPLAY
56
IRDA
FACEPLATE MODULE
122
CODEC
120
LOGIC UNIT
124
RF TRANSCEIVER (OPTIONAL)
68
62
100
GPS CHIPSET
102
CODEC
96
AUDIO SIGNAL PROCESSOR
98
AM/FM TUNER MODULE
92
USB I/F
94
VGA CONTROLLER
SUPPORT MODULE
90
LOGIC UNIT
110
FAST DATA MEMORY
66
64
138
PC CARD I/F
140
SMART CARD I/F
COMPUTER MODULE
130
µP
136
FLASH
134
DRAM
132
DISK

Fig. 3


90
66
PCI BUS
CLK
ADD/DATA
CNTL
32
150
D Q
152
D Q
154
Q D
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32
32
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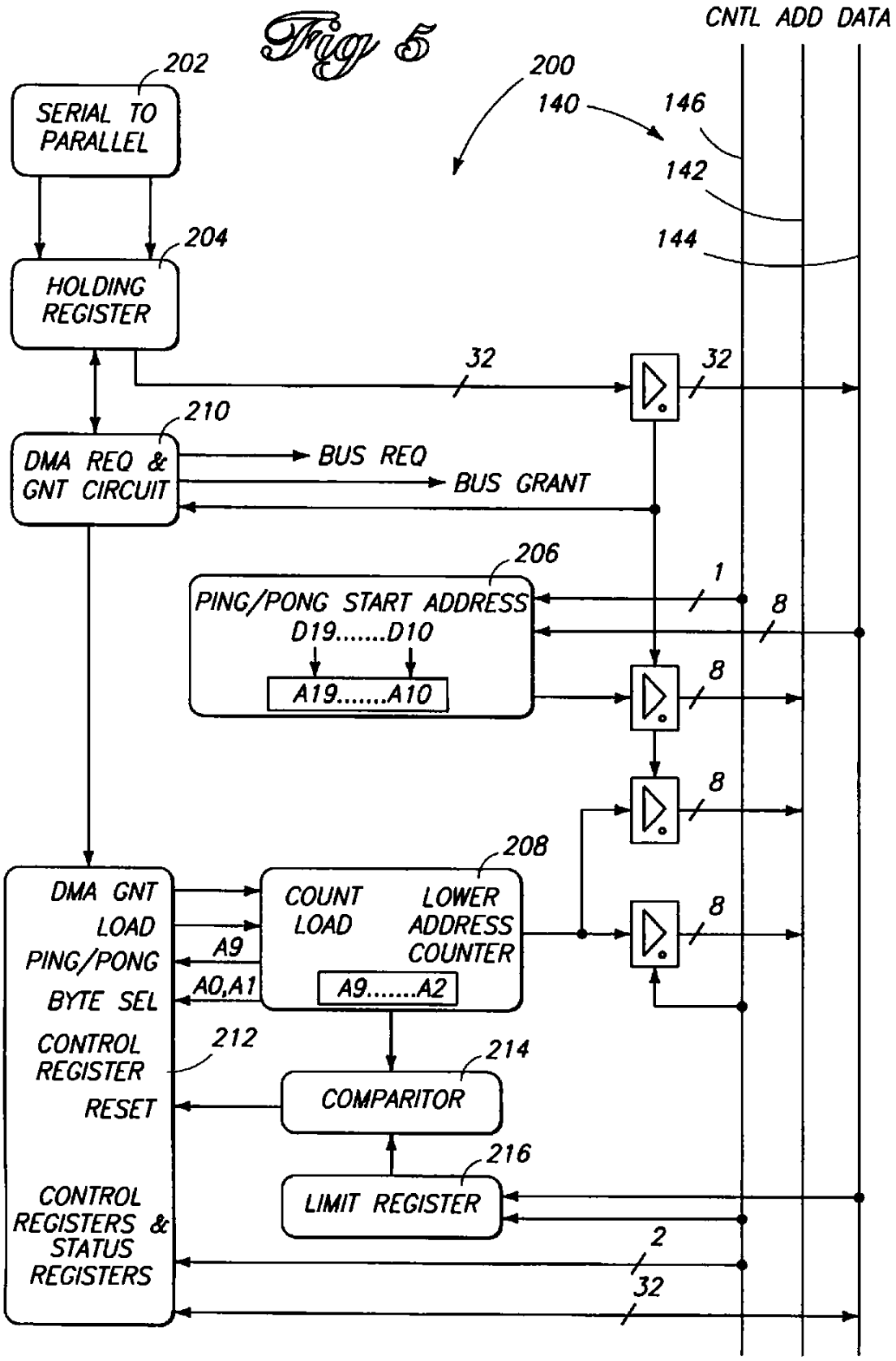
USB I/F
94
VGA CONTROLLER
PCI BUS I/F
156
BUS ARBITER
148
PING/PONG DMA CIRCUITS
164
32
162
SERIAL DEVICES WITH DMA
32
SERIAL I/F
166
SERIAL DEVICES WITHOUT DMA
160
REGISTER DECODER
168
32
172
32
170
IDE PORT
16
32
174
146
144
110
FAST DATA MEMORY
32
32
142
20
32
140
CTNL
DATA
ADD

Fig 4

Fig 5


CNTL ADD DATA
202
SERIAL TO PARALLEL
200
140
146
142
144
204
HOLDING REGISTER
32
32
210
DMA REQ & GNT CIRCUIT
BUS REQ
BUS GRANT
206
PING/PONG START ADDRESS D19.....D10
A19.....A10
1
8
8
8
8
208
DMA GNT
LOAD
PING/PONG
BYTE SEL
A9
A0,A1
COUNT LOAD
LOWER ADDRESS COUNTER
A9.....A2
212
CONTROL REGISTER
RESET
214
COMPARITOR
216
LIMIT REGISTER
CONTROL REGISTERS & STATUS REGISTERS
2
32

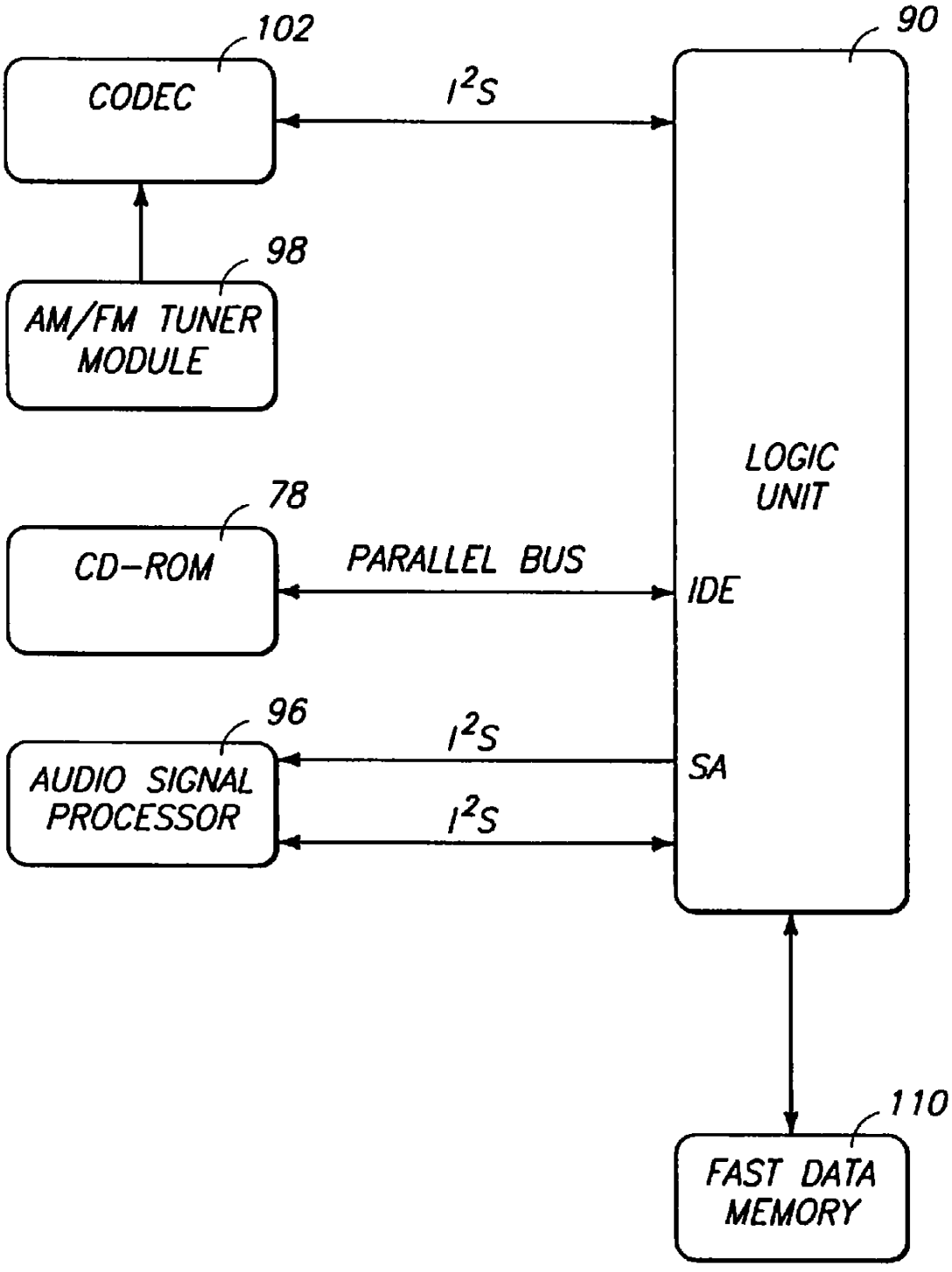

102
CODEC
I²S
90
98
AM/FM TUNER MODULE
LOGIC UNIT
78
CD-ROM
PARALLEL BUS
IDE
96
AUDIO SIGNAL PROCESSOR
I²S
SA
I²S
110
FAST DATA MEMORY

Fig 6

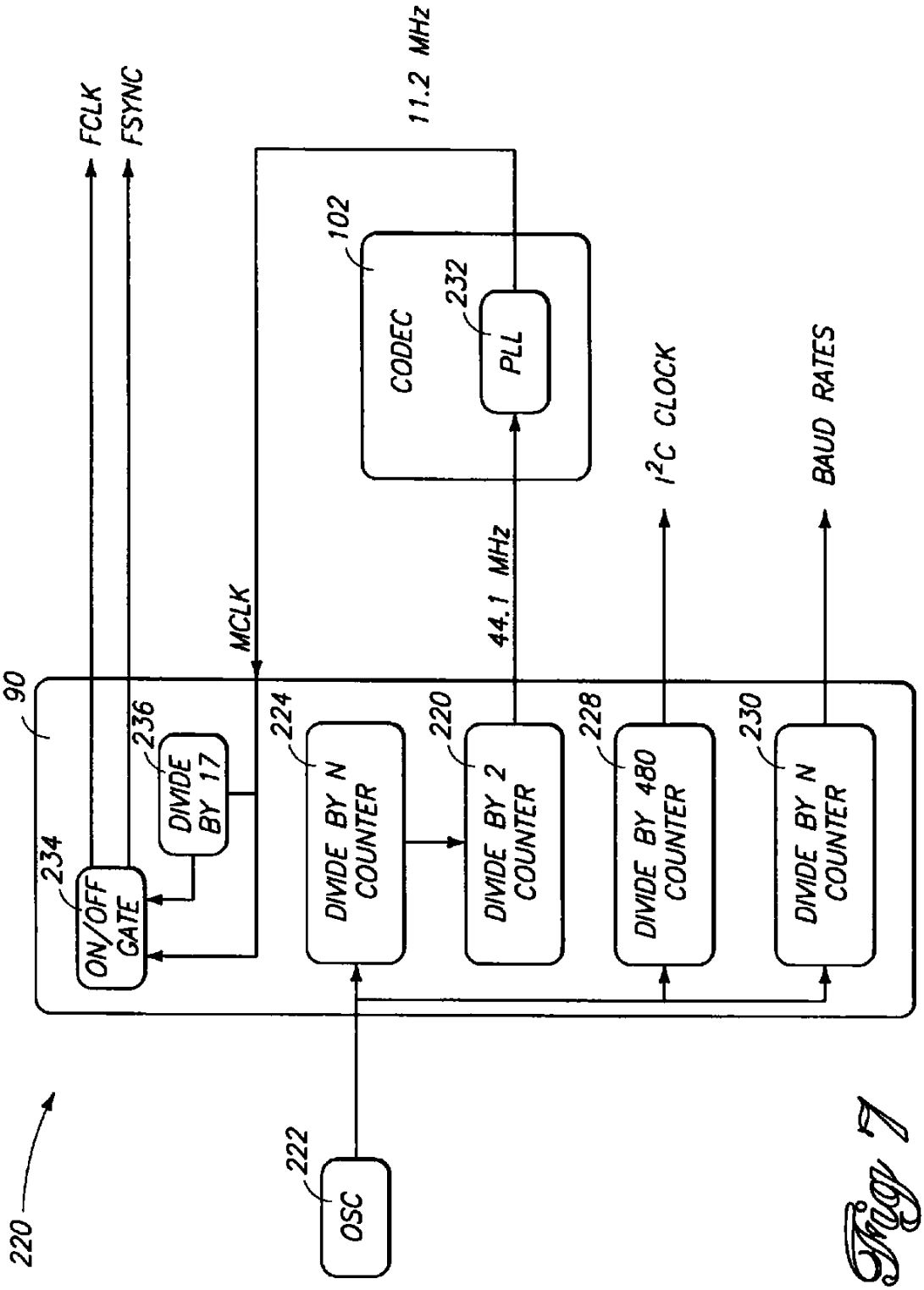

FCLK
FSYNC
11.2 MHz
102
CODEC
232
PLL
I²C CLOCK
BAUD RATES
MCLK
44.1 MHz
90
236
DIVIDE BY 17
224
DIVIDE BY N COUNTER
220
DIVIDE BY 2 COUNTER
228
DIVIDE BY 480 COUNTER
230
DIVIDE BY N COUNTER
234
ON/OFF GATE
222
OSC
220

Fig. 7

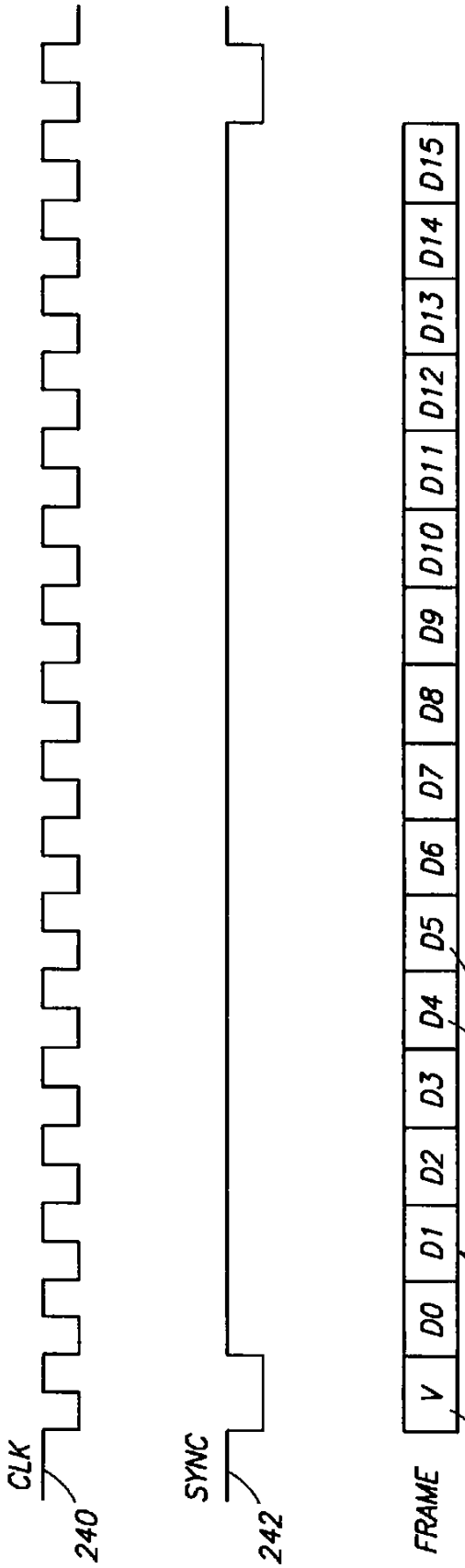

CLK
240
SYNC
242
FRAME
246
V
D0
D1
D2
D3
D4
D5
D6
D7
D8
D9
D10
D11
D12
D13
D14
D15
244
248

Fig 8

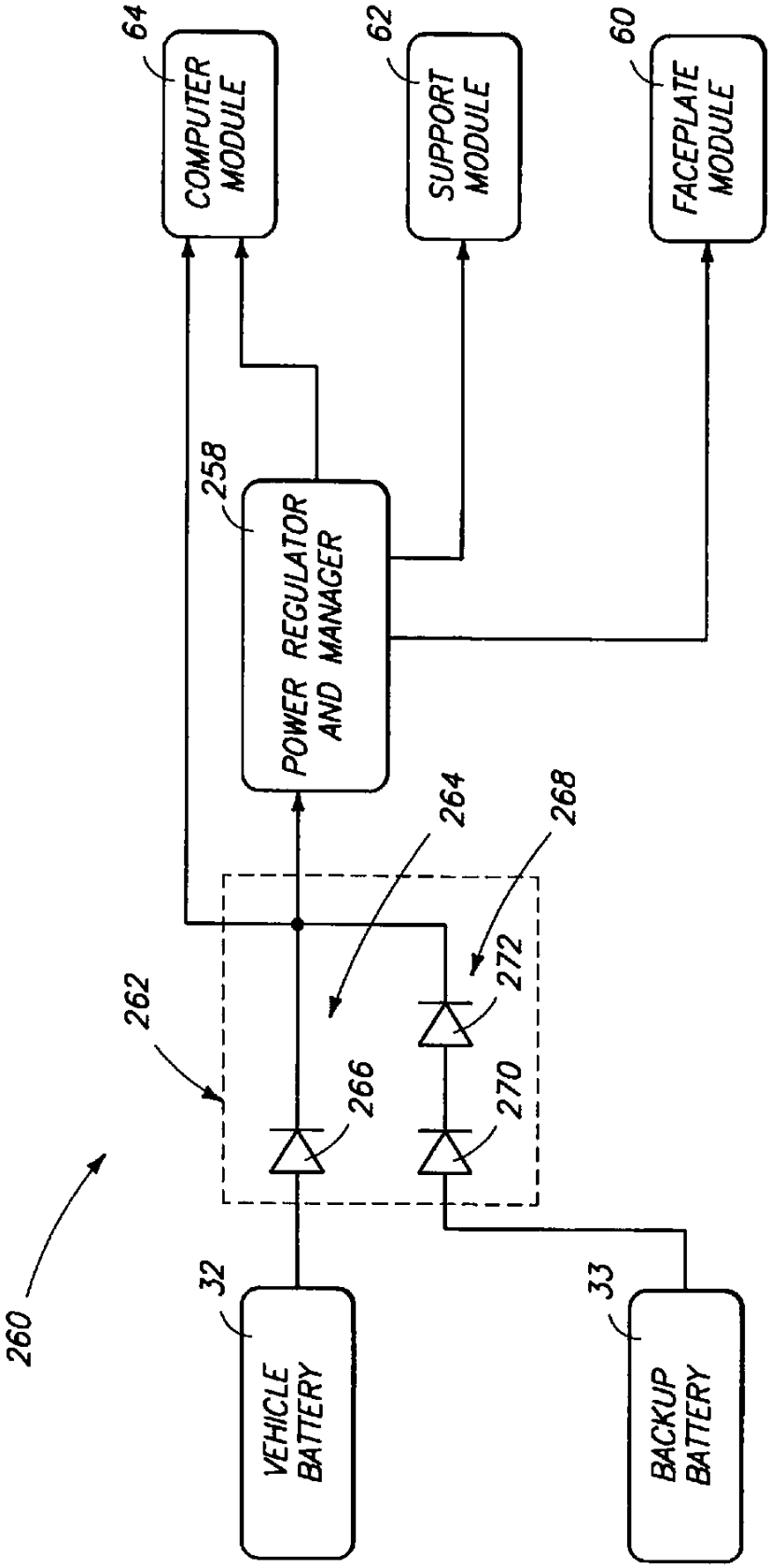

64
COMPUTER MODULE
62
SUPPORT MODULE
60
FACEPLATE MODULE
258
POWER REGULATOR AND MANAGER
264
268
262
272
266
270
260
32
VEHICLE BATTERY
33
BACKUP BATTERY

Fig. 9

VEHICLE COMPUTER SYSTEM WITH HIGH SPEED DATA BUFFER AND SERIAL INTERCONNECT

This is a continuation-in-part of U.S. Pat. application Ser. No. 08/564,586, filed Nov. 29, 1995, which issued as U.S. Pat. No. 5,794,164, on Aug. 11, 1998.

TECHNICAL FIELD

This invention relates to computer systems for vehicles.

BACKGROUND OF THE INVENTION

Modern vehicles are typically equipped with several independent electronic systems. For instance, most modern vehicles have a sound system and a security system. The sound system usually consists of an AM/FM radio, a cassette or CD (compact disk) player, an equalizer/amplifier, and speakers. The radio and player are arranged in a metal casing or housing that is mounted in a dashboard of the vehicle. The housing has a standardized size, often expressed in terms of DINs (Deutsche Industry Normen), to ensure that the sound system is compatible with and can be retrofit into most vehicle dashboards.

The security system is entirely separate from the sound system. The security system generally consists of security sensors placed throughout the vehicle, and a central application-specific integrated circuit (ASIC) to monitor the sensors and determine whether security is being jeopardized. Security System also controls actuators to lock/unlock doors or windows, and an alarm or siren.

Most late model vehicles are also constructed with a diagnostic system that analyzes performance of the vehicle's engine, transmission and fuel system, and other components (1996 or later for OBD II, 1993 or later for OBD I). The diagnostic system can be coupled to an external computer to download or monitor diagnostic information that is useful to a vehicle mechanic during servicing of the vehicle. Additionally, the diagnostic system might include dashboard displays that inform the driver of various operating conditions.

In some recent models, vehicles are being equipped with a navigation system that incorporates a global positioning system (GPS) receiver. The GPS receiver has an antenna to receive signals from a satellite network. The vehicle navigation system uses the satellite positioning signals to compute coordinates that locate the vehicle over the surface of the earth with regard to longitude, latitude, and altitude. Also, with the appropriate map software, the vehicle's location can then be shown on a map.

Cellular communications systems have also been added to vehicles. These communications systems enable the vehicle driver or occupant to transact telephone calls from their vehicle. Some of the more sophisticated systems are voice controlled which permit the driver to initiate or receive calls while traveling without removing a hand from the driving wheel, or diverting his/her eyes from the operation of the vehicle.

While these various electronics systems have proven useful to vehicle users, there is a drawback in that the systems are unrelated and incompatible. Each system employs separate proprietary dedicated processors or ASICs (application specific integrated circuits) which execute incompatible proprietary software. If a vehicle owner would like to add a security system to his/her vehicle, the owner must purchase an entire security system from one of the vendors and have it customarily installed. There is no way to add security functionality to an existing electronics system, such as the navigation system or the sound system.

SUMMARY OF THE INVENTION

This invention concerns a vehicle computer system that is capable of integrating these diverse and separate systems as well as offering a general purpose computing platform that allows for easy expandability. The vehicle computer system has a housing sized to be mounted in a vehicle dashboard or other convenient location. This system provides an open hardware architecture and supports an open platform operating system. The open platform operating system supports multiple different applications that can be supplied by a software vendor. For instance, the operating system can support applications pertaining to entertainment, navigation, communications, security, diagnostics, and others. In the preferred implementation, the operating system is a multitasking operating system capable of concurrently running multiple applications. The computer has one or more storage devices (e.g., hard disk drive, CD drive, floppy disk drive, cassette player, or smart card reader) which permits the user to download programs from a storage medium (e.g., hard disk, CD, diskette, or cassette) to the computer. Also, the user can read or write data to writeable medium (e.g., hard disk, diskette, cassette, or smart card). In this manner, the vehicle owner can easily add new systems to his/her vehicle by installing additional programs.

In the described implementation, the vehicle computer system has three modules: a support module, a computer module, and faceplate module. The support module is formed as part of a stationary base unit of the housing that resides in the vehicle dashboard or other location. It has its own logic unit which can be implemented in a field programmable gate array (FPGA), application specific integrated circuit (ASIC), customized processor, or the like. The support module also has an audio signal processor, such as a digital signal processor (DSP), which performs the signal processing for audio and video data. One could combine this DSP into the ASIC if desired.

The computer module can be connected to or removed from the support module. The computer module has a processor, such as an x86-type microprocessor, which runs the operating system. The computer module and support module are interfaced using a multi-bit bus, such as a PCI bus.

The faceplate module is detachably connected to the support module. The faceplate module has a logic unit of its own to control an RF transceiver such as a Cell phone, a two-way pager, or a point-to-point spread spectrum transceiver, a display, a keypad, and a CODEC. The faceplate and support modules are connected using a high speed serial connection. Data is exchanged between the faceplate and support module as a synchronized serial bit stream which is organized into multiple frames. Each frame has multiple data bits and at least one valid bit to indicate whether the data bits are valid.

According to one aspect of this invention, the support module is configured to support multiple peripheral devices (including such components as CD-ROM, AM/FM tuner, audio signal processor, navigation system, security sensors, vehicle diagnostics interface (OBD interface), etc.) and to facilitate data communication between them. The support module has a logic unit with an internal address/data bus structure that is independent and separate from the internal bus of the computer module. This logic unit's bus functions

as the peripheral communication pathway so that peripheral devices can communicate with one another without intervention from the computer module. For instance, all of the audio sound generation, processing, and output can be handled through the support module while consuming minimal processing resources of the computer module.

According to another aspect, a fast data memory is coupled to the internal address/data bus structure of the support module's logic unit to temporarily hold data being communicated between peripheral devices. The fast data memory is partitioned into storage areas that correspond to each of the peripheral devices. The logic unit has memory access circuits associated with each of the peripheral devices which designate particular storage areas of the fast data memory to hold data received from, or to be sent to, the associated peripheral device. The memory access circuits and fast data memory form a fast communications buffer in which data being received from, or sent to, a peripheral device is quickly exchanged through the memory.

The data exchange speed is further improved through use of a mapping overlay technique, in which memory access circuits for two communicating peripheral devices have pointers designating the same memory area. In this manner, while one memory access circuit is filling the storage area with data from one peripheral device (e.g., an AM/FM tuner, CD-ROM, etc.), the other memory access circuit is reading data from the storage area to output to the other peripheral device (e.g., an audio signal processor).

BRIEF DESCRIPTION OF THE DRAWINGS

The same reference numerals are used throughout the drawings to reference like components and features.

FIG. **1** is a diagrammatic illustration of a vehicle computer system.

FIG. **2** is a diagrammatic illustration of the vehicle computer system interfaced with multiple external peripheral devices.

FIG. **3** is a block diagram of the vehicle computer system according to one implementation having a faceplate module, a support module, and a computer module.

FIG. **4** is a block diagram of an interface and internal bus structure of the support module. FIG. **4** shows the use of a fast data memory as a high speed data communications buffer.

FIG. **5** is a block diagram of a memory access circuit which maps data from peripheral devices into storage locations within the fast data memory.

FIG. **6** is a block diagram of the support module which is used to illustrate audio data exchange among multiple serial devices through the fast data memory.

FIG. **7** is a functional block diagram of a master clock generating unit which produces a master audio clock signal used throughout the vehicle computer system.

FIG. **8** is a timing diagram illustrating a serial bit stream used to communicate data between the support and faceplate modules.

FIG. **9** is a block diagram of a power system employed by the vehicle computer system.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

FIG. **1** shows a vehicle computer system **20** according to one implementation of this invention. Vehicle computer system **20** has a centralized computer **22** coupled to various external peripheral devices, including a monitor **24**, security sensors **26**, a vehicle diagnostic interface **28**, speakers **30**, a vehicle battery **32**, a backup battery **33**, and antenna(s) **34**. The computer **22** is assembled in a housing **36** that is sized to be mounted in a vehicle dashboard, similar to a conventional automobile stereo. Preferably, the housing **36** has a form factor of a single DIN (Deutsche Industry Normen). But, it possibly could be housed in a 2 DIN unit or other special form factor for an OEM.

The computer **22** runs an open platform operating system which supports multiple applications. Using an open platform operating system and an open computer system architecture, various software applications and hardware peripherals can be produced by independent vendors and subsequently installed by the vehicle user after purchase of the vehicle. This is advantageous in that the software applications do not need to be specially configured for uniquely designed embedded systems. The open hardware architecture preferably runs a multitasking operating system that employs a graphical user interface. One preferred operating system is a Windows® brand operating system sold by Microsoft Corporation, such as Windows 95® or Windows NT® or other derivative versions of Windows®. A multitasking operating system allows simultaneous execution of multiple applications.

The computer **22** includes at least one storage drive which permits the vehicle user to download programs and data from storage medium. In the illustrated implementation, the computer **22** has a CD ROM drive **38** which reads application-related CDs, as well as musical, video, game, or other types of entertainment CDs. In this manner, the CD ROM drive **38** performs a dual role of storage drive and entertainment player. The computer **22** has an optional 3.5" floppy diskette drive **40**, a smart card reader **42**, and dual PCMCIA card sockets **44** which accept PCMCIA card types I, II and III. Two types I or II cards can be simultaneously used, but only one card if a type III can be used. Hereinafter, the acronym "PC-Card" will be used in place of the acronym "PCMCIA." Also, a hard disk drive (not shown) can be included on the computer **22** for storing both application programs and user data. A DVD (digital video disk) player may also be included in the computer **22**.

The storage drives are mounted in a base unit **46** of housing **36**. The base unit **46** is constructed and sized to be mounted in the dashboard. Optionally, this base unit may be removable in the same fashion as a laptop computer and its associated docking station. This high end option allows the user to take his vehicle computer to his home or office to serve as his portable PC. The housing **36** also has a detachable faceplate **48** which is pivotally mounted to the front of the base unit **46**. The faceplate can be rotated to permit easy and convenient access to the storage drives.

The computer **22** has a keypad **52** and a display **54** on the faceplate **48**. The operating system executing on the computer **22** controls the faceplate peripheral, which through the faceplate processor, can control the faceplate keys **52** and the faceplate display **54** as peripheral devices when the faceplate is attached to the base unit. Additionally, the computer **22** has a voice recognition device to permit the user to verbally enter commands in a hands-free, eyes-free environment. These voice commands can be used for controlling most operating modes of the vehicle computing platform. The computer **22** is also equipped with an IrDA (infrared developers association) transceiver port **56** mounted on the faceplate **48** to transmit and receive data and programs using infrared signals. The entire faceplate unit **48** behaves as a multifunction peripheral to the computing platform.

To load an application or data onto the computer **22**, the vehicle user inserts a CD or other media (if the application is not already contained on the hard disk) into the appropriate drive and the operating system downloads the application or data therefrom. The installation process can be automatically handled by the operating system, or with the assistance of commands input from the user in the form of keyed sequences on the keypad **52** or verbal instructions using the voice recognition device. Another technique to load data or applications or transfer data with other computing devices is through the use of the IrDA transceiver port **56**, or the wireless Internet link **76**.

The computer **22** can output visual data to the LCD **54** at the faceplate, or to the monitor **24**. The display **54** is preferably a back lit LCD. The monitor **24** is preferably a small flat panel display (e.g., 6.4" screen) that is movably mounted on a stand or yoke and remotely located from the computer. The monitor **24** is fully adjustable to different viewing positions that can be seen by the driver or other passengers in the vehicle. The type of data displayed on the monitor can range widely from word instructions concerning the vehicle's performance, to diagrammatic directions used by the navigation system, to video movies for in-car entertainment. The monitor **24** is equipped with an automatic override switch **58** which automatically disables the display of any non-driving related data when positioned to be viewed by the driver. When facing the driver, only information supportive and helpful to driving (e.g., diagnostics, navigation directions) is displayed on the monitor, while distracting information (e.g., video movies, games) is blocked from display. In one implementation, the switch is an electrical cylindrical switch which closes when the display is capable of being viewed by the driver; thus, the software can sense the display position and only allow permitted information to be displayed.

In general, the vehicle computer system **20** can be used to integrate multiple vehicle-related systems onto one open platform hardware and software architecture. For instance, the vehicle computer system **20** can serve as a multimedia entertainment system, a navigation system, a communications system, a security system, and a diagnostics system. Moreover, the vehicle computer system **20** provides additional functionality traditionally associated with desk-top and laptop personal computers. For instance, vehicle computer system **20** can support word processing applications, spreadsheet applications, database applications, and appointment/schedule applications. Furthermore, the vehicle computer system **20** can be configured to operate as a server to other computing units in the vehicle to distribute games, video movies, and the like to passengers.

FIG. **2** shows the computer **22** according to one implementation of the invention. Computer **22** has three primary modules: a faceplate module **60**, a support module **62**, and a computer module **64**. The computer module **64** is operatively connected to the support module **62** via a multi-bit bus **66**. In the preferred implementation, the multi-bit bus is a PCI (Peripheral Component Interconnect) bus. The support module **62** and faceplate module **60** are interconnected via a high speed serial interface **68** which supports high speed, serial data communication. A preferred serial transmission scheme is described below in more detail with reference to FIG. **8**.

In FIG. **2**, the support module **62** is also connected to a universal serial bus (USB) hub **70** via a multi-bit connector **72** (e.g., 8 bits). The USB hub **70** provides connections to many peripheral devices (e.g., 128 devices). Example peripheral devices include the OBD (On Board Diagnostic) system **28**, the security system **26**, navigation system **74**, a wireless link **76** to the Internet, a CD-ROM changer **78**, a TV tuner **80**, and user I/O devices such as a joystick, keyboard or a mouse **82**. This USB hub could be separate as shown in FIG. **2** or it could be integrated into one or more of the USB peripherals.

FIG. **3** shows the three modules of the vehicle computer **22** in more detail. The support module **62** resides in the typically stationary base unit **46** (FIG. **1**) that is mounted in the vehicle dashboard or other convenient location. The support module **62** includes a logic unit **90** which is responsible for facilitating communication among peripheral devices, establishing a master audio clock signal used throughout the vehicle computer system, and coordinating the entertainment functionality of the computer system. The logic unit **90** can be implemented as an FPGA (field programmable gate array). It is noted that the logic code for an FPGA is developed using a hardware description language, such as VHDL (IEEE standard 1076-1993), and can be recompiled for an ASIC (application specific integrated circuit) architecture. The logical unit **90** can further be implemented as a microprocessor, a RISC (reduced instruction set computing) processor, or other processing devices.

The support module **62** has several hardware interfaces. A USB interface **92** is driven from the PCI bus **66** and provides the interconnection to the various USB peripherals shown in FIG. **2**. A USB hub may be required as shown if the peripherals do not incorporate one and more USB peripherals than supported directly by the support module are attached. A VGA controller **94** is provided on the support module **62** to drive the display **24** (FIG. **1**). The VGA controller **94** is also driven from the PCI bus. It is noted that the USB interface and VGA controller could be incorporated into the logic unit **90**. An ATAPI-IDE interface (used to drive the CD ROM or DVD player), and a PCI interface are implemented as part of the logic unit **90**. For supporting higher bandwidth video applications such as multiple video screens, a P1394 interface could be added to the system and driven from the PCI interface or incorporated in logic unit **90**.

The support module **62** also includes an audio signal processor **96** to perform the sound processing algorithms which may include: sound equalization, digital crossover, bass, treble, volume, surround sound, Dolby pro-logic™, AC-3 and MPEG decoding. The audio signal processor **96** also drives digital to analog converters for a six channel audio output (not shown). The audio signal processor **96** is preferably implemented as a DSP (digital signal processor), such as a Motorola DSP56009. The support module also includes an AM/FM tuner module **98**, a GPS (global positioning system) chipset **100** to provide for satellite navigation such that the longitude, latitude, and altitude of the vehicle may be readily determined, and one or more audio analog to digital converters and digital to analog converters (or "CODECS") **102**.

A fast data memory **110** functions as a high speed data communications buffer between the serial peripheral devices. The fast data memory is preferably implemented as a high speed SRAM (static random access memory) which provides high speed buffering and "ping-ponging" of audio data or USB data to minimize processor interaction. In the preferred implementation, the fast data memory **110** acts as a fast data memory buffer which accommodates data exchange among many devices. The fast data memory **110** is described below in more detail with reference to FIG. **6**.

With continuing reference to FIG. **3**, the faceplate module **60** resides on the detachable faceplate **48** (FIG. **1**). The

faceplate module **60** is connected to the support module through a connector that facilitates easy detachability of the faceplate **48** from the main housing **36**. The faceplate module **60**, through the detachable connector, communicates bi-directional data to the support module **62** by means of the high speed serial interconnect **68**. The faceplate module **60** includes a logic unit **120** which can be implemented as an FPGA, ASIC, DSP, or other device. The faceplate module **60** also includes a keypad **52**, a display **54**, an IrDA port **56**, and a CODEC **122**. Additionally, the faceplate module contains a slot for an optional plug-in RF transceiver **124** such as a cellphone, two-way pager, or point-to-point spread spectrum transceiver.

Typically, the computer module **64** resides in the dashboard-mounted base unit **46** and includes a processor in the form of a microprocessor **130**, such as an Intel® x86-type microprocessor. When plugged in, the computer module **64** is connected to the PCI bus **66** to communicate with the support module **62**.

The microprocessor **130** runs an open platform operating system, such Windows 95® or Windows NT™ or other Windows® derivative operating systems from Microsoft Corporation. The operating system is stored in a hard disk drive **132** (e.g. typically >200 Mbytes). This hard disk drive may be either integrated into the computer module as shown or it may be in the form of a PC-Card. The computer module **64** supports any variety of applications that the vehicle user might desire. These applications can also be stored on the hard disk drive **132** or on a removable storage medium, such as a CD ROM, cassette, PC-Card Flash memory, PC-Card hard disk drive, or floppy diskette. Additionally, user applications may be downloaded from an optional wireless Internet connection. A DRAM memory **134** and Flash memory (or other non volatile memory) **136** are employed in the computer module to support the microprocessor **130** in running the operating system and loaded applications.

The computer module **64** has a PC-Card interface **138** which includes a PC card socket used to support types I, II, or III PC cards (e.g., extra memory, hard disk drives, modems, RF transceivers, network adapters, or other PC-Card peripherals). The computer module **64** also has a Smart Card interface **140** which accepts Smart Cards.

A more detailed explanation of the three modules in the vehicle computer system is provided in co-pending U.S. patent application Ser. No. 08/564,586 entitled "Vehicle Computer System," which was filed on Nov. 29, 1995 in the names of Richard D. Beckert, Mark M. Moeller, and William Wong and which issued as U.S. Pat. No. 5,794,164 on Aug. 11, 1998. This application is assigned to Microsoft Corporation and is incorporated herein by reference.

According to one aspect of this invention, the logic unit **90** within the support module **62** is configured with its own multi-bit bus structure that is separate from the bus of the microprocessor **130** of the computer module **64**. The logic unit **90** and microprocessor **130** are interfaced using a bus, such as PCI bus **66**. By configuring the logic unit **90** with its own bus, the logic unit **90** is capable of better performing its tasks independent of intervention from the microprocessor **130**. Moreover, the internal bus of the logic unit **90** facilitates data communication between the audio components and other serial devices while using minimal processing resources of the microprocessor **130**.

FIG. **4** shows a preferred implementation of an internal bus structure **140** of the logic unit **90** of the support module and the interface between the internal bus **140** and external devices. The internal multi-bit bus structure **140** includes an address bus **142**, a data bus **144**, and a control bus **146**. In the illustrated implementation, the data bus **144** is a 32-bit bus and the address bus **142** is a sufficiently large to support in parallel at least **19** address bits, such as through a 32-bit bus. The busses are tri-state busses which are driven by one of several sources. An internal bus arbiter **148** determines which device is in control of the bus structure **140**.

The PCI bus **66** connecting the support module **62** to the computer module **64** is connected to the internal bus structure **140** via latches **150**, **152**, and **154**, and a PCI bus interface **156**. The PCI connection has primary control over the internal bus structure **140**. The USB interface **92** and the VGA controller **94** are devices on the PCI bus interconnect, or they may be incorporated into the logic unit **90**.

Serial devices are connected to the internal bus structure **140** via a serial interface **160**. Some of the peripheral devices are implemented to write data directly to the fast data memory **110** use a direct memory access (DMA) process (described below). Such serial devices are referenced by number **162**. Example of DMA-configured peripheral devices include the audio signal processor **94**, the faceplate module **60** (which is treated as a multifunction peripheral when attached to the support module), the AM/FM tuner **98**, etc. From the perspective of the logic unit, these serial devices behave with respect to the DMA process as any peripheral device. Accordingly, in this context, the serial devices internal to the support module may be referred to as "serial devices," "serial peripheral devices," or simply "peripheral devices."

The data from the serial devices **162** are received at the serial interface **160** and transferred to ping/pong DMA circuits **164**. The DMA circuits **164** include a serial to parallel converter to convert the data to a parallel format. The parallel data is transferred from the ping/pong DMA circuits **164** over the bus structure **140** to the fast data memory **110**. An example ping/pong DMA circuits **164** is described in more detail below with reference to FIG. **5**.

Other peripheral devices, referenced by number **166**, are not linked to DMA circuitry because of their low bandwidth requirements. An example of this peripheral device is the navigation GPS chipset **100**. Serial data from a peripheral device **166** is received at the serial interface **160** and stored in a parallel format in an internal register where it may be read by the computer module **64**.

The logic unit **90** supports an IDE (Integrated Device Eletronics) port **170** for connection to the CD ROM or other IDE compatible device, such as a DVD player or IDE hard disk drive. The CD ROM is an IDE device with an ATAPI software interface, and typically has a 16-bit bus. The IDE port **170** is accessible from the bus structure **140** through two 16-bit bi-directional buffers **172** and **174** to translate the 16-bit CD-ROM data to the proper word location in the 32-bit internal data bus **144**. The microprocessor in the computer module communicates to the CD ROM through a sequence of ATAPI commands written to registers decoded by the logic unit. The register decoder **168** decodes and transfers read/write timing signals to IDE port **170** for output to the IDE compatible device.

Memory locations within the fast data memory **110**, the I/O ports to the peripheral devices **162**, **166**, and the IDE port **170** can be mapped into the address space presented by the logic unit **90**. Data can be sent to the peripheral devices or memory **110** over the internal address/data bus **140** by using addresses which have been uniquely assigned to each peripheral device or memory block. In a preferred implementation, the memory **110** is a 32-bits wide SRAM

with four byte enable lines to allow for combinations of byte, word, or double word access. The Fast Data memory address and data lines are driven by the logic unit **90** from the internal address/data bus structure **140** and the Fast Data Memory will be enabled when the address is in the range mapped to the multiport memory **110**. The address/data bus structure **140** will also be driven for transfers between the host processor and peripheral registers such as the computer module reading the GPS receive registers.

The internal address/data bus **140** splits its time between requests from the PCI bus **66** and DMA requests for accessing the memory **110**. The bus arbiter **148** controls the bus ownership and has selection logic to transition between a PCI bus request and a DMA request. The bus arbiter circuit **148** generally tries to grant one-half of the bus bandwidth to the PCI bus **66** and one-half to the DMA processes. When the arbiter decodes an active request, it initiates a bus cycle state machine and the active request grants the bus to either the PCI bus or to one of the internal DMA circuits.

As noted above, signals received from the PCI bus **66** have priority on the address/data bus **140**. The PCI bus signals are input into the logic unit **90** as 32-bit multiplexed signals consisting of address/data bits plus the PCI control/timing signals. When a PCI bus cycle begins, the logic unit **90** decodes the address. If the address corresponds to a mapped I/O port in or controlled by logic unit **90** or to a memory location within fast data memory **110**, the logic unit **90** drives a device select signal back to the PCI master at the computer module **64**, which in turn sets a PCI BUS REQUEST bit inside the logic unit **90**. The bus arbiter **148** grants the PCI bus **66** access to the internal address/data bus **140** at the next opportunity.

While this is happening the PCI bus is held in a wait state until the logic unit **90** asserts a target ready signal. The bus arbiter **148** grants the PCI bus interface circuit **156** access to the internal bus when the PCI BUS GRANT signal is active. This initiates a bus cycle state machine in the logic unit, which generates an internal read or write bus cycle. If the logic unit starts a write cycle, it waits for an initiator ready signal from the PCI bus to indicate that the write data is valid. For a read cycle, the internal bus cycle completes and the data is latched in the output data latch **154** of the PCI interface circuit. The logic unit **90** then asserts the target ready signal to allow the PCI master of the PCI bus **66** to complete the bus cycle.

When the PCI bus cycle is not mapped to an I/O port or to a memory location in memory **110**, the PCI bus interface **156** in the logic unit keeps the internal address and data bus isolated from the PCI bus **66**. In this manner, the PCI bus **66** and the internal bus structure **140** of the logic unit **90** can both be executing independent bus cycles. As a result, the data/address bus **140** of the logic unit **90** can service DMA bus operations occurring between the various serial devices **162** and the memory **110** without impacting the bandwidth of the PCI bus **66** or the microprocessor in the computer module **64**.

One aspect of this design is the way in which multiple peripheral devices **162** communicate through shared memory buffers in the fast static memory **110**. Many serial devices can be receiving data and buffering the data in the fast data memory **110** without intervention from the microprocessor on the computer module. The internal address/data bus structure **140** of the logic units, combined with the ping/pong DMA circuits **164**, form an effective communications buffer for handling the data communications between the serial devices, thereby significantly reducing the processor overhead in handling numerous data streams.

In the preferred implementation, there is one ping/pong DMA circuit for each corresponding DMA-configured serial peripheral device **162**. Recall from above that the fast data memory **110** has partitioned memory space that is mapped to corresponding ones of the peripheral devices. In this manner, storage areas within the memory **110** correspond to different peripheral devices. The ping/pong DMA circuit designates through memory pointers particular storage areas of the fast data memory **110** that belong to its associated peripheral device.

FIG. **5** shows a ping/pong DMA circuit **200** in more detail. The DMA circuit **200** has a serial-to-parallel converter **202** to convert the serial data received from the associated peripheral device into a parallel format for transfer on the internal bus **140**. The parallel data is placed initially in a holding register **204**.

A start address register **206** is provided to locate the appropriate buffer area within the fast data memory to hold the data in the holding register **204**. The logic unit initializes a DMA process by writing a word to the start address register **206**. The word defines the beginning of the buffer area in the fast data memory **110**. The upper bits of the start address register **206** represent the upper address lines of a buffer pointer into the memory **110**. In this implementation, the lower address bits in the start address register **206** are not used. The start address of the buffer area is on a page boundary and the size of the buffer area is a pre-determined size corresponding to the page size.

A lower address counter **208** is used to access the specific location within the designated buffer area of the memory. The number of bits in counter **208** corresponds to the size of the buffer area. In this implementation, the counter employs ten address bits A0–A9. A count output by the counter **208** is used as a pointer to the specific location into which the data in the holding register **204** is to be stored. Once the data is transferred to the storage location, the counter is incremented to reference the next appropriate location.

Each ping/pong DMA circuit defines two buffers within the buffer area of the memory **110**: a "ping" buffer and a "pong" buffer. The ping buffer represents a portion of the buffer area for a particular device into which data is being written from that device. Conversely, the pong buffer represents another portion of the buffer area from which data is being read. The upper address bit A9 of the counter **208** divides the buffer area into the ping and the pong buffers. When a transition of the upper counter bit occurs an interrupt may be generated, if the corresponding interrupt mask is enabled.

Address bits A0 and A1 are used to generate the four byte select signals of the internal address/data bus **140**. The lower two bits A0 and A1 of the counter **208** are used to select one of the byte select lines if the transfer is byte wide. The lower bit A1 is used to select an upper pair or lower pair of the byte select lines if the transfer is word wide. All byte enables are active for double word transfers. In this manner, the DMA process accommodates byte, word, or double word size data packets. As an example, a DMA circuit for an I^2C bus™ compatible peripheral device is configured for byte size data packets (i.e., 8 bits) because data is received from an I^2C bus™ in byte sizes. CD-ROM data is transferred in word sizes (i.e., 16 bits) which is appropriate for its bus size. I^2S digital audio data is transferred on a double word size (i.e., 32 bits).

In the case of a serial receive process, a serial data stream received from a peripheral device is shifted within the serial-to-parallel converter **202** to form units of 8, 16, or 32

bits in length. After the appropriate number of shifts, the data is transferred to register **204**. This transfer causes the DMA REQ & GNT circuit **210** to set a Bus Request signal.

The bus arbiter circuit **148** (FIG. **4**) looks at the bus request and grants the bus **140** to the DMA request at the next opportunity. Initiating a bus grant signal signifies that the bus has been granted to the DMA process. The bus grant signal enables the upper address bits **A10–A19** in the start address register **206** and the lower address bits **A2–A9** in the counter **208** to drive the internal address bus **142** for locating the appropriate address space in the fast data memory buffer. The appropriate byte enable lines are also driven. The data is transferred from the holding register **204** onto the data bus **144** and written into the fast data memory **110** at the address on the address bus **142**. The counter **208** is then incremented by one byte, word, or double word to prepare for the next address space of the buffer.

The logic unit can clear the counter **208** or inhibit the request signal by writing to a control register **212**.

In the illustrated implementation, a limit register **216** is used to set a limit value which may be less than that of the full size of the ping/pong buffer. For most cases, the limit value is set equal to the buffer size. In some cases, however, the buffer size might need to be smaller to handle odd size data blocks, such as data from the CD-ROM or other certain USB peripheral devices. The comparitor **214** compares the pointer moving through the buffer with the limit value stored in register **216**. When the counter **208** reaches the limit value in register **216**, the counter is reset and starts again. As a result, the size of the ping/pong buffer is not restricted to some capacity based on a power of two. The comparitor and limit register enable the buffer to accommodate irregular data block sizes.

The serial transmission case in which data is read out of the memory buffer is similar in the way of seizing control of the internal address bus and moving data out of the memory and onto the bus. In the transmission case, the Bus Request signal is activated when the data contents of the holding register **204** are transferred to the converter **202** for output, thereby leaving the holding register empty and awaiting the next data unit.

The direct memory access configuration of the logic unit **90**, memory **110**, and DMA circuits **200** enable fast and effective handling of the data communication to and from the serial peripheral devices. It permits the logic unit **90** to support many different serial peripheral devices without burdening the computer module. Another advantage is that the logic unit **90** enables efficient use of the memory space through the use of an "overlay" technique.

To illustrate an efficient memory overlay technique, FIG. **6** shows a simplified block diagram of the logic unit **90** coupled to various peripheral devices including, for example, the CD-ROM **78**, audio signal processor **96**, AM/FM tuner **98** via CODEC **102**. A sound source can be linked to the digital audio signal processor **96** by overlaying the ping/pong buffer area in the fast data memory **110** designated for the sound source with the ping/pong buffer area designated for the audio signal processor **96**. In this manner, the buffer area for the sound source has the same beginning and end points as the buffer area for the audio signal processor. This overlay allows the two devices to share the same buffer to efficiently exchange data. The sound source fills up its corresponding ping buffer area which happens to be the pong buffer for the audio signal processor. Concurrently, the audio signal processor is reading out of its ping buffer (i.e., the sound source's pong buffer) to retrieve data just filled by the sound source. When the sound source fills its ping buffer and the audio processor finishes reading its ping buffer, the sound source begins writing data to its corresponding pong buffer and the audio processor begins reading from its pong buffer which was just filled by the sound source.

Whenever a DMA process crosses a ping or pong boundary, an interrupt is generated, if unmasked. This is true for both the DMA process of the audio source and for the DMA process for an output to the signal processor. The interrupts may be used by software to guarantee that the two DMA processes stay synchronized.

The DMA overlaying process is further demonstrated by the following examples in which memory buffers designated for different data sources are overlaid on the memory buffers designated for the signal processor. These examples are described with reference to FIGS. **4–6**.

Suppose the AM/FM tuner **98** is the source of the audio data. The AM/FM tuner **98** produces audio data which is digitized into a serial data stream in the a CODEC. The DMA circuit **200** corresponding to the AM/FM tuner **98** receives the serial stream, converts it to a parallel format, and requests permission to write the data over the internal data bus **144** to the buffer pointed to by the ping/pong start address register **206**. More particularly, the data is written to a location within the buffer referenced by the counter **208**. For discussion purposes, suppose that the upper bit **A9** is "**0**" to designate that the data is written to "ping" buffer.

Concurrently, the DMA circuit **200** corresponding to the audio signal processor **96** maintains an address in its register **206** which references the same buffer area of the memory **110** used by the AM/FM tuner **98**. However, the upper counter bit **A9** of its counter **208** has a binary "1" to reference the "pong" buffer of the signal processor space. While data from the AM/FM tuner **98** is written to its ping buffer (also the audio signal processor's ping buffer), the signal processor is reading data from its pong buffer (also the tuner's pong buffer). Both of these events are based on a master clock signal so that the toggle between the ping and pong buffers for both the tuner and signal processor occur simultaneously in both incoming and outgoing data. The interrupts generated by both incoming and outgoing toggles can be ignored, unless the logic unit **90** has some interest in the data.

Accordingly, the architecture promotes efficient data transfer from the AM/FM tuner to the signal processor without burdening the processing resources of the computer module or the logic unit.

As another example, suppose the CD ROM **78** is the source of the data. The DMA circuits associated with the CD ROM **78** and the audio signal processor **96** are configured to point to the same buffer area of the fast data memory **110** buffer, with the ping buffer of each overlapping with the pong buffer of the other. In this case, the logic unit **90** interfaces with the CD ROM **78** through the IDE port, but the overlay aspects are essentially the same. The CD ROM alternately fills its associated ping and pong buffer spaces within the fast data memory **110** while the audio processor concurrently reads from its associated ping and pong buffers to extract the audio data just written by the CD ROM.

The logic unit facilitates similar data flow between the signal processor and other serial devices, including the CODEC, the USB hub which connects to many outside peripheral devices, the computer module via the PCI bus, and so forth.

FIG. **7** shows a master audio clock generating unit **220** that is resident in the support module **62**. The master clock

generating unit provides clock signals to many components and interfacing busses. The master clock generating unit **220** includes a clock oscillator **222** which, in the preferred implementation, is a 48 MHz oscillator. A divide-by-N counter **224** and a divide-by-two counter **226** are formed as part of the logic unit **90** to produce a master audio clock signal used to synchronize the various audio components in the vehicle computer system. Assuming a 48 MHz oscillator, the counters **224** and **226** produce an audio clock signal of approximately 44.1 KHz. The clock generating unit **220** also includes a divide-by-480 counter **228** to produce a 100 KHz I^2C bus™ clock signal, and a divide-by-N counter circuit **230** which produces various baud rates for UARTs.

The master clock generating unit **220** employs a phased lock loop (PLL) **232** of the CODEC **102** which multiplies the audio clock signal to yield a high speed clock signal that can be transmitted over the high speed serial interface **68** to the faceplate module. In the illustrated implementation, for example, the PLL **232** multiplies the 44.1 KHz signal by a factor **256** to produce a high speed clock signal of approximately 11.2 MHz. This high speed clock signal is passed back through the logic unit **90** where it is passed through an on/off gate **234** to be selectively output to the faceplate module as the faceplate clock FCLK signal when the faceplate is attached. Additionally, the logic unit **90** has a divide-by-17 counter **236** which generates a synchronizing bit FSYNC every 17th bit of the high speed clock signal. The faceplate module is equipped with a clock generation circuit which divides the high speed clock signal back down to the desired audio rate of 44.1 KHz. If the faceplate module is detached from the support module, the logic unit **90** disables the FCLK signal to conserve power.

One benefit of the master clock generating unit **220** is that it can adjust and fine tune the clock frequency to accommodate fixed rate audio devices, such as a CD ROM player. Such devices often have a fixed rate that might vary slightly from the specified optimal clock frequency. To ensure an optimum synchronization among the audio components, the master clock generating unit **220** adjusts itself by altering the value N in the divide-by-N counter **224** to thereby produce slightly different audio clock rates that approximate the desired 44.1 KHz. This master clock adjustability feature provides better synchronization which in turn promotes optimal sound quality.

Data is carried over the high speed serial interconnect between the support and faceplate modules using the 11.2 MHz clock rate. According to an aspect of this invention, the data is transferred as a synchronized serial bit stream which is organized into multiple frames. Each frame has multiple data bits and at least one valid bit to indicate whether the data bits are valid. The frames are set apart from one another by a synchronization signal.

FIG. **8** shows a timing diagram of the high speed clock **240**, a synchronization signal **242**, and one data frame **244** according to a preferred implementation. The clock signal **240** is produced at a frequency of approximately 11.2 MHz. The synchronization signal **242** is asserted every 17th clock pulse and remains asserted through one clock period. Following this synchronization bit, a 17-bit frame is transferred. The frame includes a valid bit **246** and 16 bits of data D0–D15. The valid bit **246** is set when the data bits **248** are valid and reset when the accompanying data bits are not valid.

FIG. **9** shows another aspect of this invention concerning the power system **260** for the vehicle computer system. The power system **260** is designed to ensure that the vehicle computer system has power in the event that the primary vehicle battery **32** is disconnected, becomes discharged, or during engine starting. For instance, the vehicle battery **32** may be rendered ineffective if the user accidentally leaves on the vehicle lights, or if a person attempts to disarm the vehicle by disconnecting the battery. It is desirable that the computer system remain operative to maintain security and communication features even though the system can no longer draw power from the vehicle battery. Another concern is that the voltage output of the vehicle battery **32** can be reduced to less than five volts when the vehicle is being started. This brief low voltage period may adversely affect operation of the vehicle computer system.

To alleviate these potential problems, the power system **260** has a backup battery **33** which functions as a secondary power source to the vehicle computer system. The backup battery **33** can be identical to the primary battery or something with less, but sufficient power to support a computer system. The power system **260** also includes a power source selector **262** coupled between (1) both the primary and secondary power sources **32, 33** and (2) the vehicle computer system. The power source selector **262** alternately enables the primary battery **32** or the backup battery **33** to supply power to the vehicle computer system. The power is input to a power regulator and manager **258**, which converts the power to the appropriate levels for use in the computer module **64**, the support module **62**, and the faceplate module **60**.

In the illustrated implementation, the power source selector **262** is configured using solid state electronic devices in the form of diodes that do not require any switching or relay circuitry. The selector **262** includes a first diode path **264** having n diodes (n=1, 2, . . .), as represented by diode **266**, connected between the vehicle battery **32** and the vehicle computer system. The selector **262** also includes a second diode path **268** having at least n+1 diodes, as represented by two diodes **270** and **272**, connected between the backup battery **33** and the vehicle computer system. By placing at least one more diode in the backup-to-computer path **268**, the vehicle computer system will draw voltage primarily from the vehicle battery **32** during normal operation because there is less voltage drop in the primary-to-computer path **264** so long as the vehicle battery **32** has sufficient power.

In the event that the vehicle battery **32** becomes discharged to point below the voltage level of the backup battery (plus a voltage drop for the additional diode(s) in the second path **268**), the computer system draws voltage from the backup battery **33**. The diode **266** prevents current from going back into the dead or discharged battery **32** to efficiently divert the power to the vehicle computer system.

The backup battery **33** has its own charging circuit (not shown) which enables it to be charged when the vehicle is operating. For instance, in an automobile, the charging circuit allows the automobile's alternator to charge the backup battery **33**.

The power regulator and manager **258** provides four main power states during operation of the vehicle computer system. These states include power up, intermediate power, power down, and power off. In the "power up" state, all components in the computer system are fully powered up. In the "intermediate power" state, some of the components are powered up, while others of the components and peripheral devices are powered down. The "power down" state is the lowest power state without removing power altogether. The busses and logic unit are on, but most components and peripherals are powered down. User activation can bring the

system back from the power down state to a power up state. In the "power off" state, all components are off, excepting a few wake-up circuits, battery-backed clock, and the like.

In compliance with the statute, the invention has been described in language more or less specific as to structure and method features. It is to be understood, however, that the invention is not limited to the specific features described, since the means herein disclosed comprise exemplary forms of putting the invention into effect. The invention is, therefore, claimed in any of its forms or modifications within the proper scope of the appended claims appropriately interpreted in accordance with the doctrine of equivalents and other applicable judicial doctrines.

We claim:

1. A vehicle computer system comprising:

a housing of a size suitable to be mounted in a vehicle dashboard, the housing having first and second support structures that can be physically connected to, or separated from, one another;

a first logic unit mounted to the first support structure of the housing;

a second logic unit mounted to the second support structure of the housing;

a high speed serial interface to electrically interconnect the first and second logic units when the first and second support structures are physically connected to one another; and

the first and second logic units being configured to exchange data via the high speed serial interface using a synchronized serial bit stream which is organized into multiple frames, individual frames having multiple data bits and at least one valid bit to indicate whether the data bits are valid.

2. A vehicle computer system as recited in claim 1, wherein one of the first and second logic units transmits at least one synchronizing bit to commence a start of a frame and synchronize the serial bit stream.

3. A vehicle computer system as recited in claim 1, wherein each frame is a 17-bit frame consisting of 16 data bits and one valid bit.

4. A vehicle computer system as recited in claim 1, wherein the housing has a form factor of a single DIN.

5. A vehicle computer system as recited in claim 1, wherein the first support structure is configured to be mounted within the vehicle dashboard and the second support structure is a detachable faceplate.

6. A vehicle computer system as recited in claim 1, further comprising a power system comprising:

a backup power source; and

a power source selector coupled between (1) both the backup power source and a primary vehicle battery and (2) the vehicle computer system, the power source selector alternately enabling at least one of the primary vehicle battery or the backup power source to supply power to the vehicle computer system.

7. A vehicle computer system as recited in claim 1, wherein the first logic unit is configured to interface with multiple peripheral devices, and the first logic unit uses direct access memory to facilitate data communication with the peripheral devices.

8. In a vehicle computer system having a clock generator that generates clock pulses, a method for transmitting data comprising the step of serially sending one synchronizing bit every N clock pulses followed by an N-bit frame comprising N-1 data bits and one valid bit to indicate whether the data bits are valid, wherein N is an integer greater than one.

9. A method as recited in claim 8 wherein the multi-bit frame is a 17-bit frame consisting of 16 data bits and one valid bit.

10. A serial data stream transmitted over a serial conductor as a result of the step recited in claim 8.

11. A vehicle computer system programmed to perform the step recited in claim 8.

12. A vehicle computer power system for a vehicle computer system to be mounted in a vehicle, the vehicle having a primary power source, the power system comprising:

a secondary power source mounted external to the vehicle computer system;

a power source selector coupled between (1) both the primary and secondary power sources and (2) the vehicle computer system, the power source selector alternately enabling at least one of the primary power source or the secondary power source to supply power to the vehicle computer system;

the power source selector having a first diode path connected between the primary power source and the vehicle computer system, the first diode path having n diodes; and

the power source selector having a second diode path connected between the secondary power source and the vehicle computer system, the second diode path having at least n+1 diodes.

13. A vehicle computer system comprising a vehicle computer power system as recited in claim 12.

14. A vehicle computer system, comprising:

a housing of a size suitable to be mounted in a vehicle dashboard;

a logic unit mounted in the housing, the logic unit having an internal multi-bit bus structure and being configured to interface with one or more peripheral devices;

a processing unit mountable in the housing, the processing unit having an internal multi-bit bus structure separate from the bus structure of the logic unit;

a data memory operatively coupled to the bus structure of the logic unit to temporarily hold data being communicated between the peripheral devices, the data memory being partitioned into storage areas for corresponding ones of the peripheral devices; and

the logic unit having one or more memory access circuits associated witb corresponding ones of the peripheral devices, each memory access circuit designating storage areas of the data memory to hold input data received from, or output data to be sent to, the associated peripheral device.

15. A vehicle computer system as recited in claim 14 wherein the logic unit and the processing unit are interfaced using a multi-bit bus.

16. A vehicle computer system for use in a vehicle, comprising:

a logic unit;

a data memory accessible by the logic unit to temporarily hold data being communicated between peripheral devices, the data memory being partitioned into storage areas for corresponding ones of the peripheral devices; and

the logic unit having one or more memory access circuits associated with corresponding ones of the peripheral devices, each memory access circuit designating one storage area of the data memory to hold input data received from the associated peripheral device and

another storage area of the data memory to hold output data to be sent to the associated peripheral device.

17. A vehicle computer system as recited in claim 16 wherein the logic unit has an address/data bus structure and the data memory is coupled to the address/data bus structure, the memory access circuits being capable of accessing the data memory directly using the address/data bus structure.

18. A vehicle computer system as recited in claim 16 configured to support first and second peripheral devices, further comprising:

first and second memory access circuits associated with the first and second peripheral devices, respectively; and

the first memory access circuit being configured to designate a particular storage area of the data memory to hold data received from the first peripheral device and the second memory access circuit being configured to designate the same particular storage area of the data memory to hold data to be sent to the second peripheral device.

19. A vehicle computer system as recited in claim 16, further comprising a power system comprising:

a backup power source; and

a power source selector coupled between (1) both the backup power source and a primary vehicle battery and (2) the vehicle computer system, the power source selector alternately enabling at least one of the primary vehicle battery or the backup power source to supply power to the vehicle computer system.

20. In a vehicle computer system to be mounted in a vehicle, the vehicle computer system having a processing unit connected to communicate with multiple peripheral devices, a subsystem for processing continuous audio or video data received from a data source comprising:

a data processor;

a memory partitioned into pages;

a first memory access circuit associated with the data source to facilitate data transfer between the memory and the data source, the first memory access circuit being configured to input data received from the data source in a particular memory page; and

a second memory access circuit associated with the data processor to facilitate data transfer between the memory and the data processor, the second memory access circuit being configured to retrieve the data from the particular memory page and to output the data to the data processor.

21. A subsystem as recited in claim 20, wherein the data processor comprises a digital signal processor.

22. A vehicle computer system comprising a subsystem as recited in claim 20.

23. In a vehicle computer system to be mounted in a vehicle, the vehicle computer system supporting at least one peripheral device having a fixed clock frequency, a master clock generating unit comprising:

an oscillator to provide a fundamental clock frequency; and

clock frequency adjustment circuitry coupled to the oscillator to produce one or more master clock frequencies based upon the fundamental clock frequency, the clock frequency adjustment circuitry being adjustable to synchronize to the fixed clock frequency of the peripheral component.

24. A vehicle computer system comprising a subsystem as recited in claim 23.

25. A vehicle computer system comprising:

a housing having a base unit and a faceplate;

a logic unit mounted to the base unit to form a support module, the support module having an interfacing slot and being configured to support multiple peripheral devices;

the faceplate having at least one electronic component to form a faceplate module, the faceplate module being compatibly connected to the interfacing slot of the support module;

a high speed serial interface electronically coupling the logic unit to the electronic component on the faceplate module, the high speed serial interface enabling the logic unit to transfer a synchronized serial bit stream to the electronic component, the serial bit stream being organized into multiple frames, individual frames having multiple data bits and at least one valid bit to indicate whether the data bits are valid; and

the support module being configured to facilitate data communication between the peripheral devices, the support module having a data memory to temporarily hold data being communicated between the peripheral devices and one or more memory access circuits associated with corresponding ones of the peripheral devices, each memory access circuit designating at least one storage area within the data memory to hold input data received from, or output data to be sent to, the associated peripheral device.

26. A vehicle computer system as recited in claim 25, wherein the support module has another interfacing slot, and the vehicle computer system further comprises a computer module having a second processing unit, the computer module being compatibly connected to the other interfacing slot of the support module.

27. A vehicle computer system as recited in claim 26, wherein each of the first and second processing units has its own internal multi-bit bus.

28. A vehicle computer system as recited in claim 26, wherein each individual frame is a 17-bit frame consisting of 16 data bits and one valid bit.

29. A vehicle computer system as recited in claim 26, wherein the support module is configured to support first and second peripheral devices, further comprising:

first and second memory access circuits associated with the first and second peripheral devices, respectively; and

the first memory access circuit being configured to designate a particular storage area of the data memory to hold data received from the first peripheral device and the second memory access circuit being configured to designate the same particular storage area of the data memory to hold data to be sent to the second peripheral device.

30. A vehicle computer system as recited in claim 25, wherein the vehicle computer system is connected to receive power from a primary vehicle battery, and further comprising a power system comprising:

a backup power source; and

a power source selector coupled between (1) both the backup power source and the primary vehicle battery and (2) the vehicle computer system, the power source

selector alternately enabling at least one of the primary vehicle battery or the backup power source to supply power to the vehicle computer system.

31. A vehicle computer system, comprising:

first and second logic units mountable in a vehicle;

a clock generator that generates clock pulses;

a high speed serial interface to electrically interconnect the first and second logic units; and

the first and second logic units being configured to exchange data via the high speed serial interface by sending one synchronizing bit every N clock pulses followed by an N-bit frame comprising N-1 data bits and one valid bit to indicate whether the data bits are valid, wherein N is an integer greater than one.

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[54] **VEHICLE COMMUNICATION AND REMOTE CONTROL SYSTEM**

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5,526,265	6/1996	Nakhla	294/183
5,543,789	8/1996	Behr et al.	340/995
5,544,225	8/1996	Kennedy, III et al.	455/456
5,568,390	10/1996	Hirota et al.	340/990
5,572,204	11/1996	Timm et al.	340/988
5,629,693	5/1997	Janky	340/426
5,638,280	6/1997	Nishimura et al.	340/990
5,682,133	10/1997	Johnson et al.	340/426
5,712,899	1/1998	Pace, II	340/988

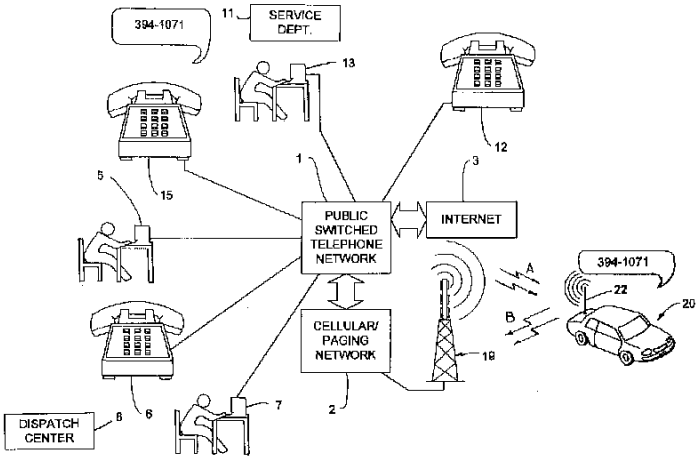
Primary Examiner—Brent A. Swarthout

Attorney, Agent, or Firm—Price, Heneveld, Cooper, DeWitt & Litton

[57] **ABSTRACT**

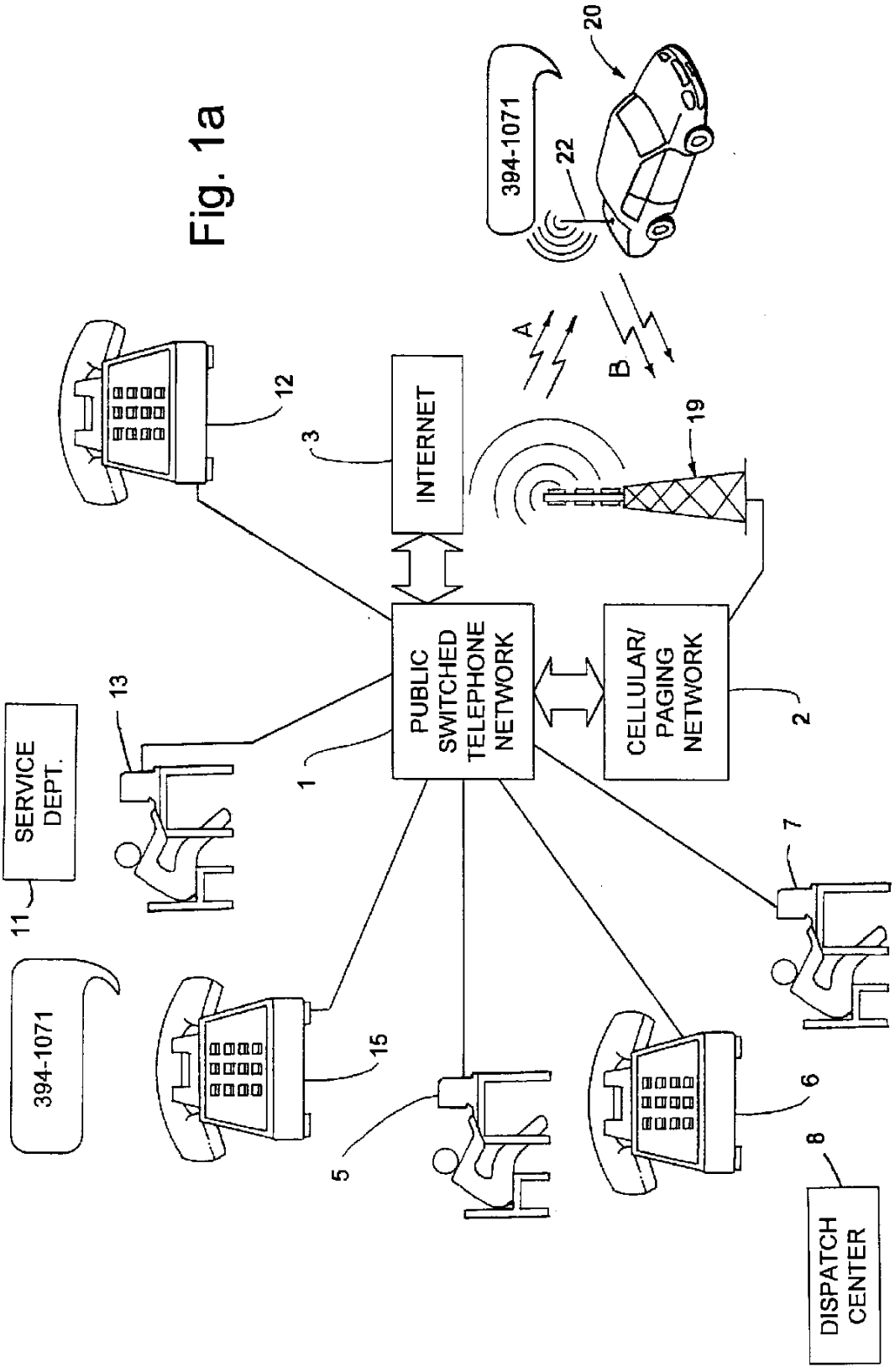
The vehicle communication and control system of the present invention includes a transceiver for sending and receiving RF signals, a processor coupled to the transceiver, a location identifying sensor coupled to the processor for supplying vehicle location data, a user interface coupled to the processor for providing information to a user and for enabling a user to input commands to be executed by the processor, and a vehicle accessory interface for coupling the processor to a vehicle accessory control circuit to enable the processor to issue commands to a vehicle accessory. The processor is preferably adapted to perform a wide variety of functions in response to user input commands, received RF signals, and other commands received from other vehicle accessories and components coupled to the system of the present invention through the vehicle system bus. Some of these functions include establishing a two-way communication link, requesting and providing location-specific information, enabling remote tracking of the vehicle, issuing an emergency request or a request for roadside assistance, requesting and receiving navigational information, remote control of vehicle functions, enabling remote diagnostics of the vehicle, and enabling reprogramming of various vehicle accessories and components.

28 Claims, 62 Drawing Sheets



OMEGA EXHIBIT 2036

Fig. 1a


PUBLIC SWITCHED TELEPHONE NETWORK
CELLULAR/ PAGING NETWORK
INTERNET
SERVICE DEPT.
DISPATCH CENTER
394-1071
394-1071
A
B
1
2
3
5
6
7
8
11
12
13
15
19
20
22

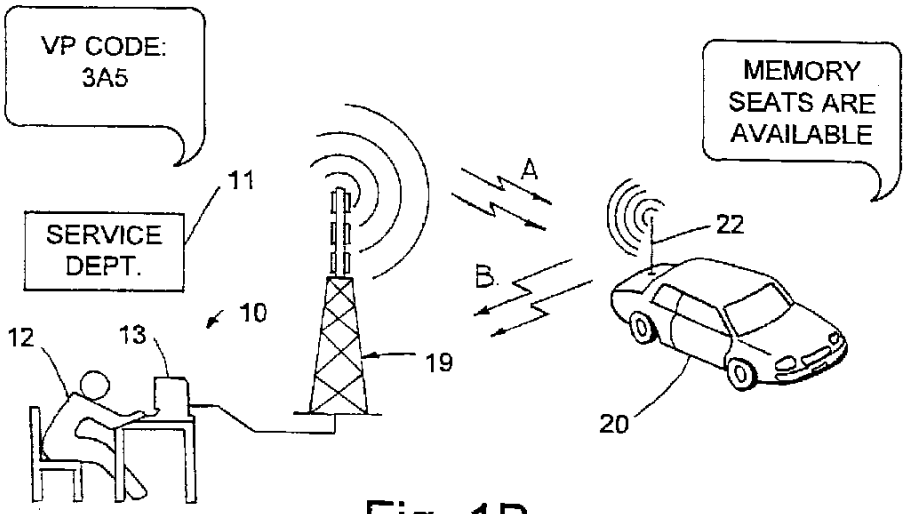

VP CODE:
3A5
MEMORY
SEATS ARE
AVAILABLE
11
SERVICE
DEPT.
A
B.
22
10
12
13
19
20

Fig. 1B

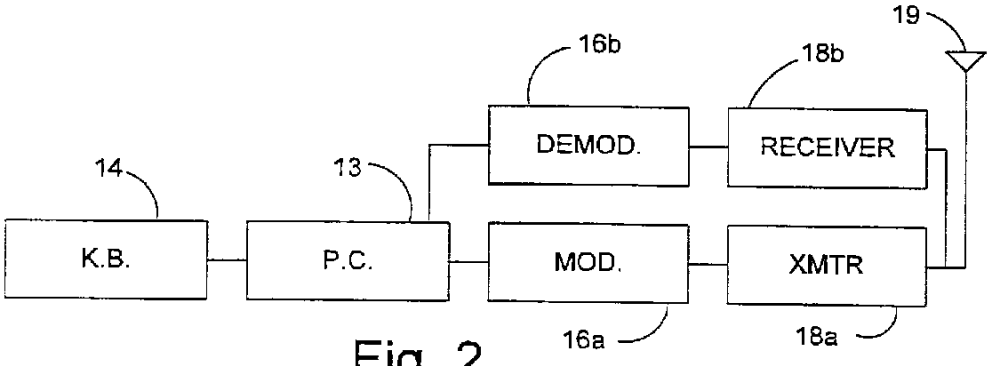

19
16b
18b
DEMOD.
RECEIVER
14
13
K.B.
P.C.
MOD.
XMTR
16a
18a

Fig. 2

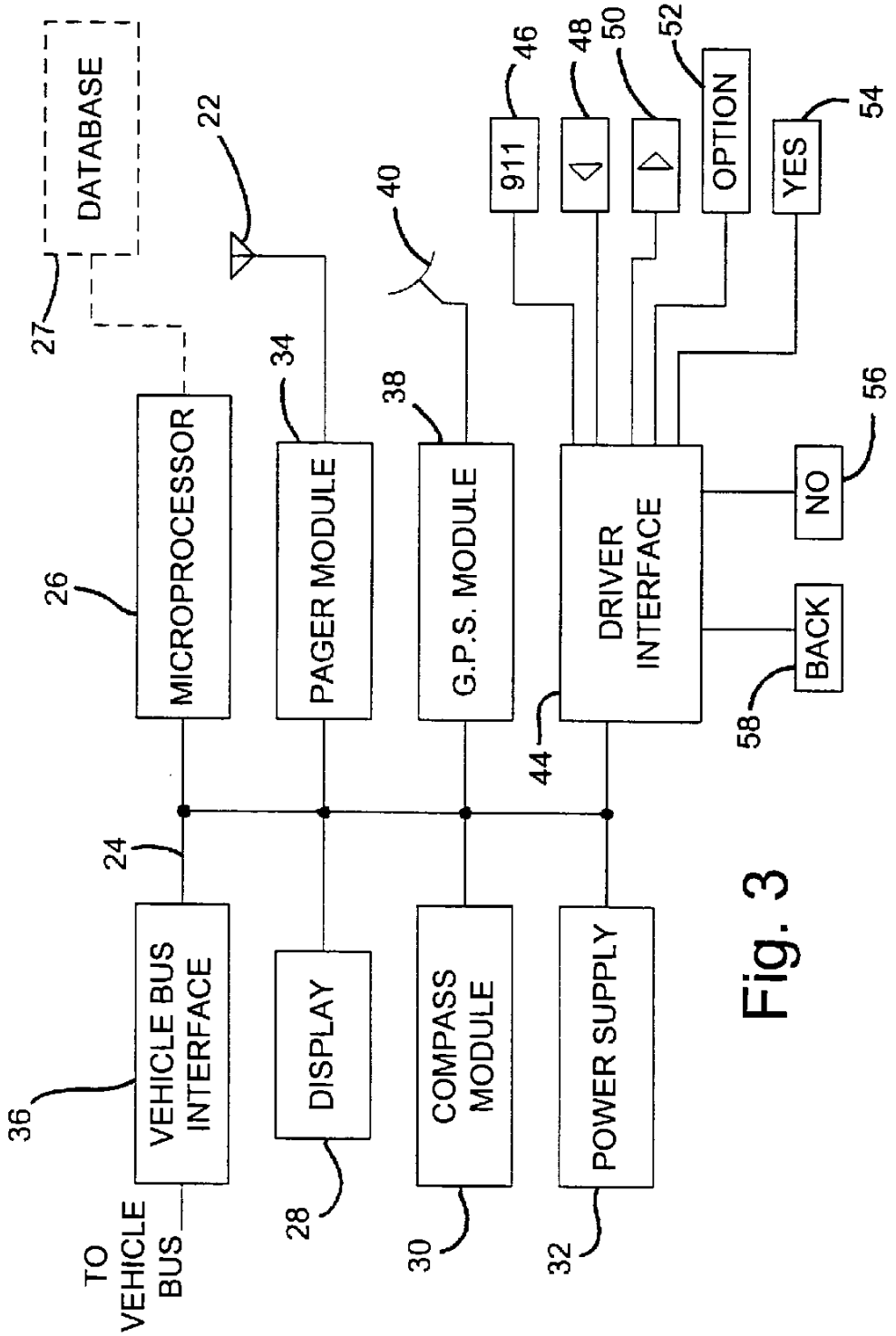

DATABASE
27
22
40
46
48
50
52
911
OPTION
YES
54
34
38
MICROPROCESSOR
PAGER MODULE
G.P.S. MODULE
DRIVER INTERFACE
NO
56
26
BACK
58
44
24
36
VEHICLE BUS INTERFACE
DISPLAY
COMPASS MODULE
POWER SUPPLY
TO VEHICLE BUS
28
30
32

Fig. 3

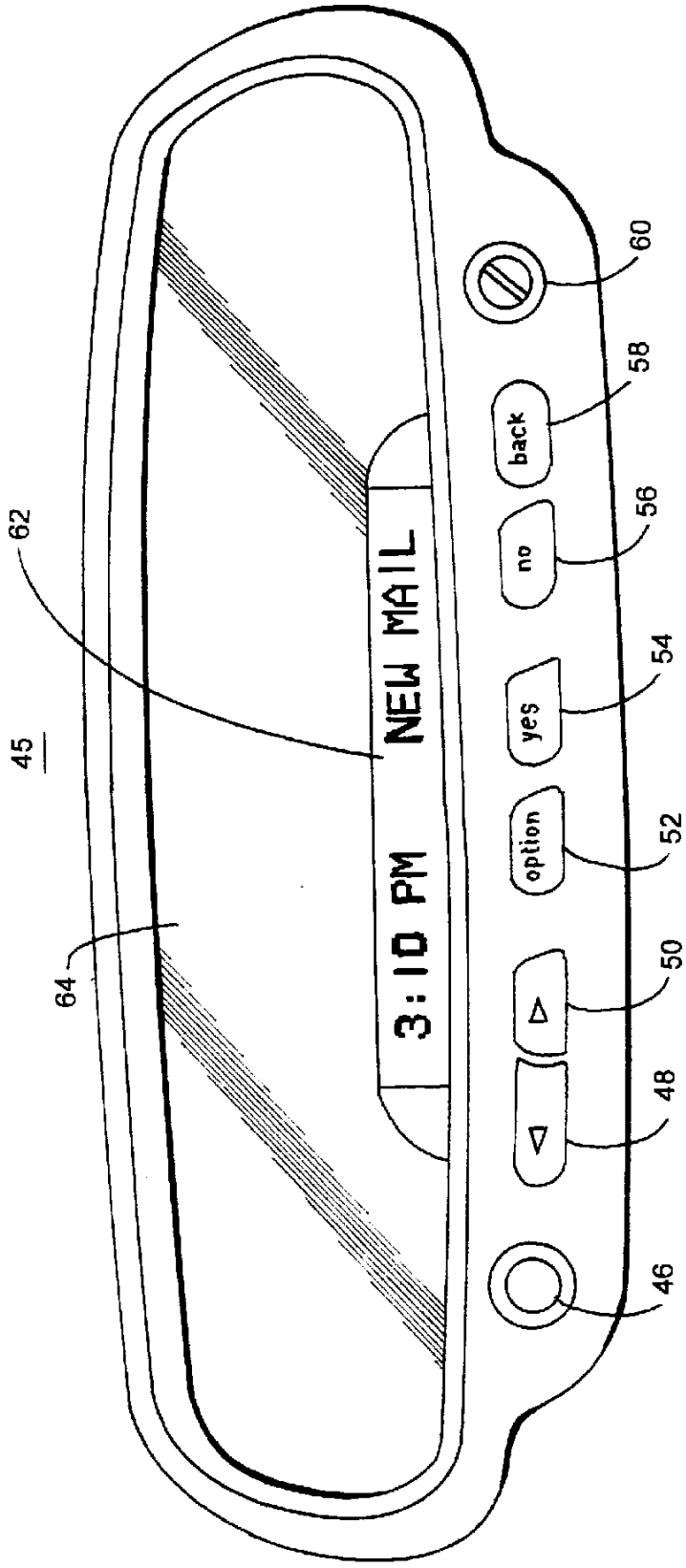

NEW MAIL
3:10 PM
back
no
yes
option
Δ
∇
45
46
48
50
52
54
56
58
60
62
64

Fig. 4

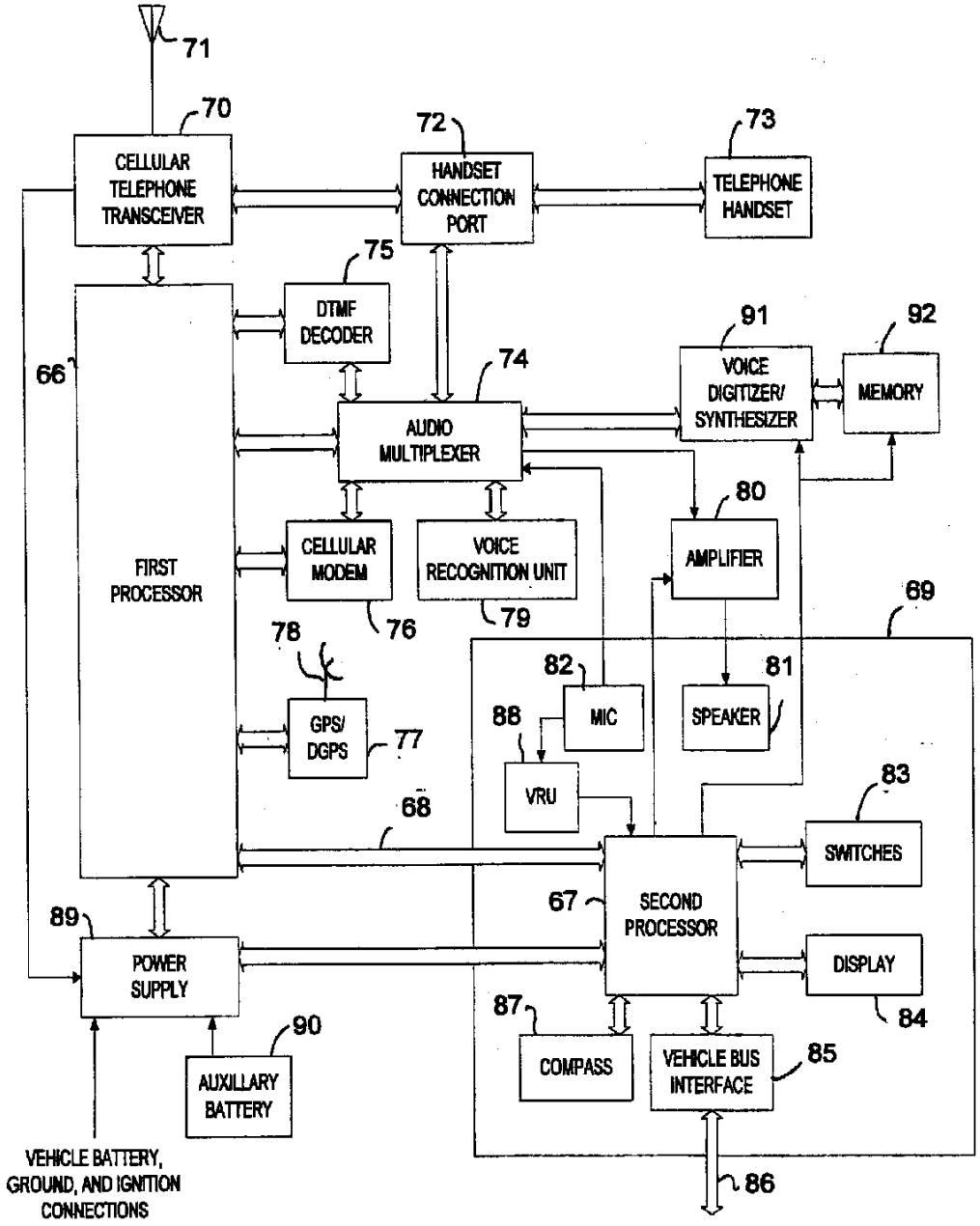

71
70
CELLULAR TELEPHONE TRANSCEIVER
72
HANDSET CONNECTION PORT
73
TELEPHONE HANDSET
75
DTMF DECODER
66
FIRST PROCESSOR
74
AUDIO MULTIPLEXER
91
VOICE DIGITIZER/ SYNTHESIZER
92
MEMORY
80
AMPLIFIER
CELLULAR MODEM
76
VOICE RECOGNITION UNIT
79
69
78
GPS/ DGPS
77
82
MIC
88
VRU
81
SPEAKER
83
SWITCHES
68
67
SECOND PROCESSOR
89
POWER SUPPLY
DISPLAY
84
87
COMPASS
VEHICLE BUS INTERFACE
85
90
AUXILLARY BATTERY
VEHICLE BATTERY, GROUND, AND IGNITION CONNECTIONS
86

Fig. 5

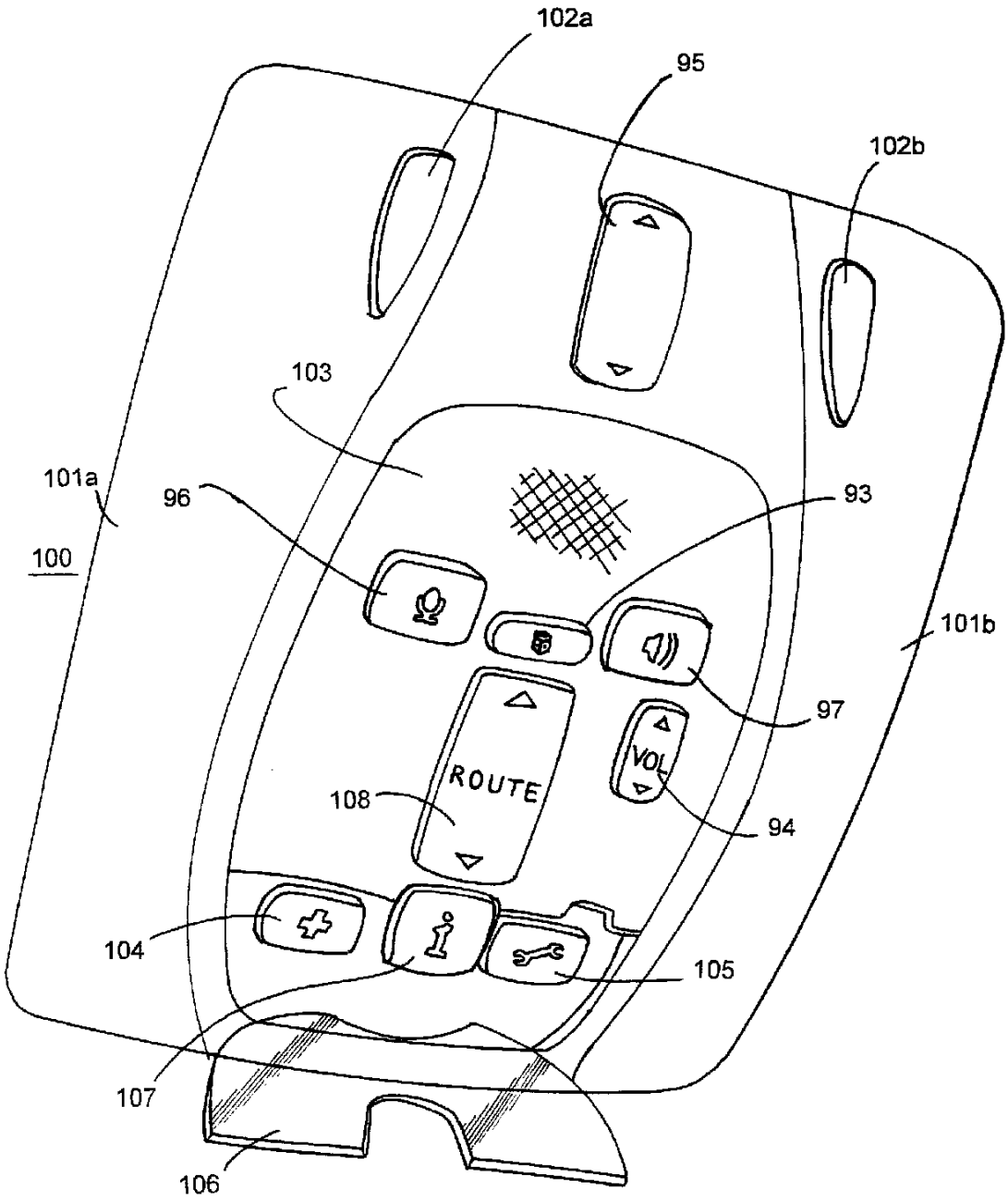

102a
95
102b
103
101a
96
93
100
101b
97
ROUTE
VOL
108
94
104
105
107
106

Fig. 6

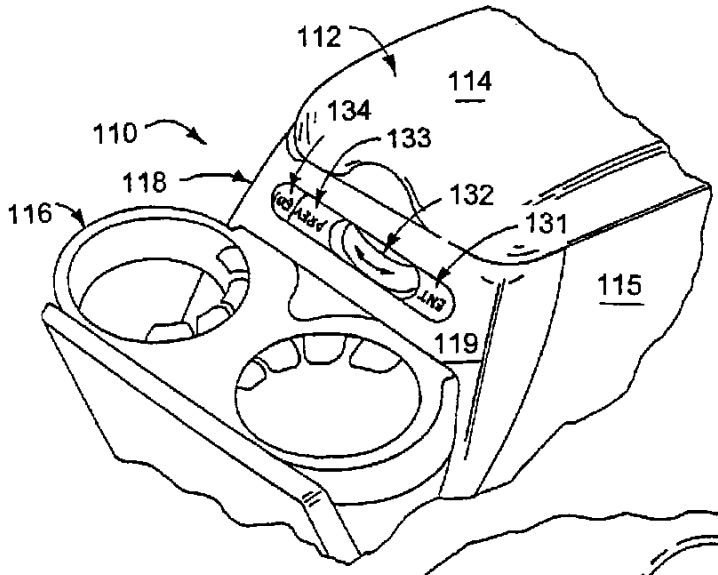


Fig. 7

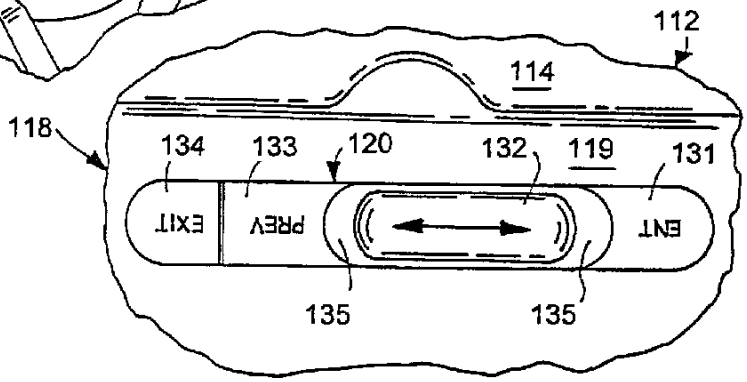


Fig. 8

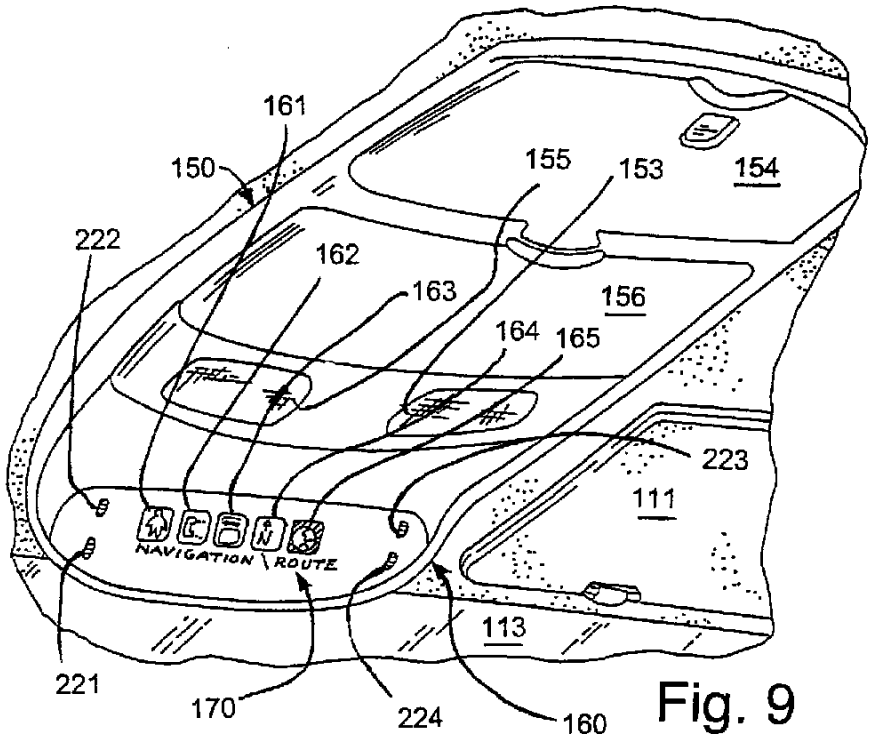


Fig. 9

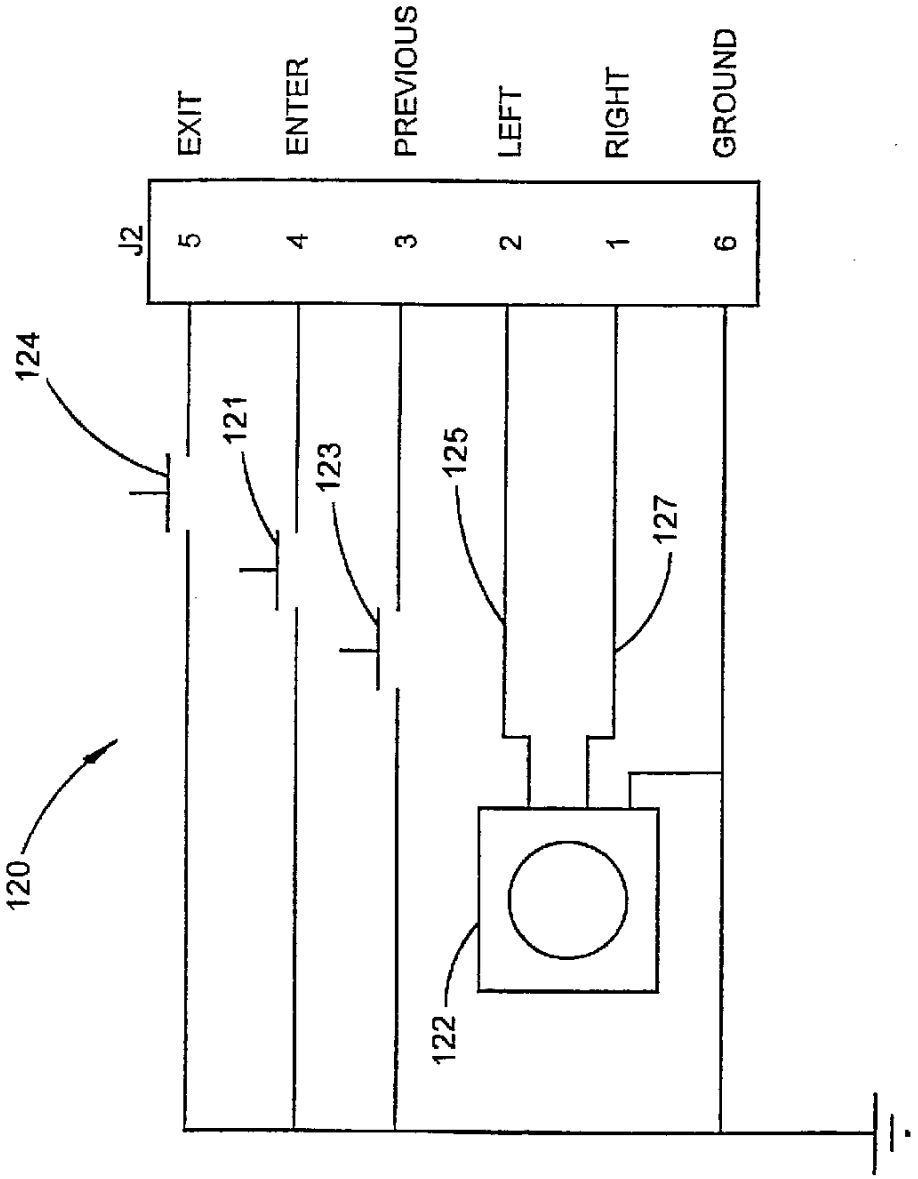
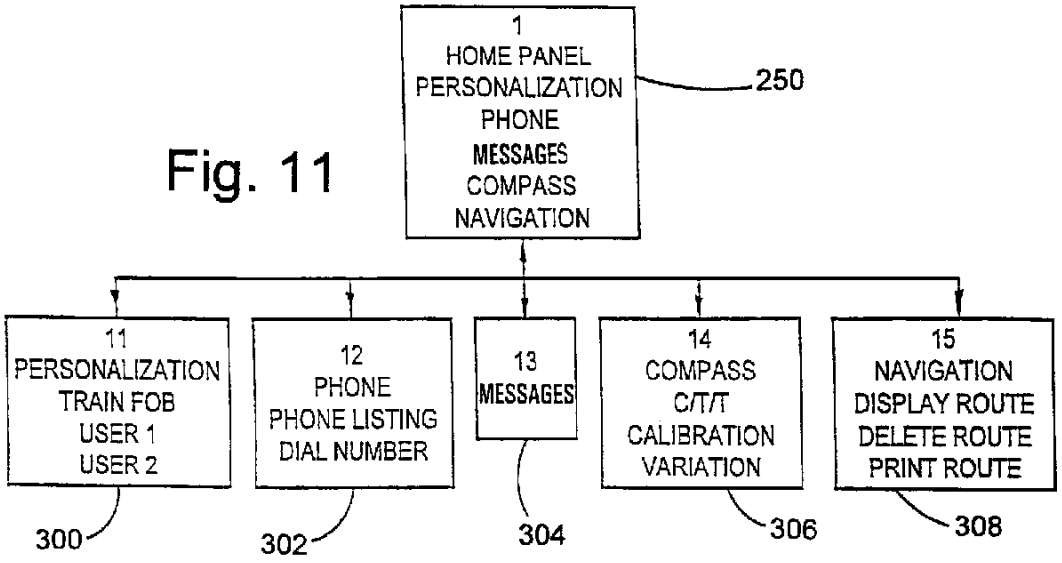

EXIT
ENTER
PREVIOUS
LEFT
RIGHT
GROUND
J2
5
4
3
2
1
6
120
121
122
123
124
125
127

Fig. 10

Fig. 11


1
HOME PANEL
PERSONALIZATION
PHONE
MESSAGES
COMPASS
NAVIGATION
250
11
PERSONALIZATION
TRAIN FOB
USER 1
USER 2
300
12
PHONE
PHONE LISTING
DIAL NUMBER
302
13
MESSAGES
304
14
COMPASS
C/T/T
CALIBRATION
VARIATION
306
15
NAVIGATION
DISPLAY ROUTE
DELETE ROUTE
PRINT ROUTE
308

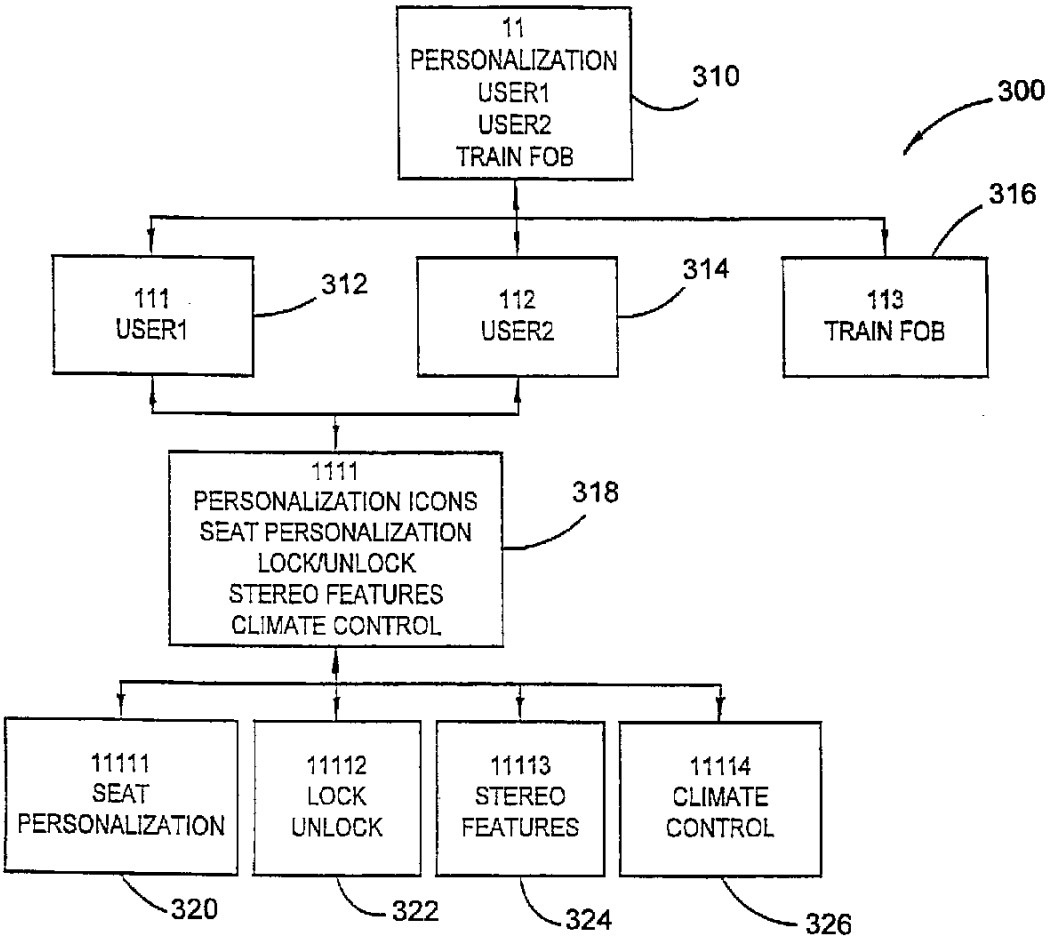

11
PERSONALIZATION
USER1
USER2
TRAIN FOB
310
300
316
111
USER1
312
112
USER2
314
113
TRAIN FOB
1111
PERSONALIZATION ICONS
SEAT PERSONALIZATION
LOCK/UNLOCK
STEREO FEATURES
CLIMATE CONTROL
318
11111
SEAT
PERSONALIZATION
320
11112
LOCK
UNLOCK
322
11113
STEREO
FEATURES
324
11114
CLIMATE
CONTROL
326

Fig. 12

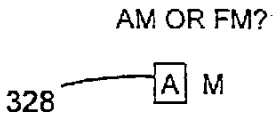


Fig. 13

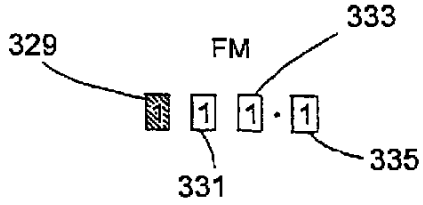


Fig. 15

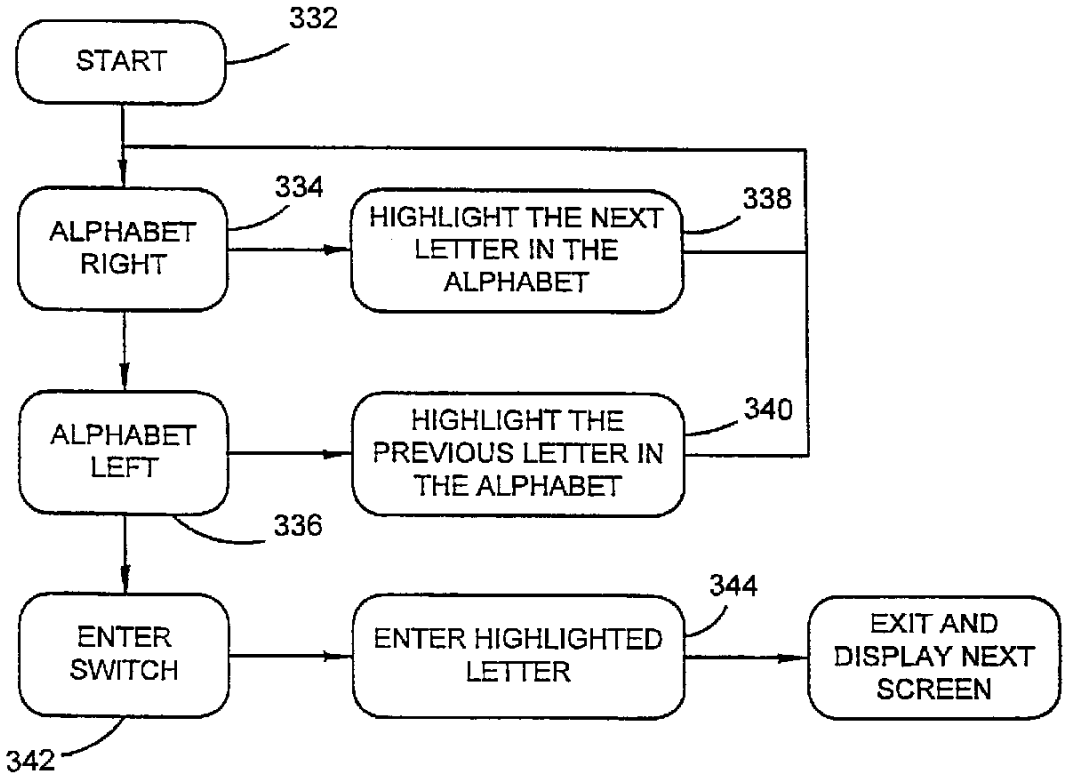


Fig. 14

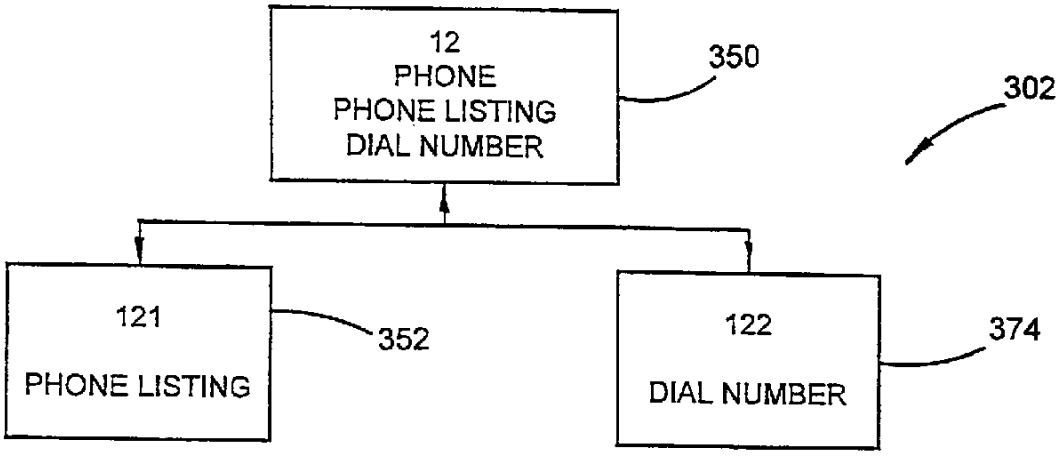


Fig. 16

PHONE LIST

1 JOE SMITH 616-123-4567
2
3

Fig. 17

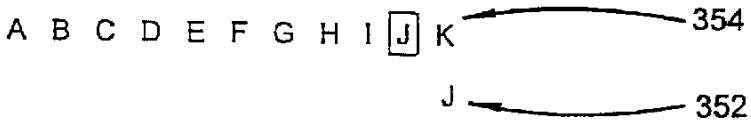


Fig. 18

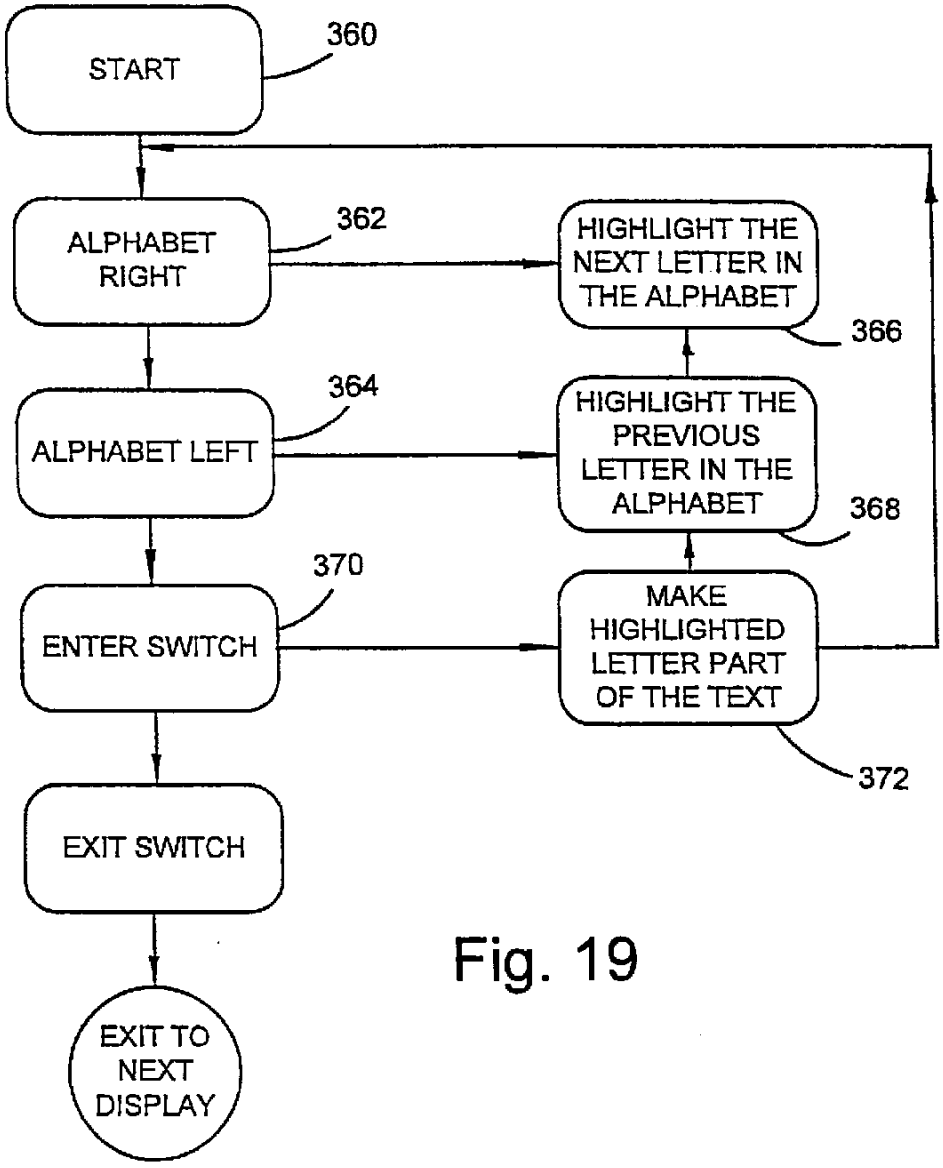

START
360
ALPHABET RIGHT
362
HIGHLIGHT THE NEXT LETTER IN THE ALPHABET
366
ALPHABET LEFT
364
HIGHLIGHT THE PREVIOUS LETTER IN THE ALPHABET
368
ENTER SWITCH
370
MAKE HIGHLIGHTED LETTER PART OF THE TEXT
372
EXIT SWITCH
EXIT TO NEXT DISPLAY

Fig. 19

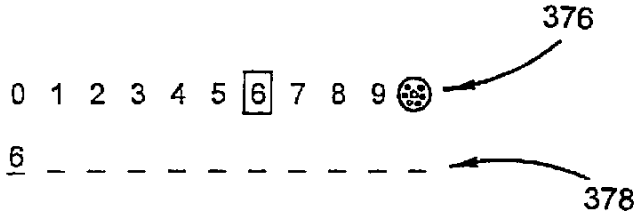

376
0 1 2 3 4 5 6 7 8 9
6
378

Fig. 20

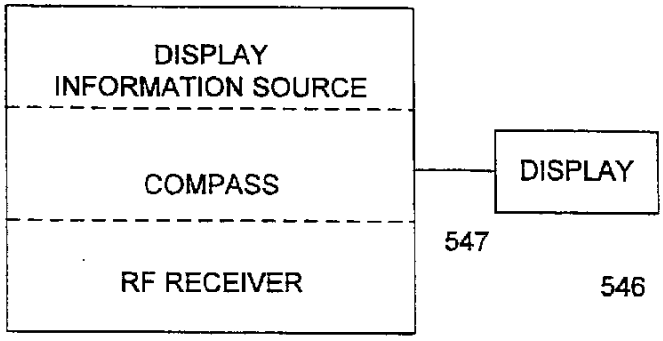

DISPLAY
INFORMATION SOURCE
COMPASS
RF RECEIVER
DISPLAY
547
546

Fig. 37

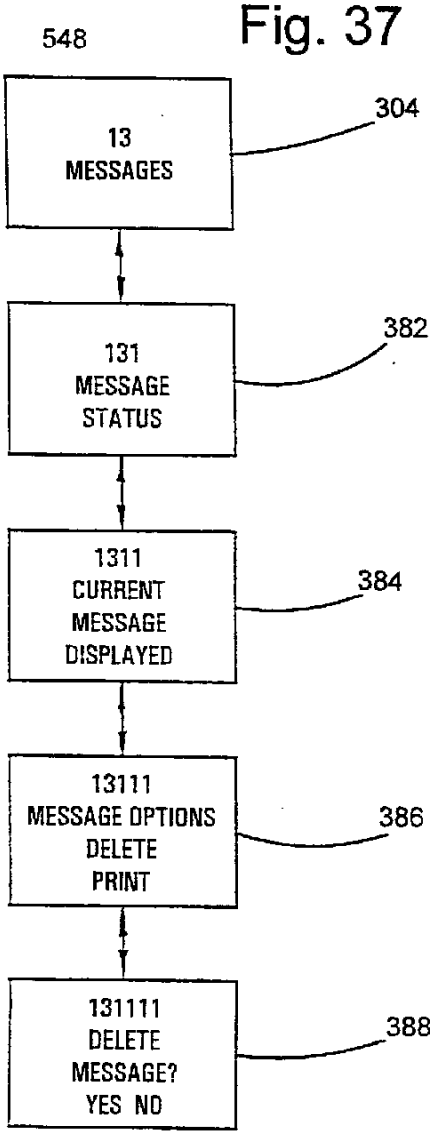

548
13
MESSAGES
304
131
MESSAGE
STATUS
382
1311
CURRENT
MESSAGE
DISPLAYED
384
13111
MESSAGE OPTIONS
DELETE
PRINT
386
131111
DELETE
MESSAGE?
YES NO
388

Fig. 21

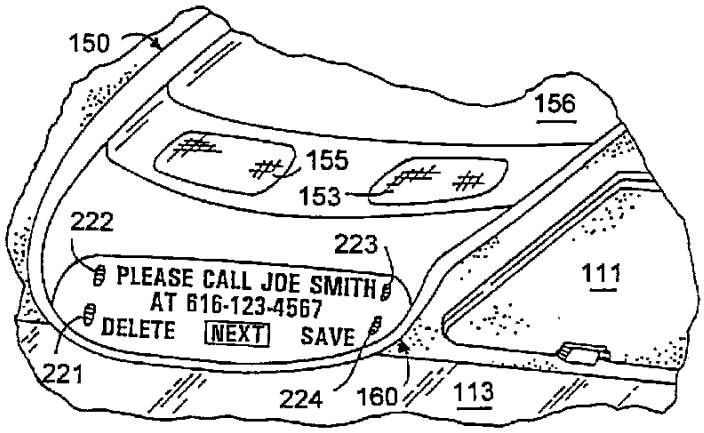


Fig. 22

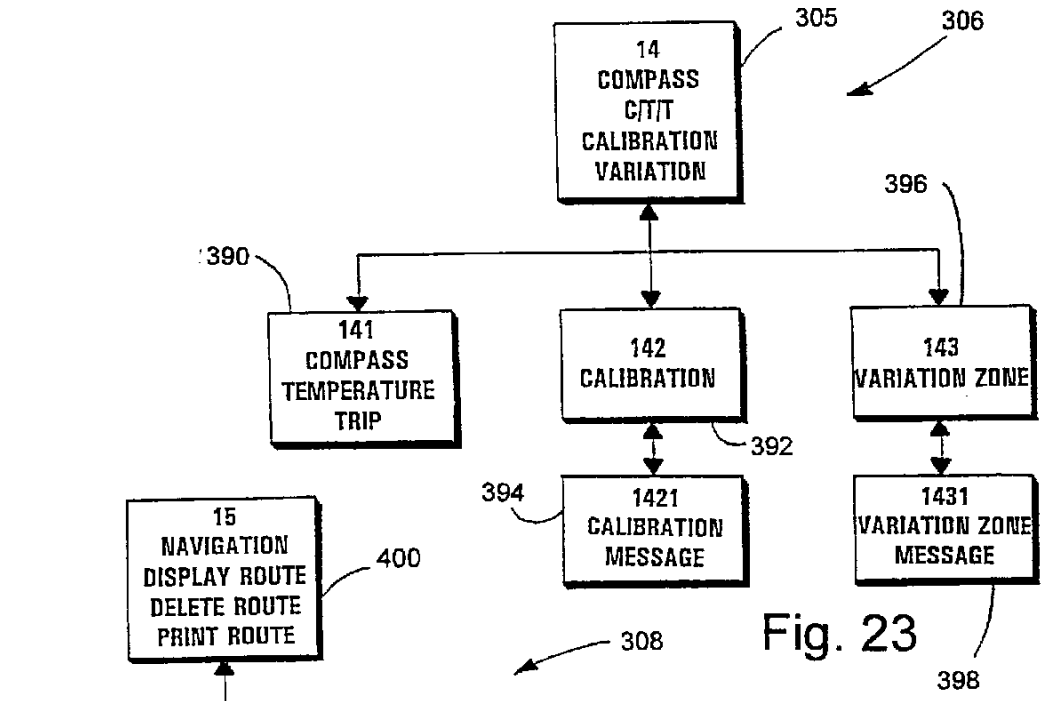


Fig. 23

Fig. 24

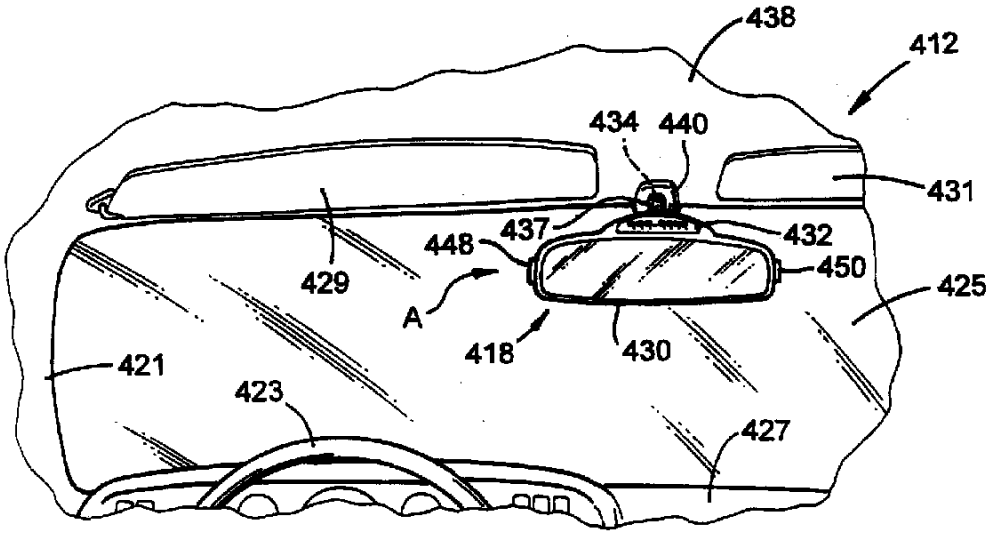

438
412
434
440
431
437
432
448
450
429
425
A
418
430
421
423
427

Fig. 25

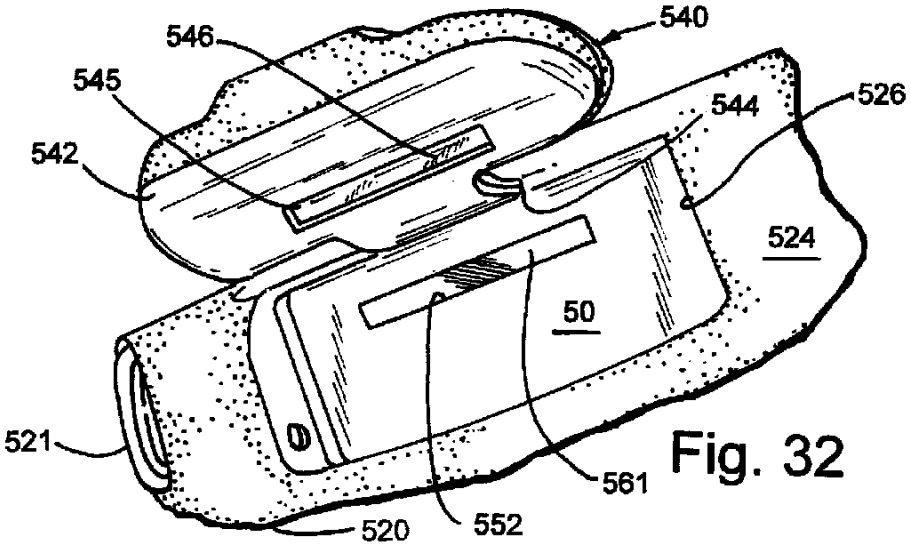
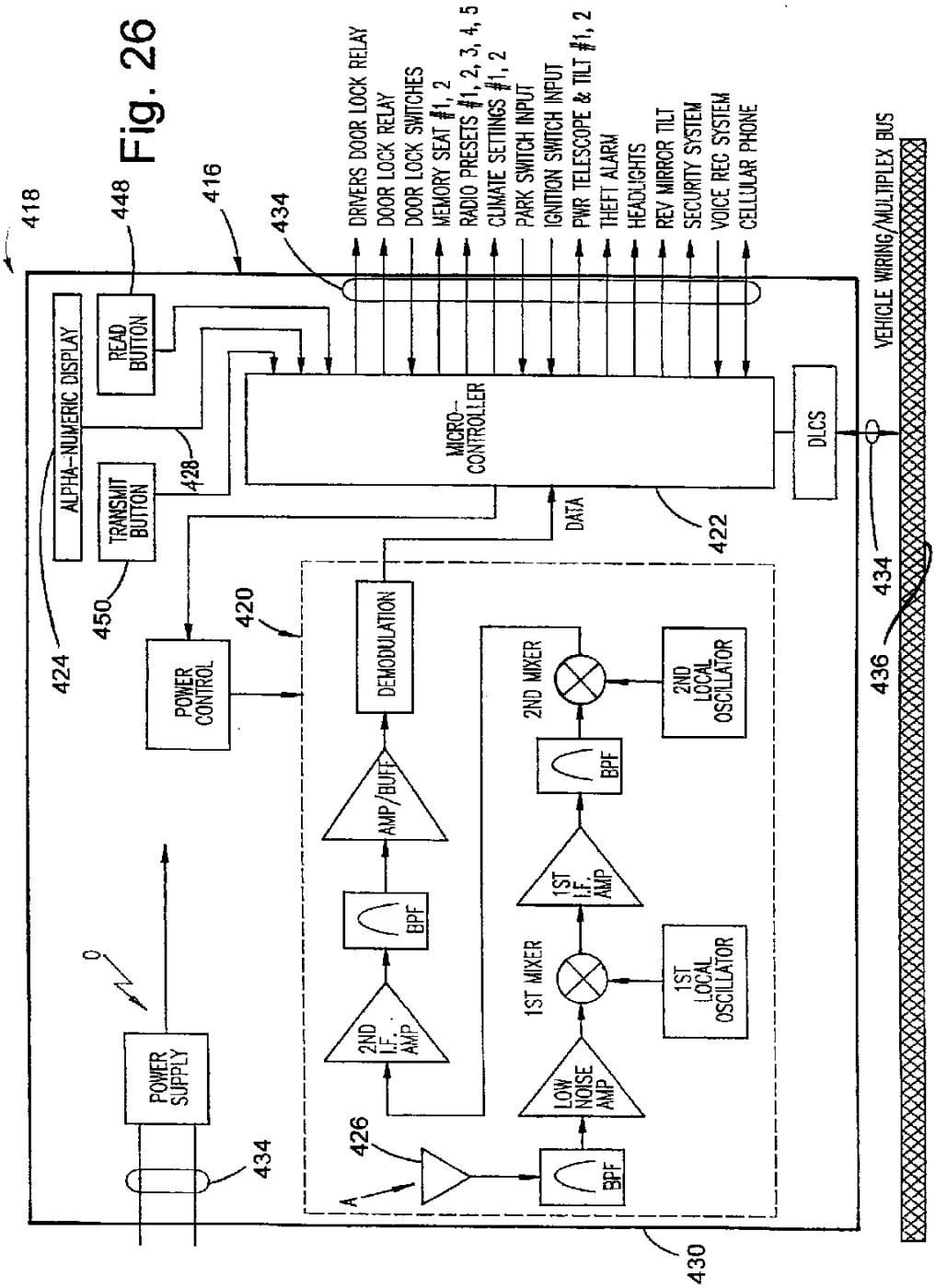

540
546
545
544
526
542
524
50
521
561
520
552

Fig. 32

Fig. 26


418
448
416
434
DRIVERS DOOR LOCK RELAY
DOOR LOCK RELAY
DOOR LOCK SWITCHES
MEMORY SEAT #1, 2
RADIO PRESETS #1, 2, 3, 4, 5
CLIMATE SETTINGS #1, 2
PARK SWITCH INPUT
IGNITION SWITCH INPUT
PWR TELESCOPE & TILT #1, 2
THEFT ALARM
HEADLIGHTS
REV MIRROR TILT
SECURITY SYSTEM
VOICE REC SYSTEM
CELLULAR PHONE
VEHICLE WIRING/MULTIPLEX BUS
READ BUTTON
ALPHA-NUMERIC DISPLAY
TRANSMIT BUTTON
MICRO-CONTROLLER
DLCS
428
DATA
422
450
420
424
POWER CONTROL
DEMODULATION
AMP/BUFF
BPF
2ND I.F. AMP
2ND MIXER
2ND LOCAL OSCILLATOR
1ST I.F. AMP
1ST MIXER
1ST LOCAL OSCILLATOR
LOW NOISE AMP
BPF
426
A
POWER SUPPLY
434
436
430

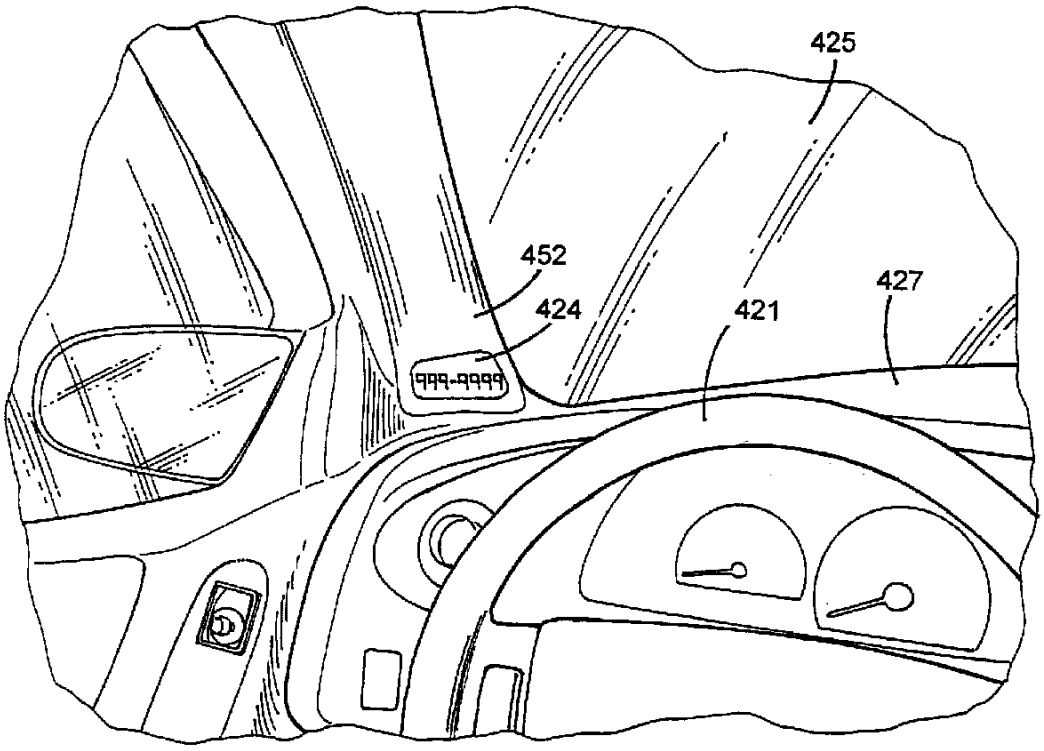

425
452
424
421
427
999-9999

Fig. 27

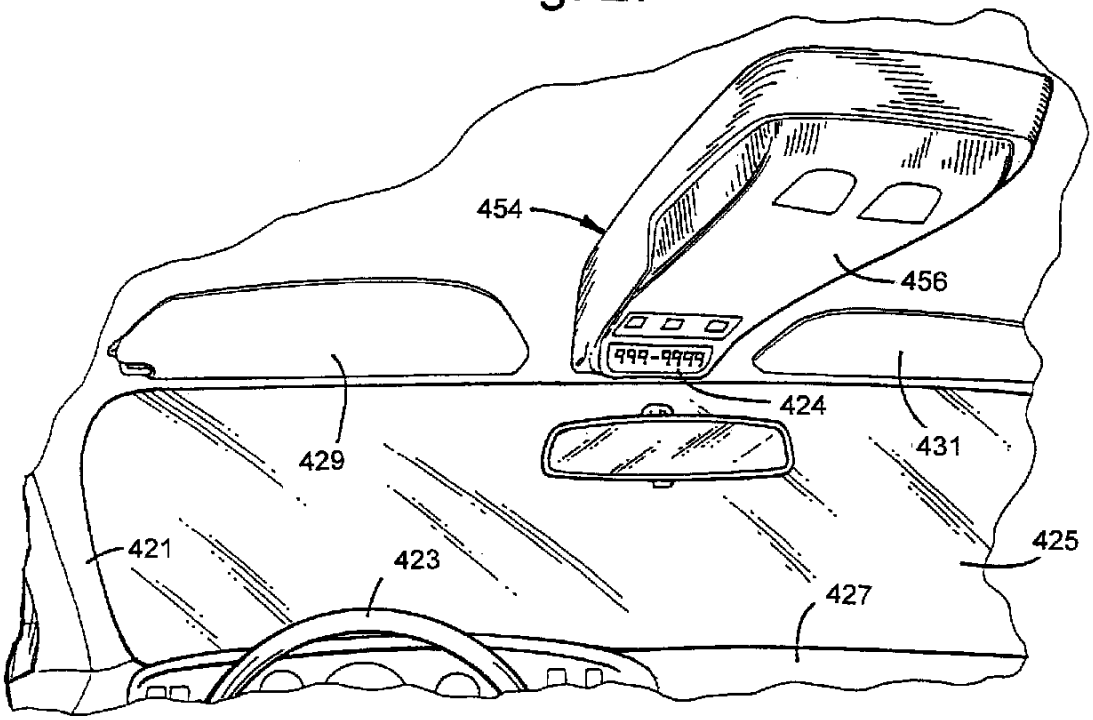

454
456
999-9999
424
429
431
421
423
425
427

Fig. 28

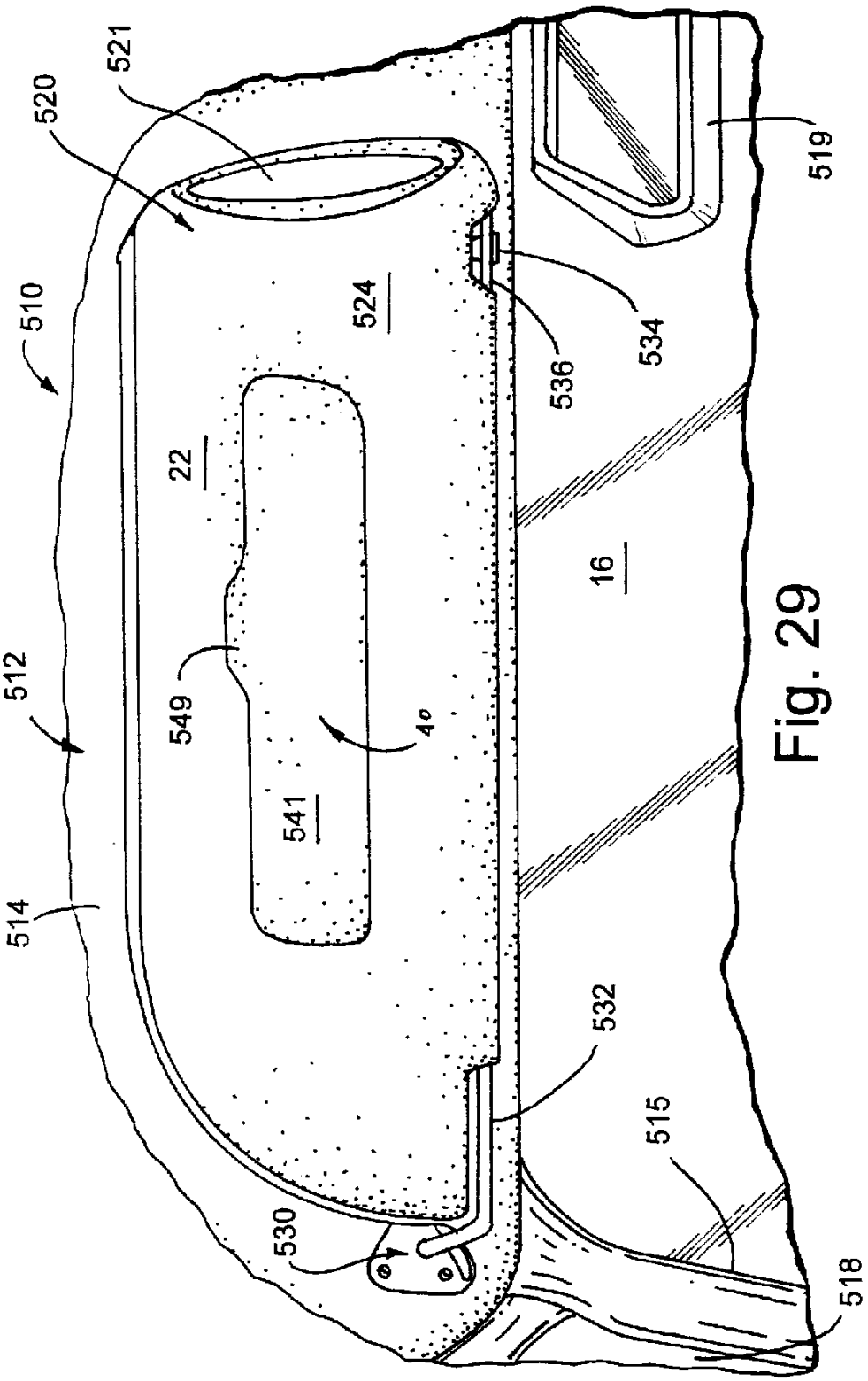

520
521
519
510
524
534
536
22
16
512
549
4°
541
514
532
515
530
518

Fig. 29

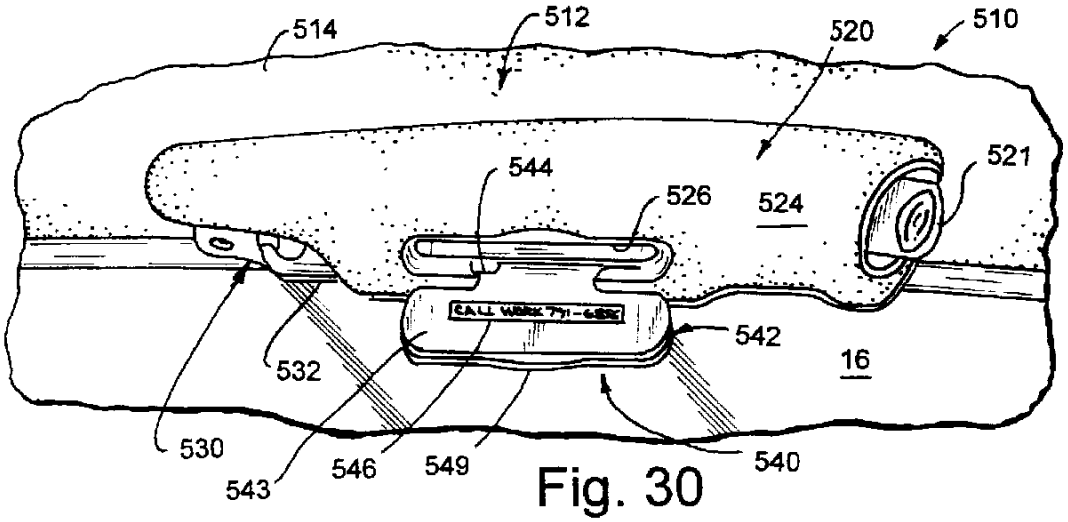


Fig. 30

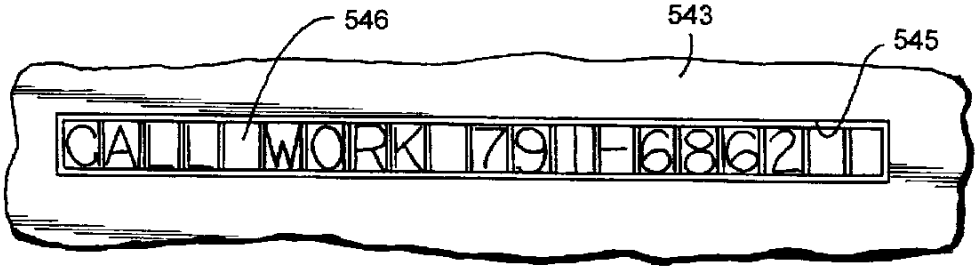


Fig. 30a

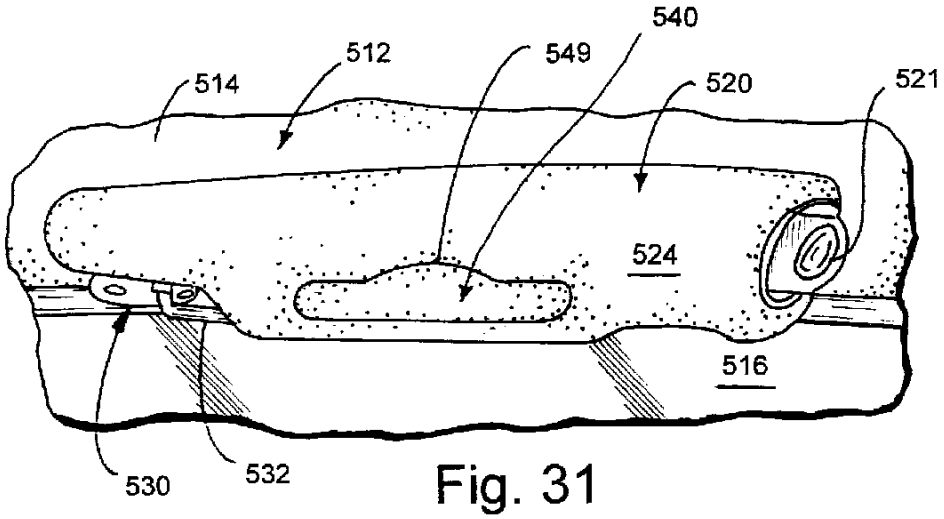


Fig. 31

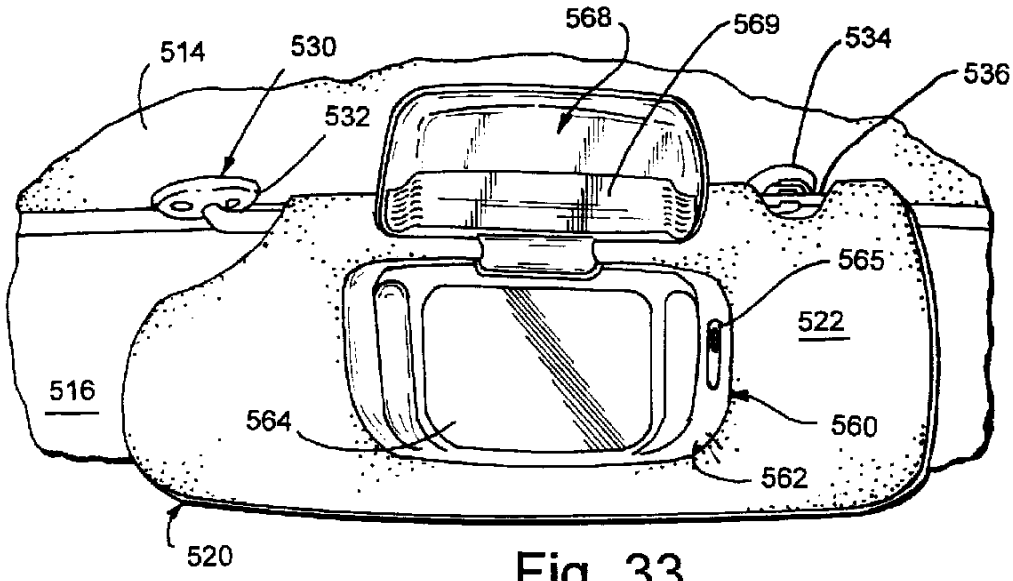

514
530
568
569
534
536
532
565
522
516
564
560
562
520

Fig. 33

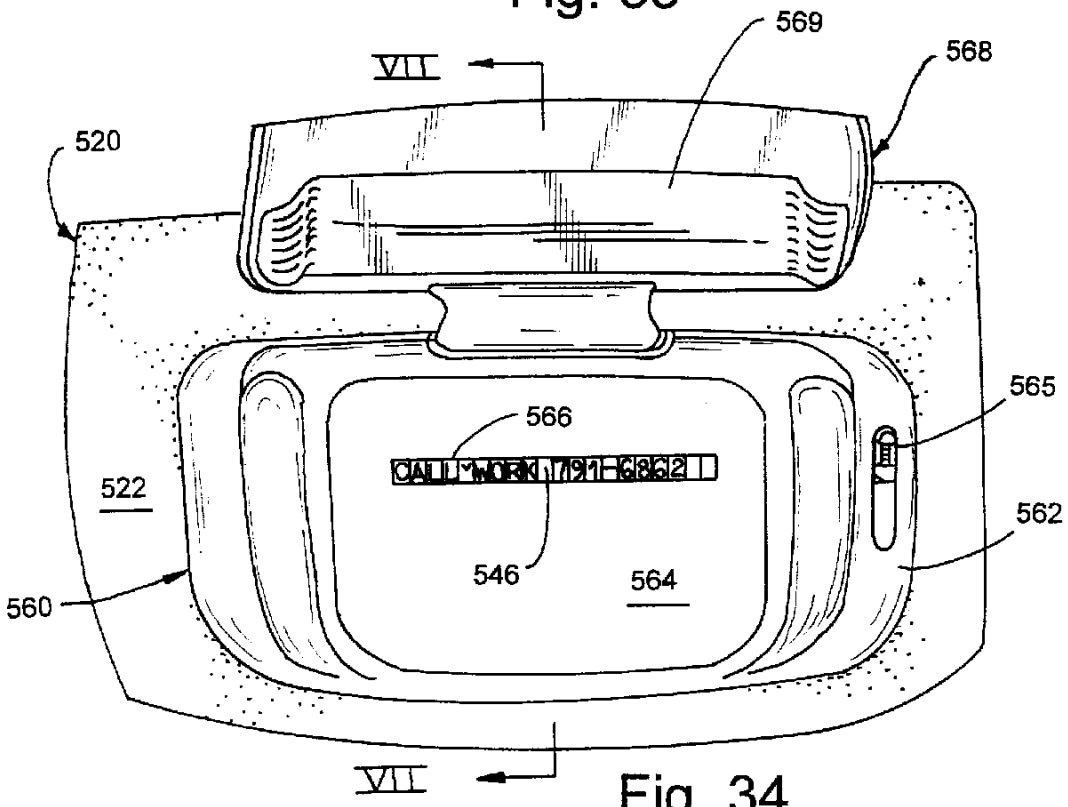

VII
569
568
520
565
566
522
562
546
564
560
VII

Fig. 34

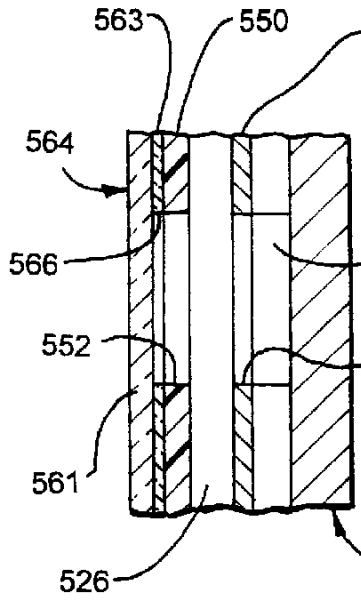

563
550
543
564
566
546
552
545
561
526
540

Fig. 35

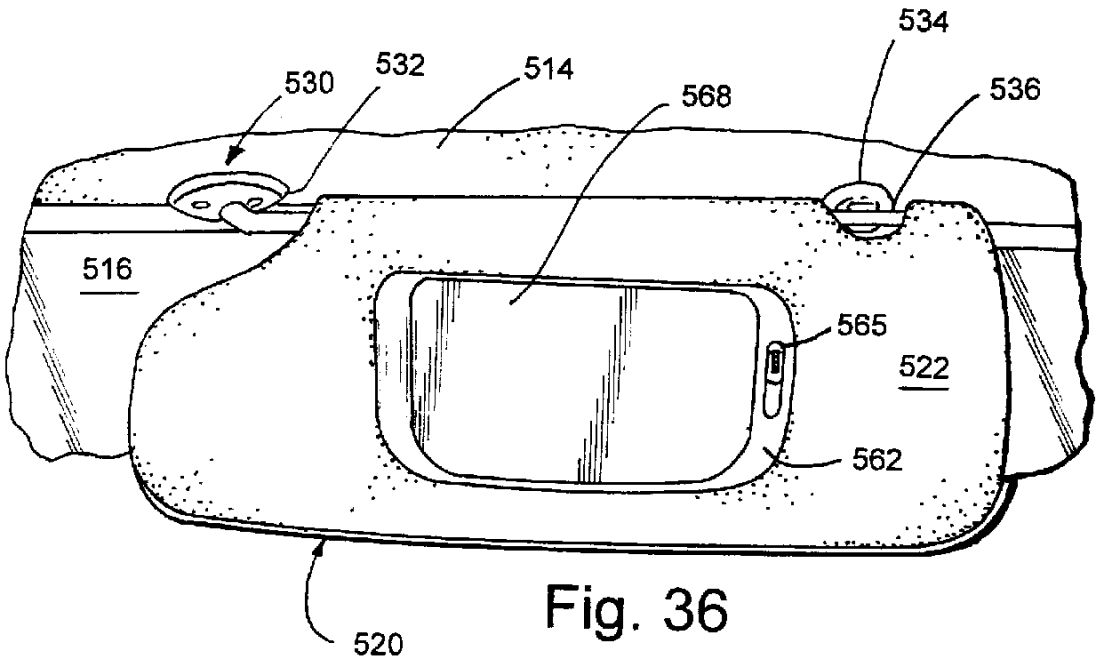

534
530
532
514
568
536
516
565
522
562
520

Fig. 36

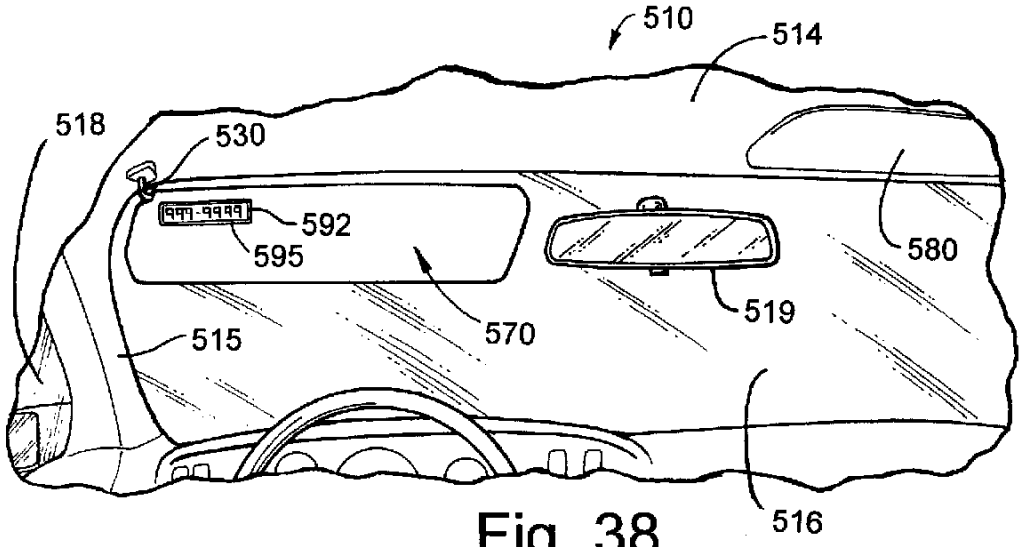


Fig. 38

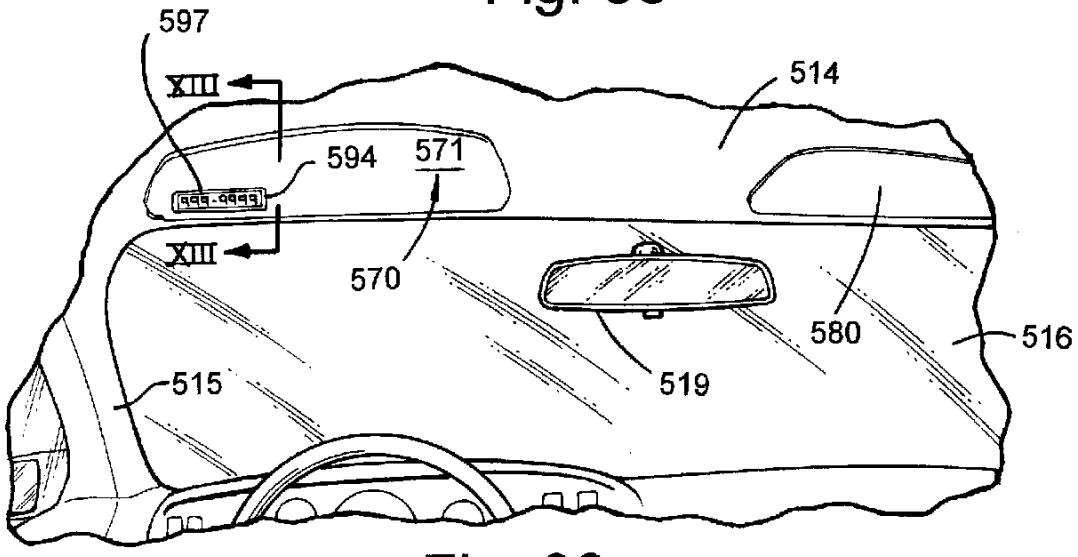


Fig. 39

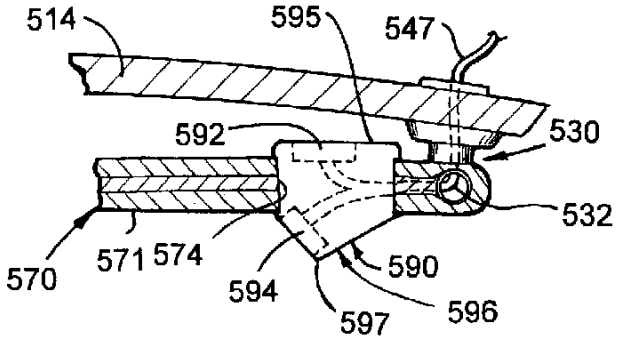


Fig. 40

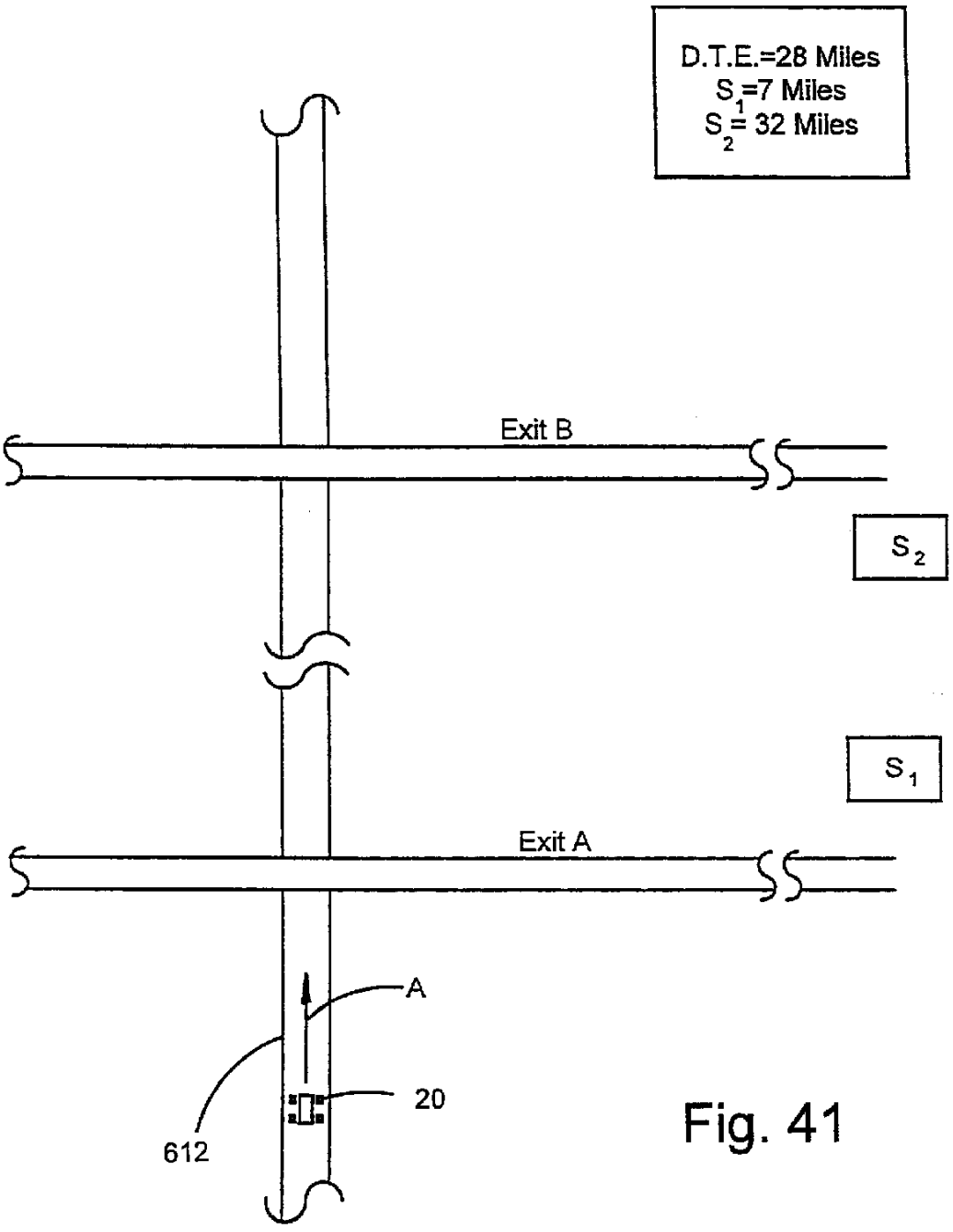


Fig. 41

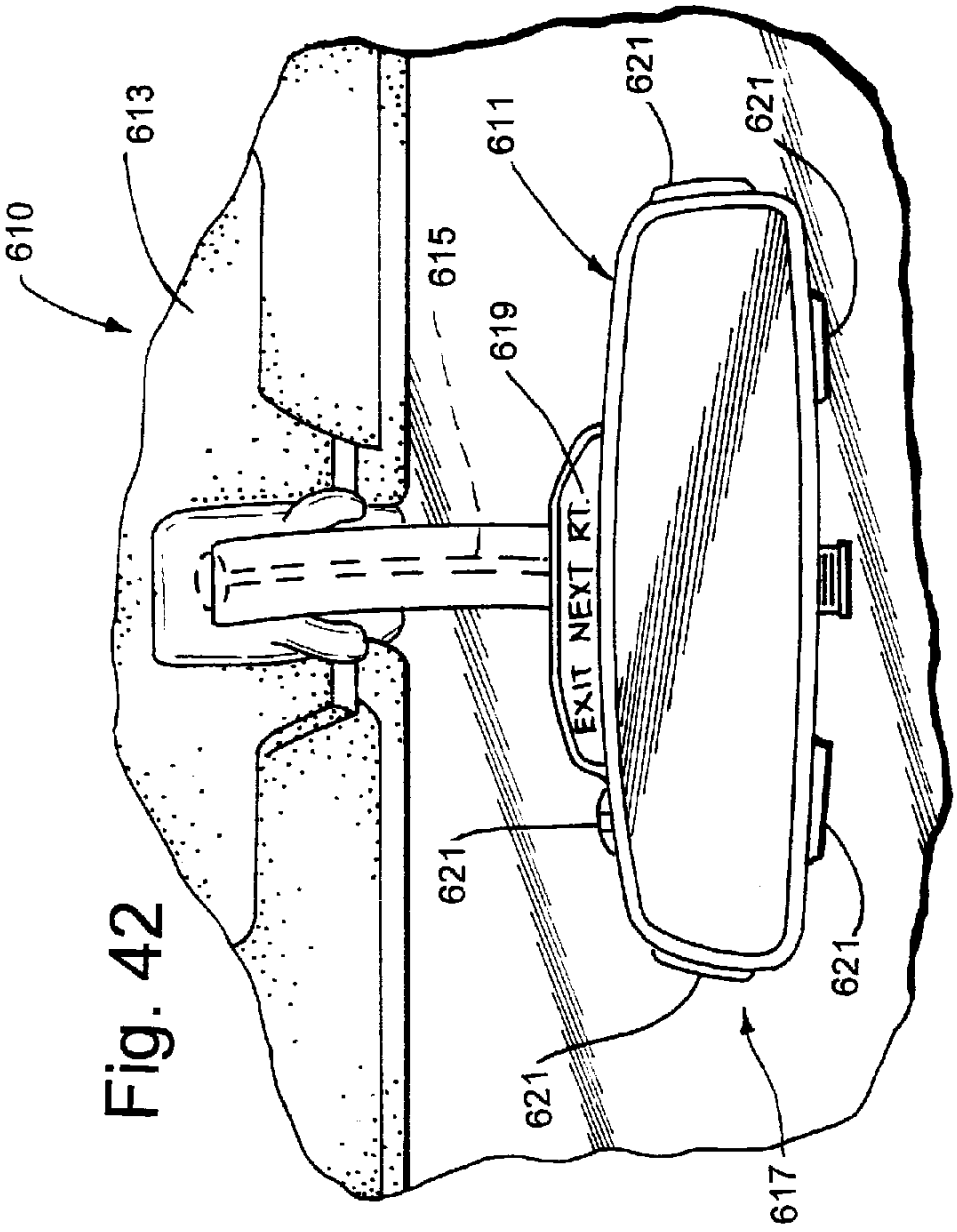


Fig. 42

Fig. 43

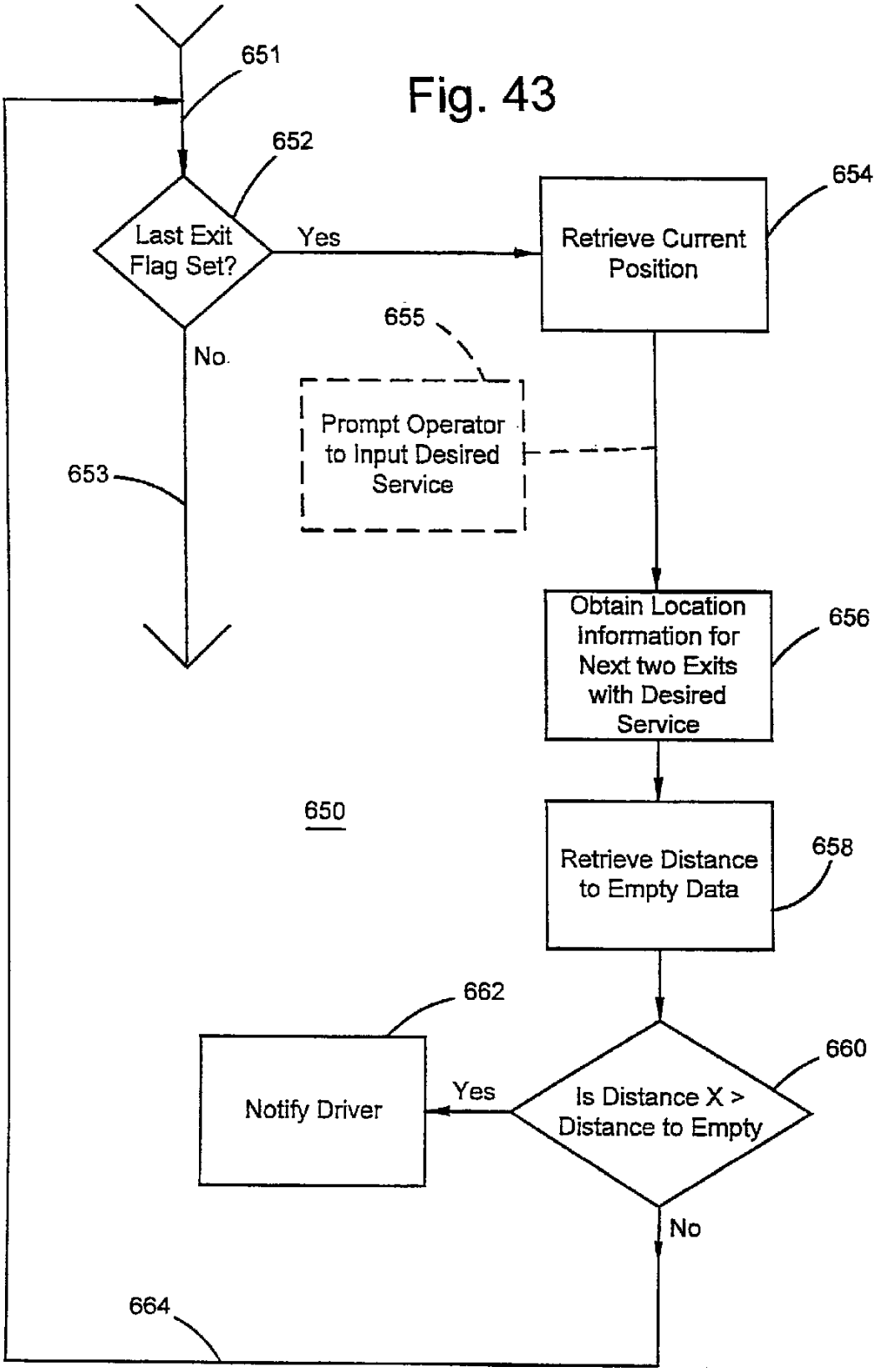
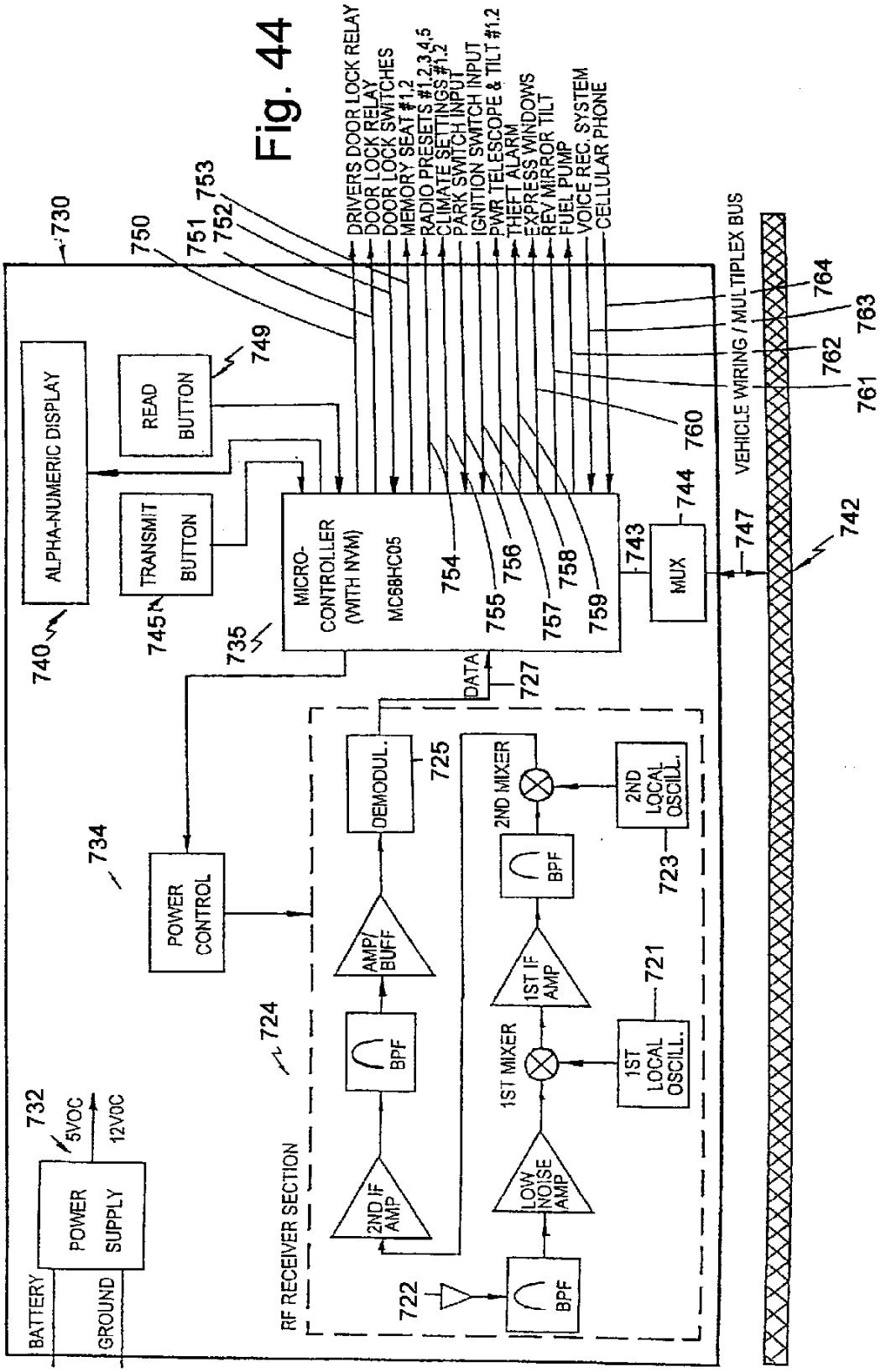

651
652
Last Exit Flag Set?
Yes
654
Retrieve Current Position
655
No
Prompt Operator to Input Desired Service
653
Obtain Location Information for Next two Exits with Desired Service
656
650
Retrieve Distance to Empty Data
658
662
Notify Driver
Yes
660
Is Distance X > Distance to Empty
No
664

Fig. 44


730
750
751
752
753
DRIVERS DOOR LOCK RELAY
DOOR LOCK RELAY
DOOR LOCK SWITCHES
MEMORY SEAT #1,2
RADIO PRESETS #1,2,3,4,5
CLIMATE SETTINGS #1,2
PARK SWITCH INPUT
IGNITION SWITCH INPUT
PWR TELESCOPE & TILT #1,2
THEFT ALARM
EXPRESS WINDOWS
REV MIRROR TILT
FUEL PUMP
VOICE REC. SYSTEM
CELLULAR PHONE
764
763
762
761
760
VEHICLE WIRING / MULTIPLEX BUS
742
747
744
MUX
743
759
757
755
754
758
756
MICRO-CONTROLLER (WITH NVM)
MC68HC05
735
740
745
ALPHA-NUMERIC DISPLAY
TRANSMIT BUTTON
READ BUTTON
749
DATA
727
734
POWER CONTROL
DEMODUL.
725
AMP/ BUFF
BPF
2ND IF AMP
724
RF RECEIVER SECTION
722
BPF
LOW NOISE AMP
1ST MIXER
1ST IF AMP
BPF
2ND MIXER
2ND LOCAL OSCILL.
723
1ST LOCAL OSCILL.
721
732
5VDC
12VDC
POWER SUPPLY
BATTERY
GROUND

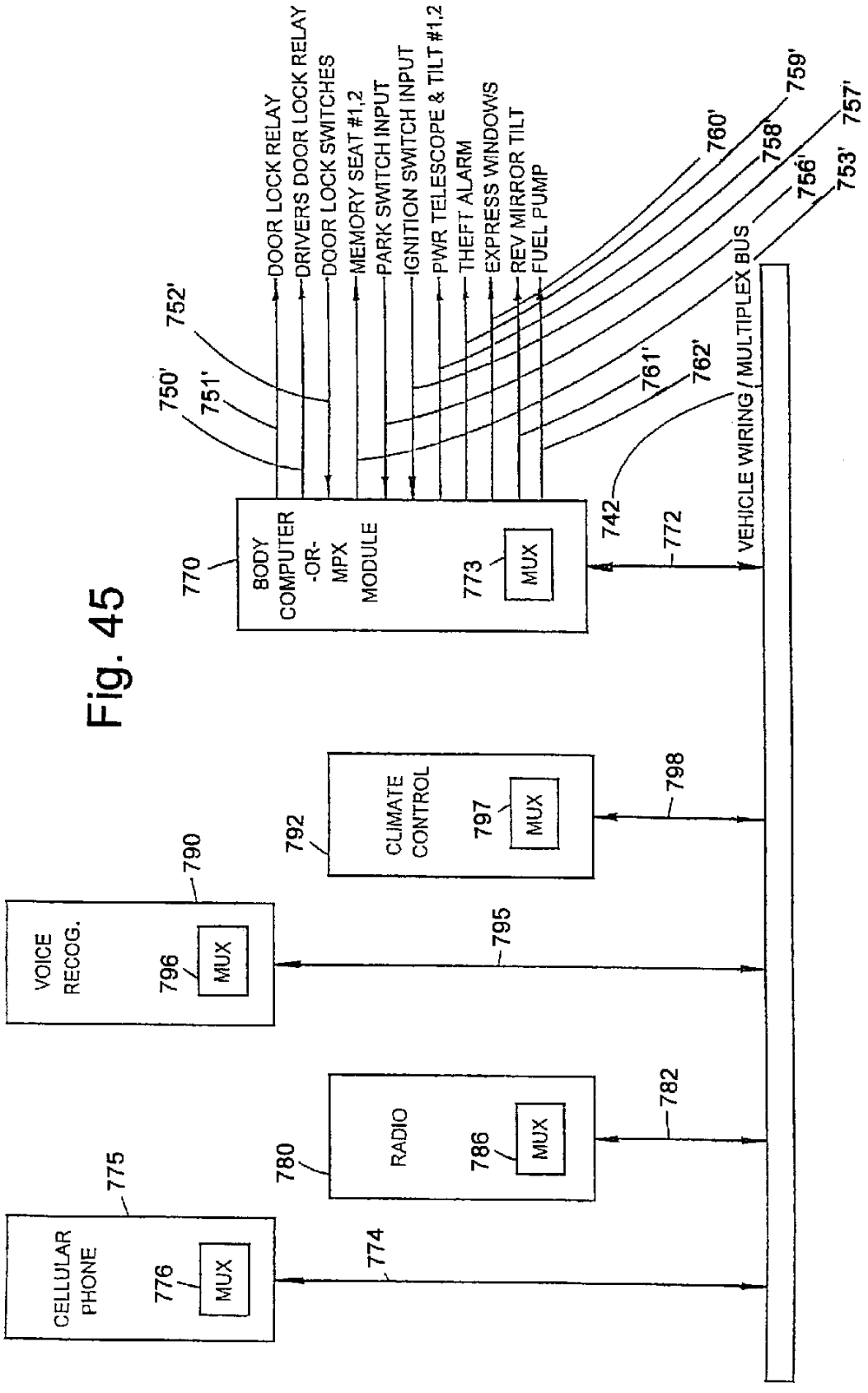

DOOR LOCK RELAY
DRIVERS DOOR LOCK RELAY
DOOR LOCK SWITCHES
MEMORY SEAT #1,2
PARK SWITCH INPUT
IGNITION SWITCH INPUT
PWR TELESCOPE & TILT #1,2
THEFT ALARM
EXPRESS WINDOWS
REV MIRROR TILT
FUEL PUMP
752'
751'
750'
760'
759'
758'
757'
756'
753'
761'
762'
742
772
VEHICLE WIRING / MULTIPLEX BUS
770
BODY COMPUTER -OR- MPX MODULE
773
MUX
792
CLIMATE CONTROL
797
MUX
798
790
VOICE RECOG.
796
MUX
795
780
RADIO
786
MUX
782
775
CELLULAR PHONE
776
MUX
774

Fig. 45

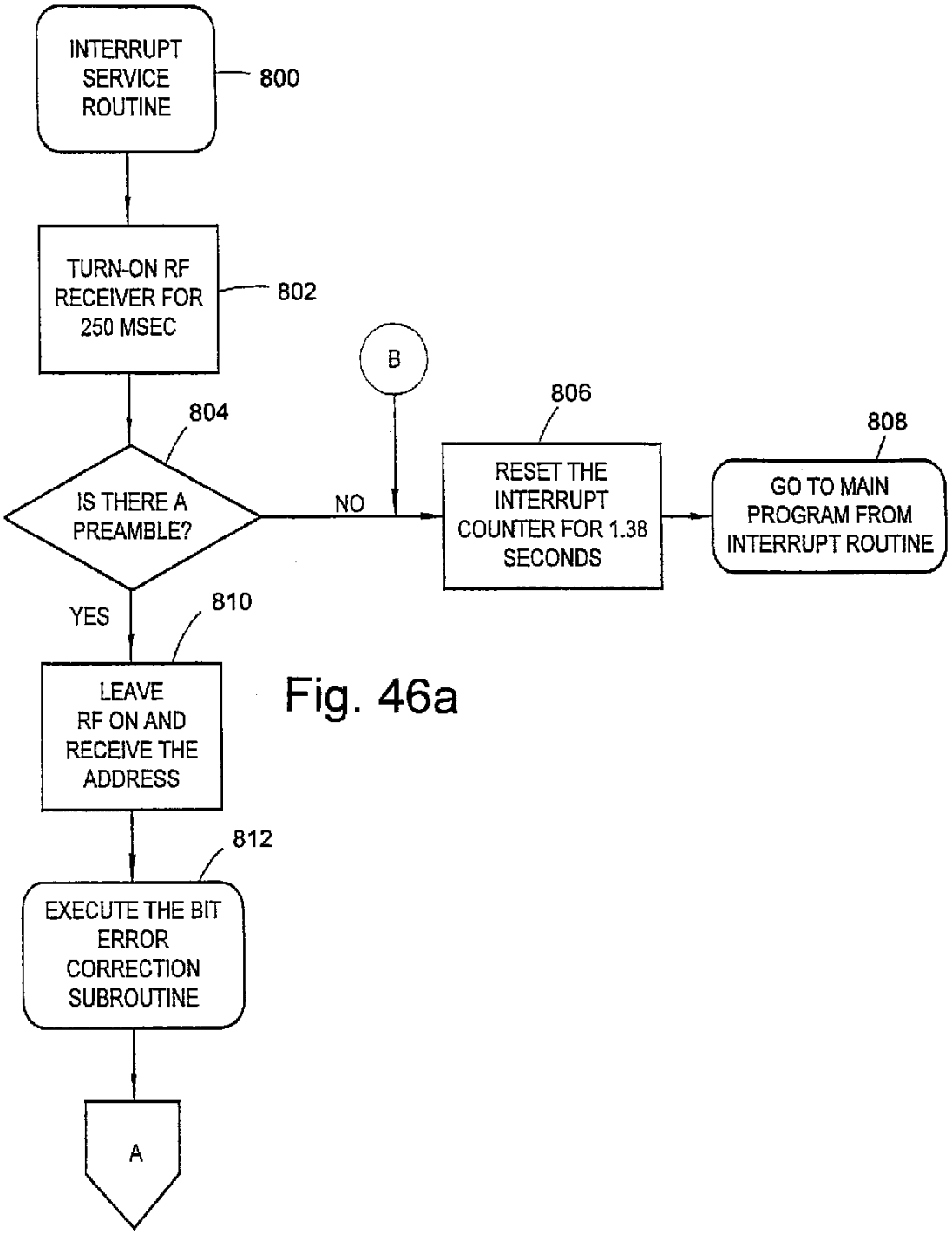

INTERRUPT SERVICE ROUTINE
800
TURN-ON RF RECEIVER FOR 250 MSEC
802
B
804
806
808
IS THERE A PREAMBLE?
NO
RESET THE INTERRUPT COUNTER FOR 1.38 SECONDS
GO TO MAIN PROGRAM FROM INTERRUPT ROUTINE
YES
810
LEAVE RF ON AND RECEIVE THE ADDRESS
812
EXECUTE THE BIT ERROR CORRECTION SUBROUTINE
A

Fig. 46a

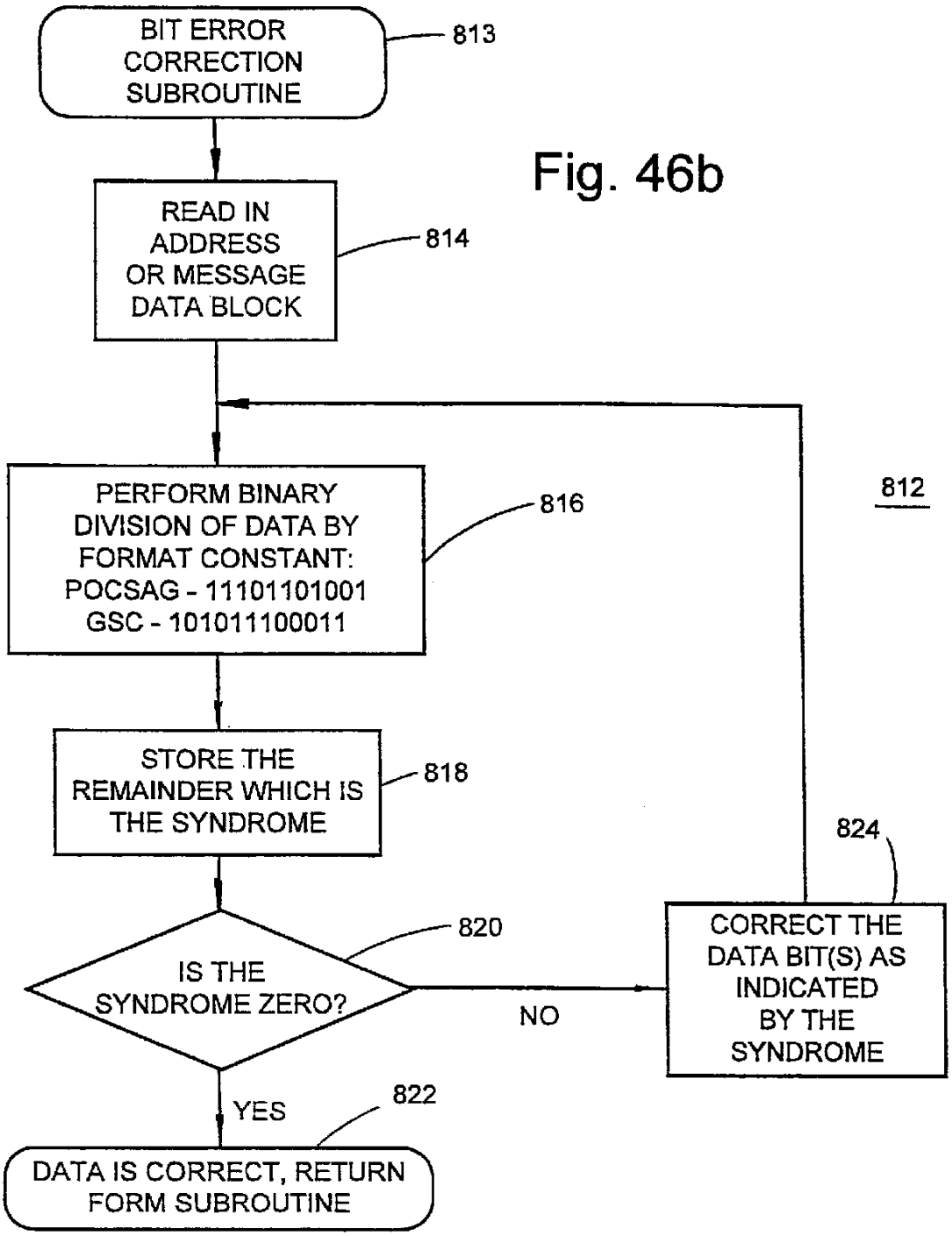

BIT ERROR CORRECTION SUBROUTINE
813
READ IN ADDRESS OR MESSAGE DATA BLOCK
814
PERFORM BINARY DIVISION OF DATA BY FORMAT CONSTANT:
POCSAG - 11101101001
GSC - 101011100011
816
812
STORE THE REMAINDER WHICH IS THE SYNDROME
818
824
IS THE SYNDROME ZERO?
820
NO
CORRECT THE DATA BIT(S) AS INDICATED BY THE SYNDROME
YES
822
DATA IS CORRECT, RETURN FORM SUBROUTINE

Fig. 46b

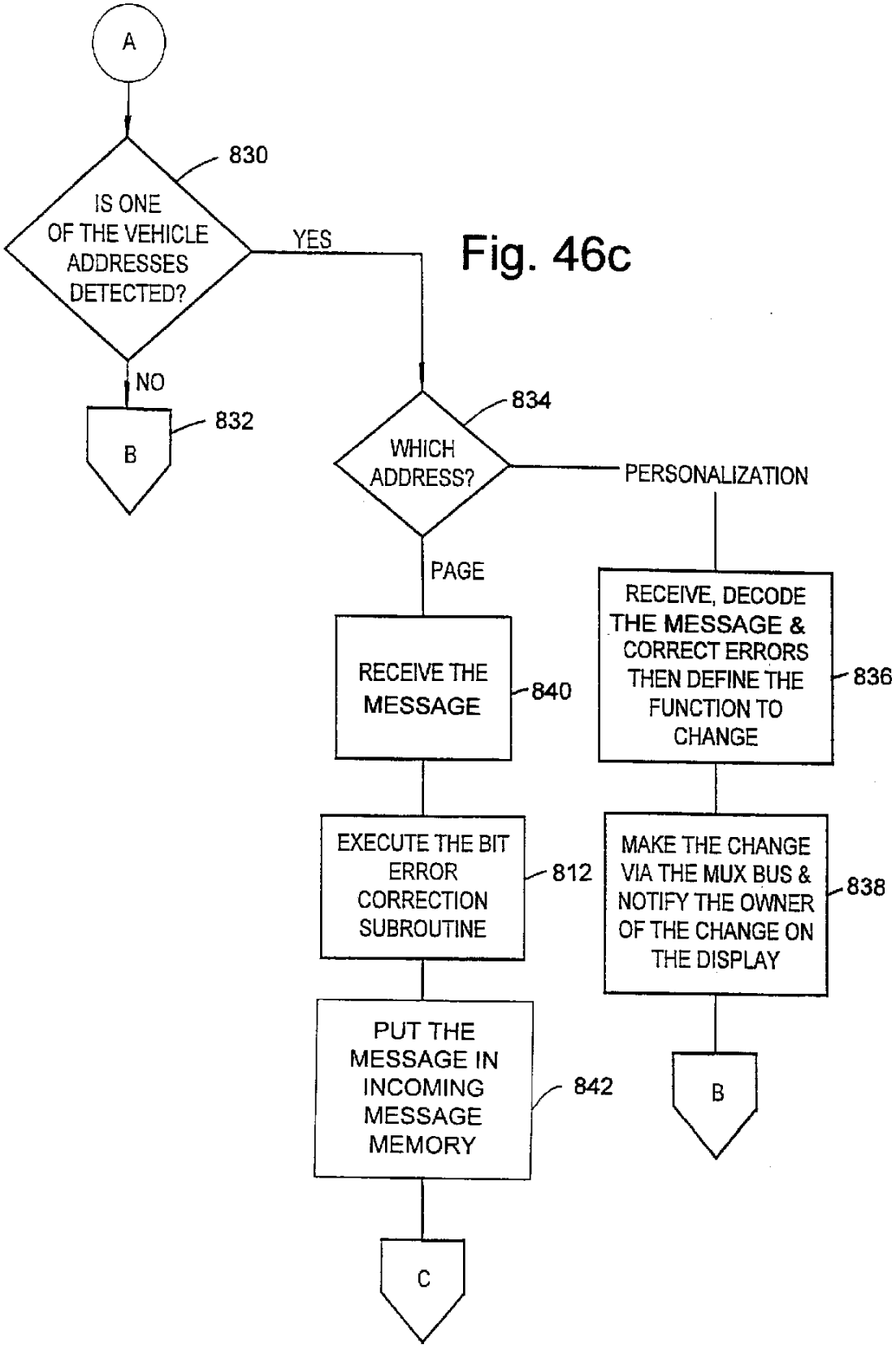

A
830
IS ONE OF THE VEHICLE ADDRESSES DETECTED?
YES
NO
832
B
834
WHICH ADDRESS?
PERSONALIZATION
PAGE
RECEIVE THE MESSAGE
840
RECEIVE, DECODE THE MESSAGE & CORRECT ERRORS THEN DEFINE THE FUNCTION TO CHANGE
836
EXECUTE THE BIT ERROR CORRECTION SUBROUTINE
812
MAKE THE CHANGE VIA THE MUX BUS & NOTIFY THE OWNER OF THE CHANGE ON THE DISPLAY
838
PUT THE MESSAGE IN INCOMING MESSAGE MEMORY
842
B
C

Fig. 46c

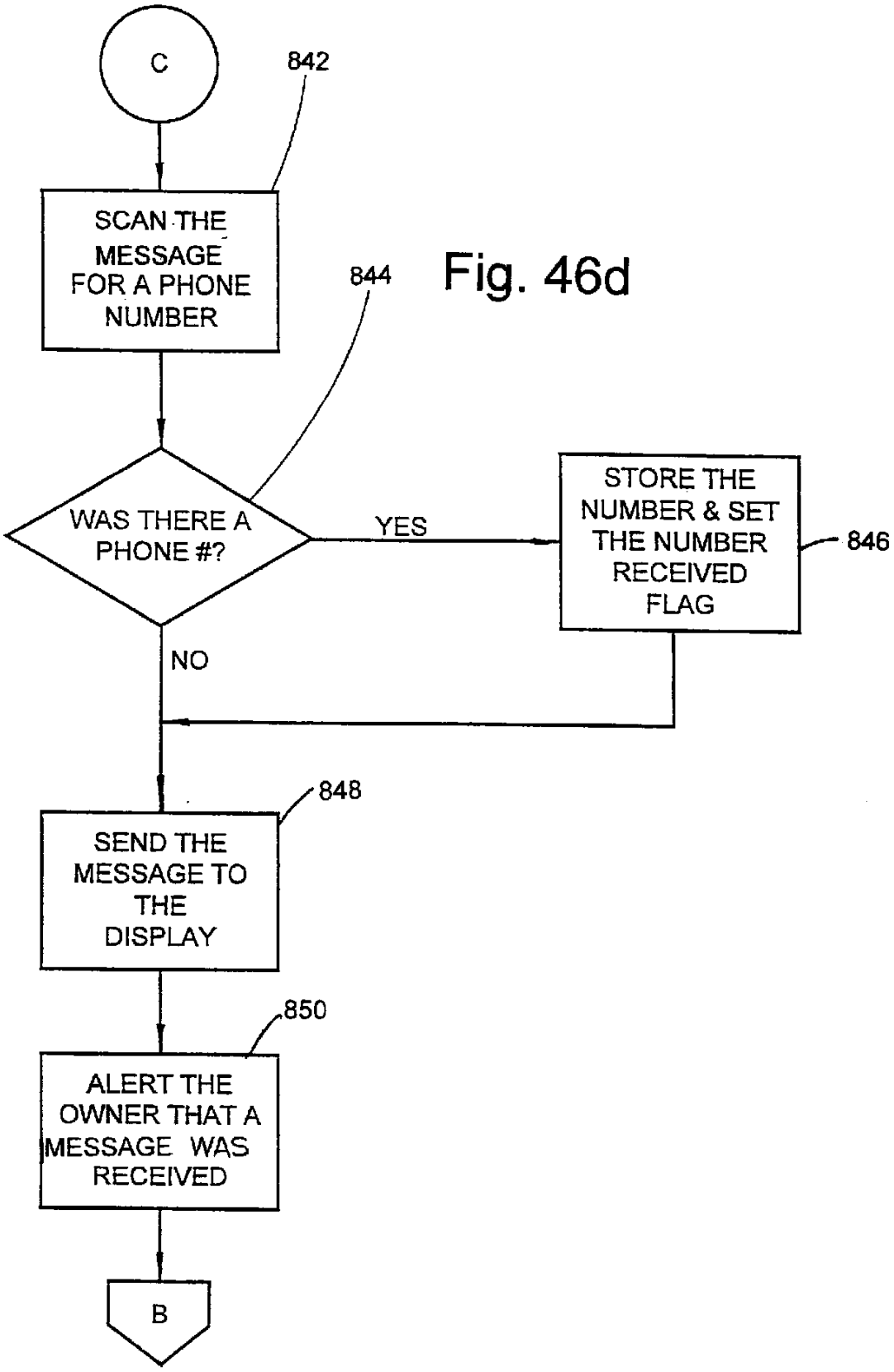

C
842
SCAN THE MESSAGE FOR A PHONE NUMBER
844
WAS THERE A PHONE #?
YES
STORE THE NUMBER & SET THE NUMBER RECEIVED FLAG
846
NO
848
SEND THE MESSAGE TO THE DISPLAY
850
ALERT THE OWNER THAT A MESSAGE WAS RECEIVED
B

Fig. 46d

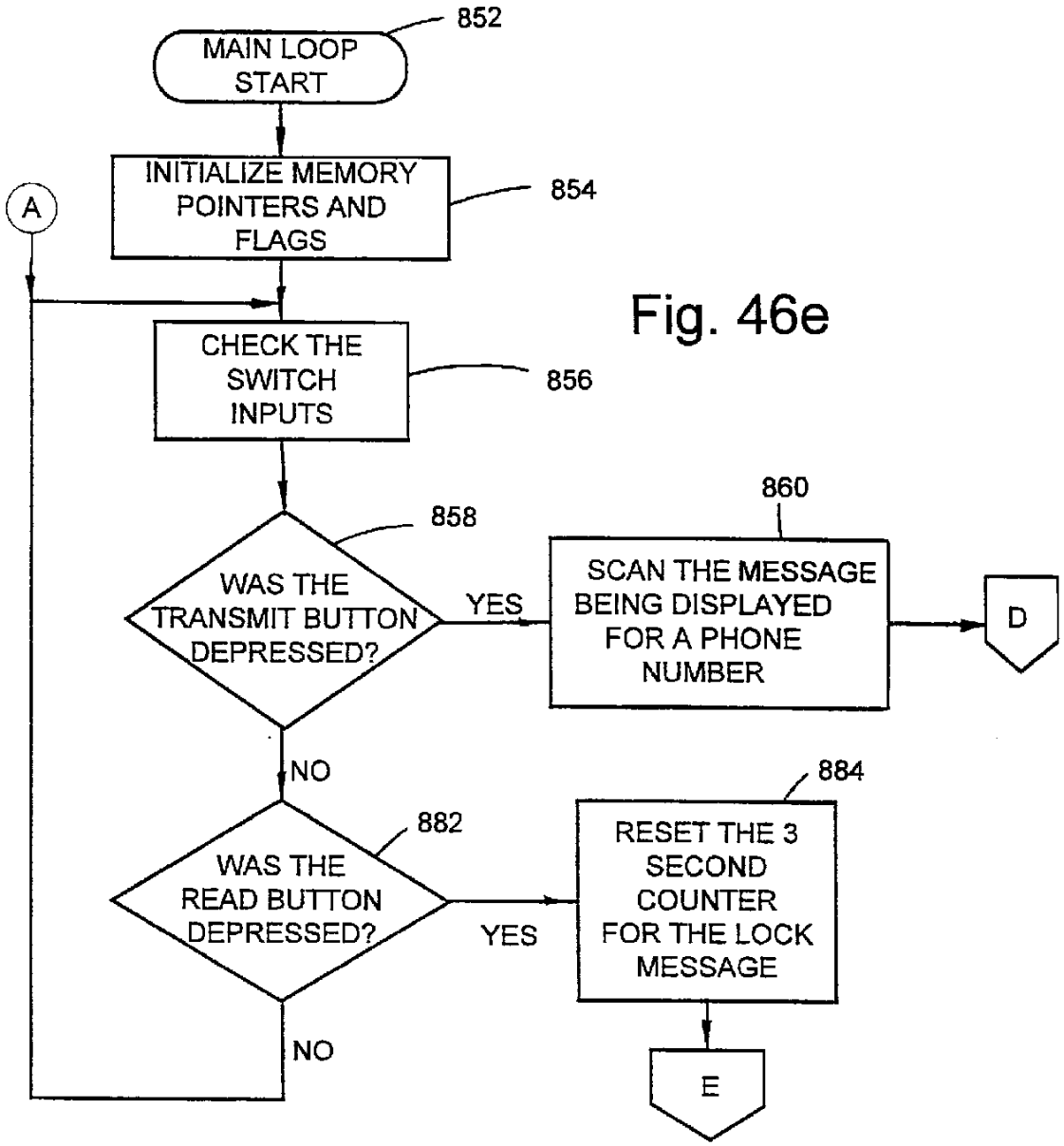
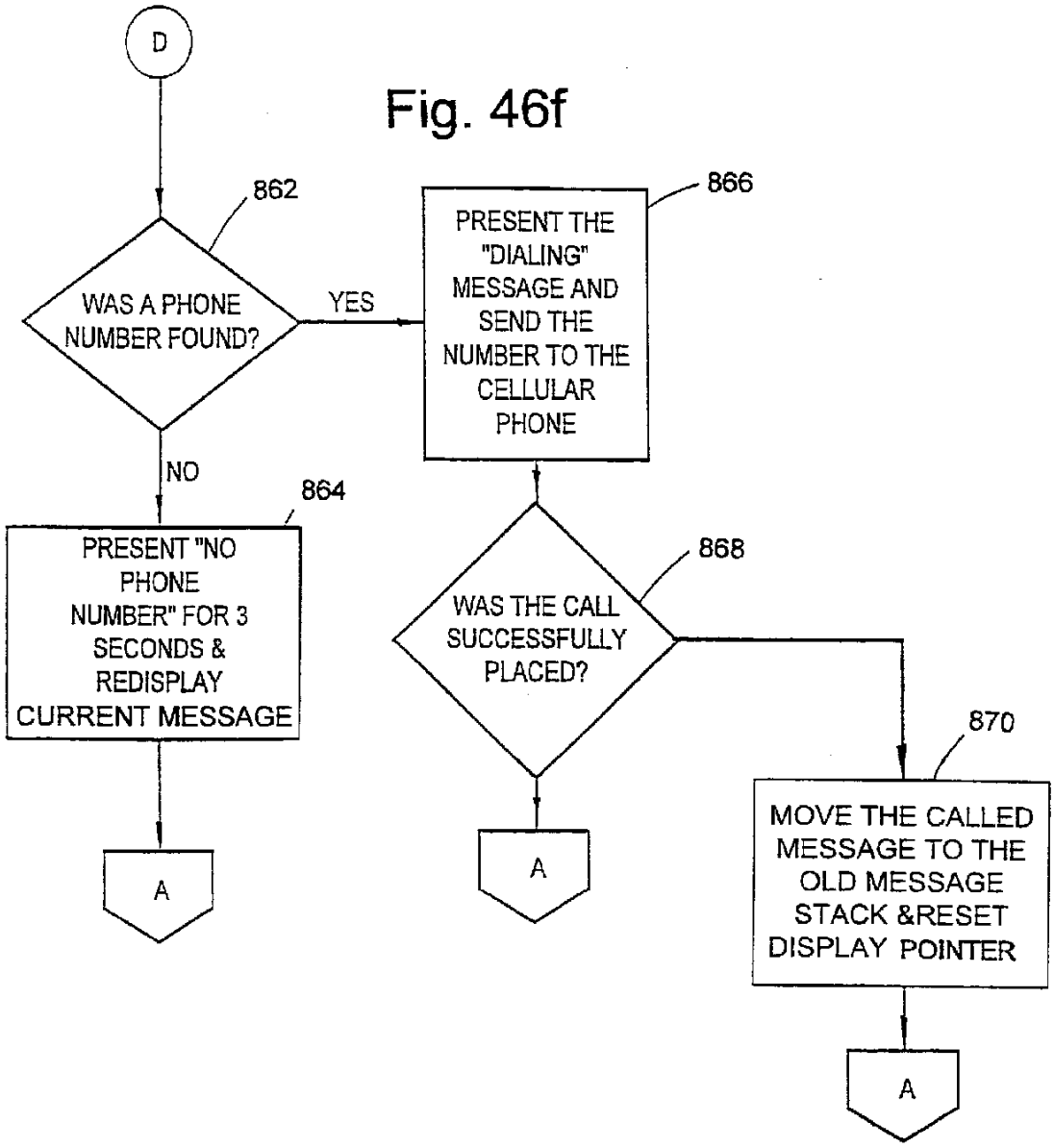

852
MAIN LOOP START
INITIALIZE MEMORY POINTERS AND FLAGS
854
A
CHECK THE SWITCH INPUTS
856
858
WAS THE TRANSMIT BUTTON DEPRESSED?
YES
860
SCAN THE MESSAGE BEING DISPLAYED FOR A PHONE NUMBER
D
NO
882
WAS THE READ BUTTON DEPRESSED?
YES
884
RESET THE 3 SECOND COUNTER FOR THE LOCK MESSAGE
NO
E

Fig. 46e

Fig. 46f


D
862
WAS A PHONE NUMBER FOUND?
YES
NO
866
PRESENT THE "DIALING" MESSAGE AND SEND THE NUMBER TO THE CELLULAR PHONE
864
PRESENT "NO PHONE NUMBER" FOR 3 SECONDS & REDISPLAY CURRENT MESSAGE
868
WAS THE CALL SUCCESSFULLY PLACED?
870
MOVE THE CALLED MESSAGE TO THE OLD MESSAGE STACK &RESET DISPLAY POINTER
A
A
A

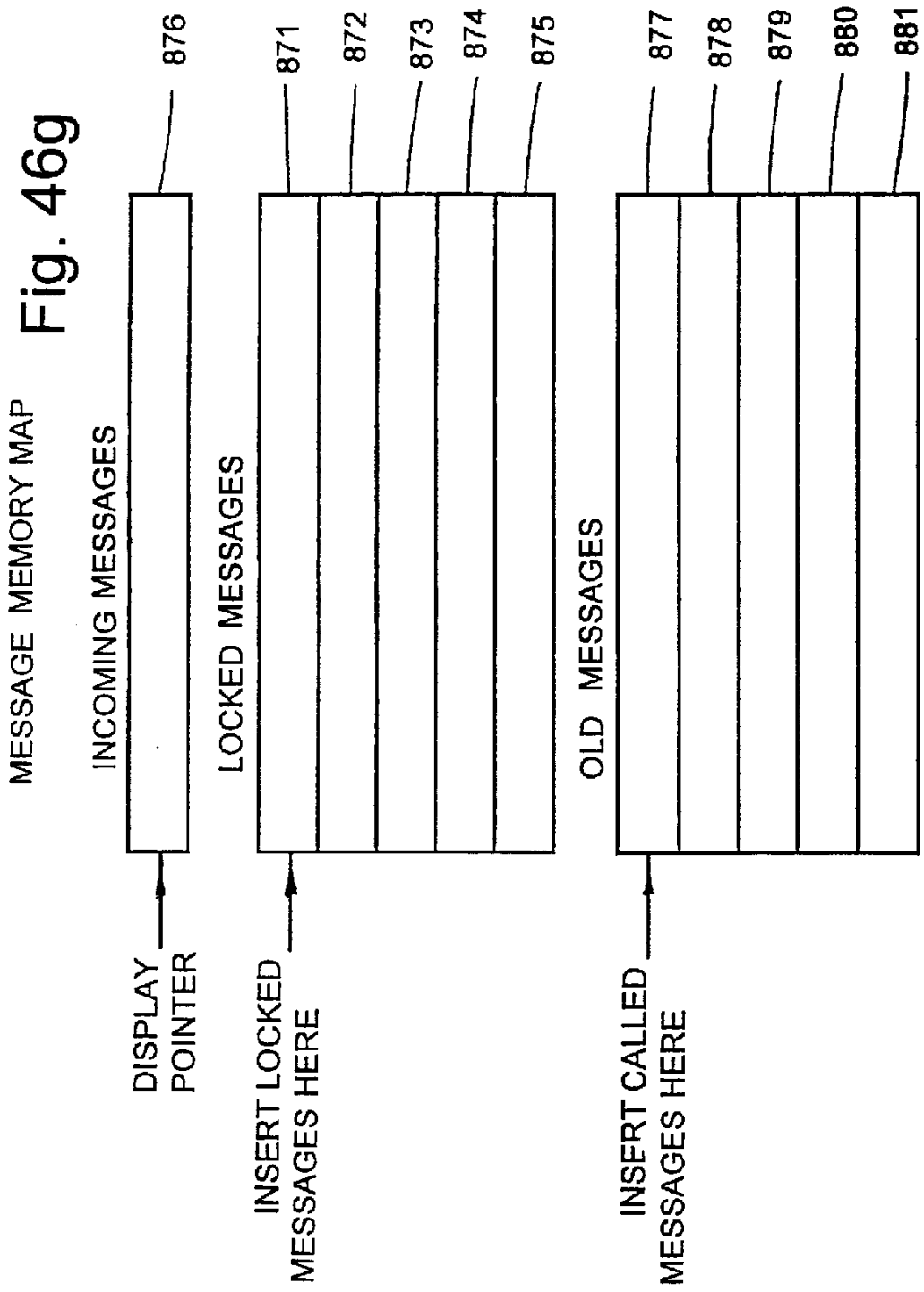
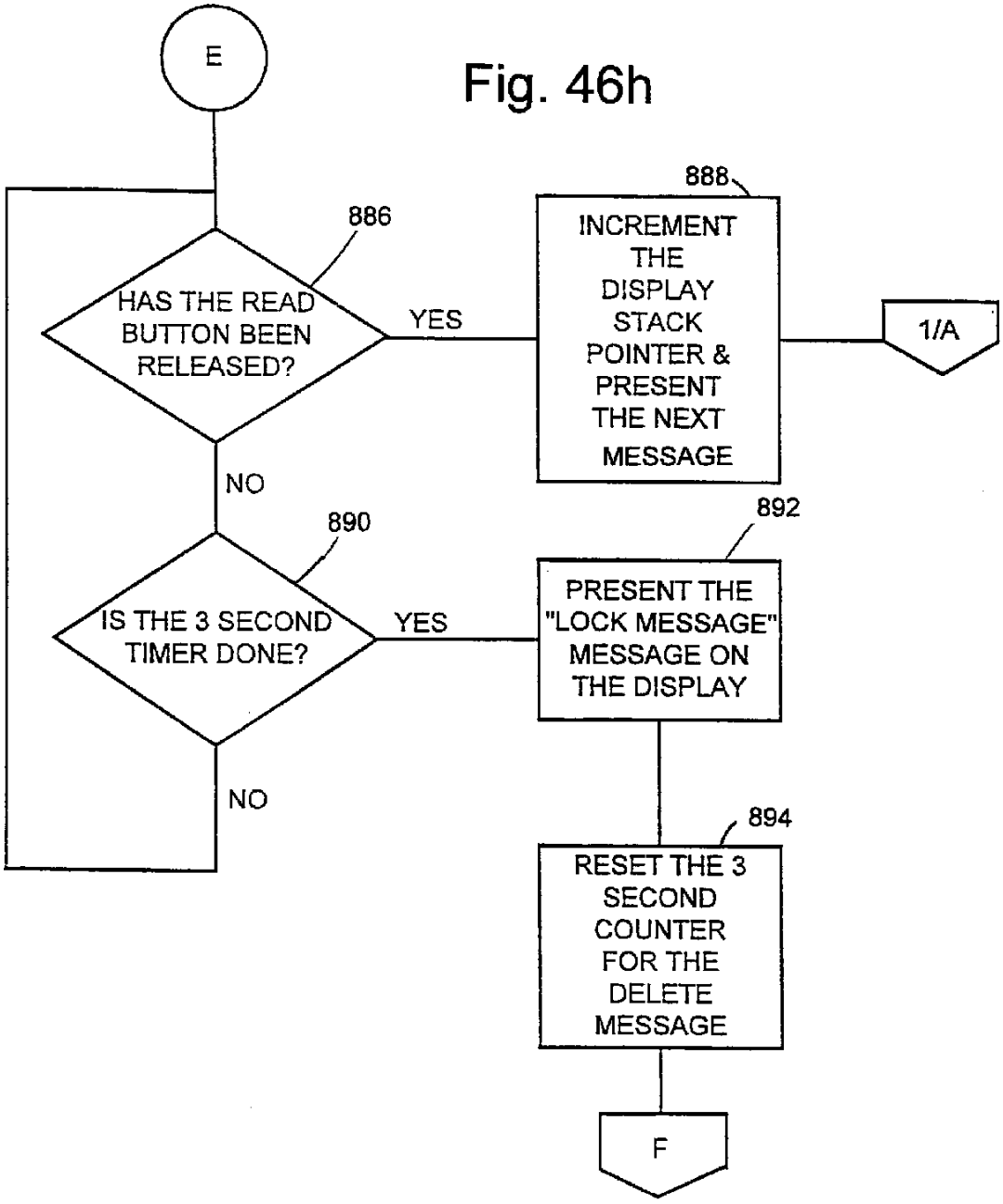

MESSAGE MEMORY MAP
INCOMING MESSAGES
LOCKED MESSAGES
OLD MESSAGES
876
871
872
873
874
875
877
878
879
880
881
DISPLAY POINTER
INSERT LOCKED MESSAGES HERE
INSERT CALLED MESSAGES HERE

Fig. 46g

Fig. 46h


E
886
HAS THE READ BUTTON BEEN RELEASED?
YES
888
INCREMENT THE DISPLAY STACK POINTER & PRESENT THE NEXT MESSAGE
1/A
NO
890
IS THE 3 SECOND TIMER DONE?
YES
892
PRESENT THE "LOCK MESSAGE" MESSAGE ON THE DISPLAY
NO
894
RESET THE 3 SECOND COUNTER FOR THE DELETE MESSAGE
F

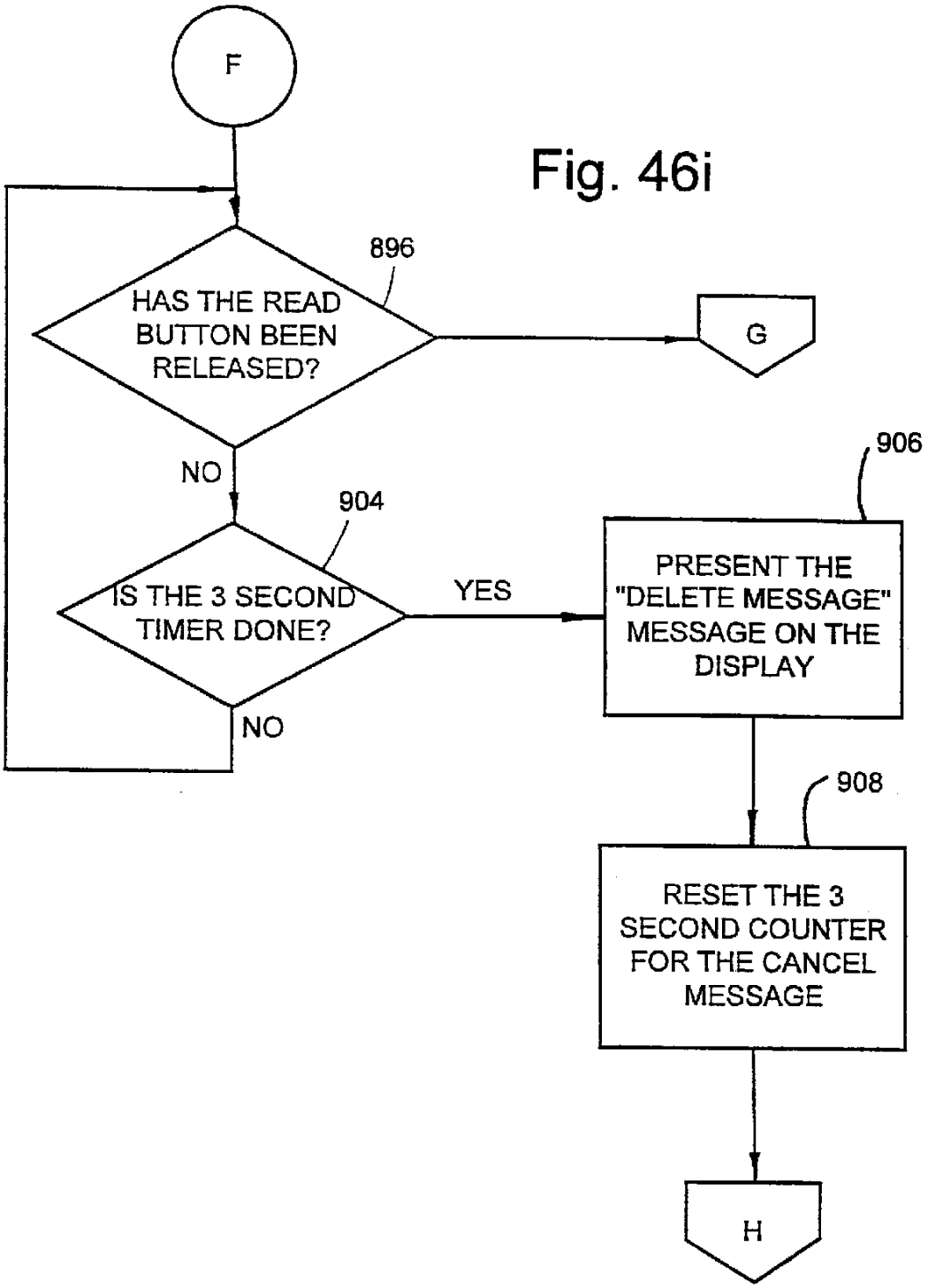

F
HAS THE READ BUTTON BEEN RELEASED?
896
G
NO
904
IS THE 3 SECOND TIMER DONE?
YES
906
PRESENT THE "DELETE MESSAGE" MESSAGE ON THE DISPLAY
NO
908
RESET THE 3 SECOND COUNTER FOR THE CANCEL MESSAGE
H

Fig. 46i

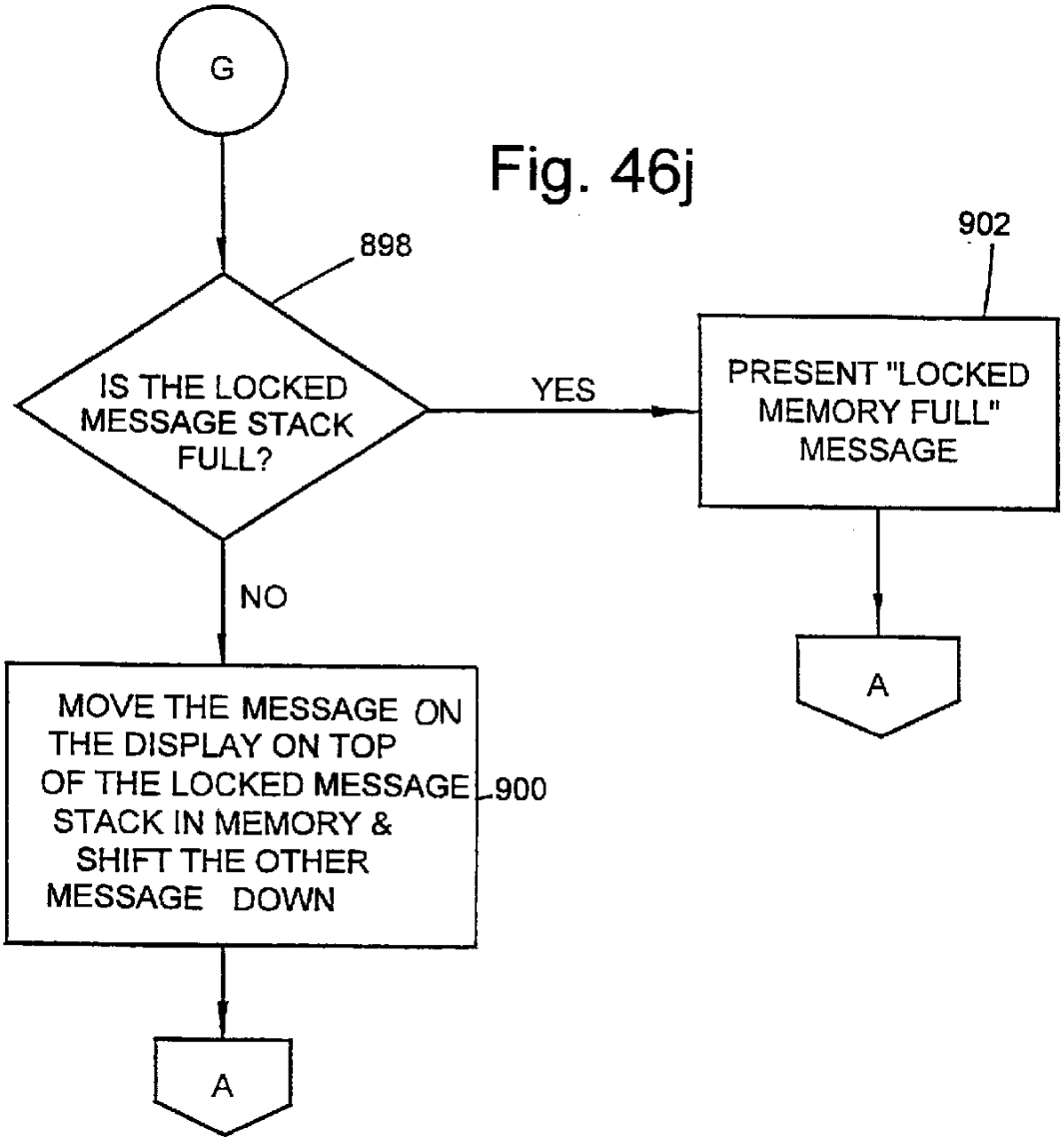
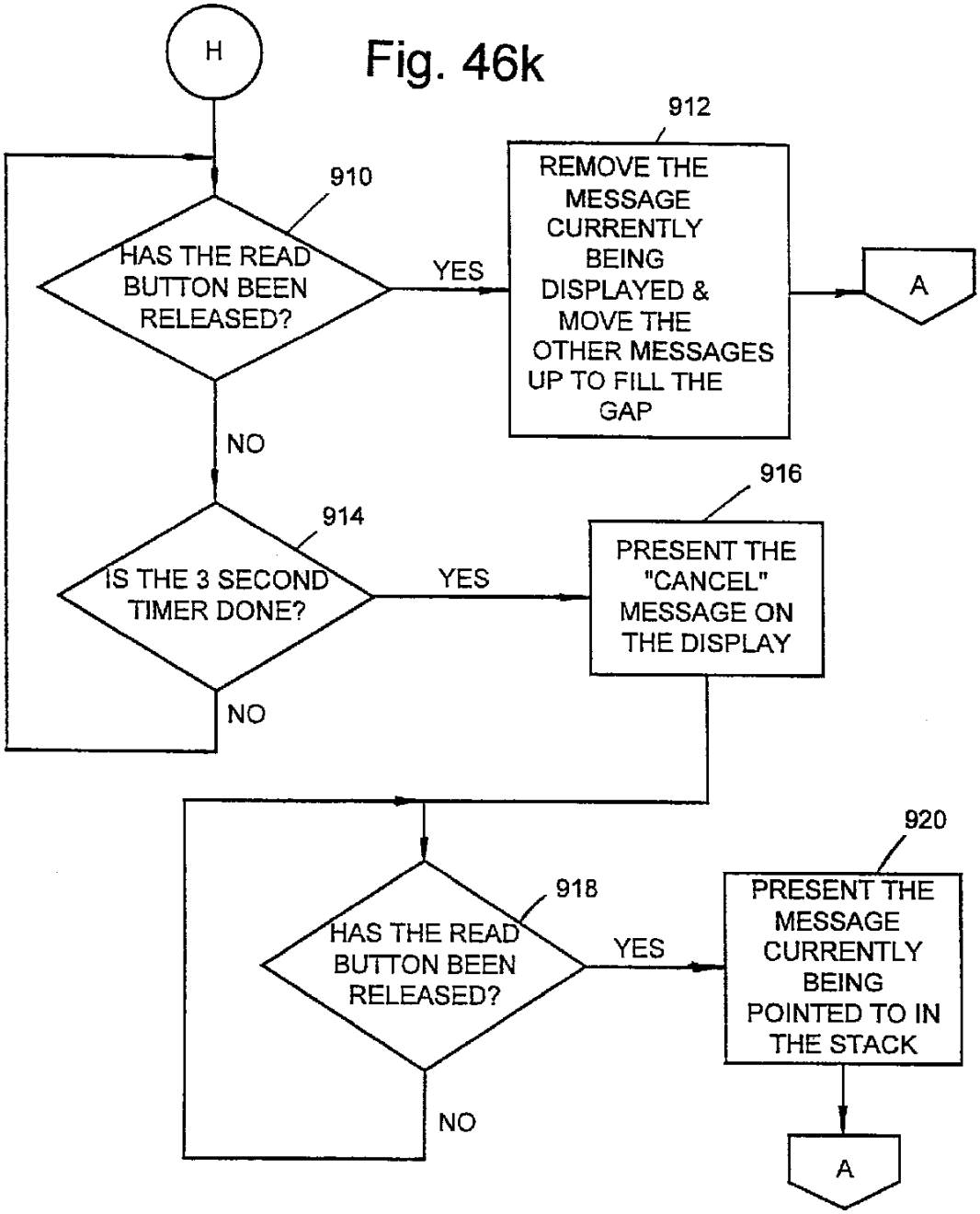

G
898
IS THE LOCKED MESSAGE STACK FULL?
YES
902
PRESENT "LOCKED MEMORY FULL" MESSAGE
A
NO
MOVE THE MESSAGE ON THE DISPLAY ON TOP OF THE LOCKED MESSAGE STACK IN MEMORY & SHIFT THE OTHER MESSAGE DOWN
900
A

Fig. 46j

Fig. 46k


H
910
HAS THE READ BUTTON BEEN RELEASED?
YES
912
REMOVE THE MESSAGE CURRENTLY BEING DISPLAYED & MOVE THE OTHER MESSAGES UP TO FILL THE GAP
A
NO
914
IS THE 3 SECOND TIMER DONE?
YES
916
PRESENT THE "CANCEL" MESSAGE ON THE DISPLAY
NO
918
HAS THE READ BUTTON BEEN RELEASED?
YES
920
PRESENT THE MESSAGE CURRENTLY BEING POINTED TO IN THE STACK
NO
A

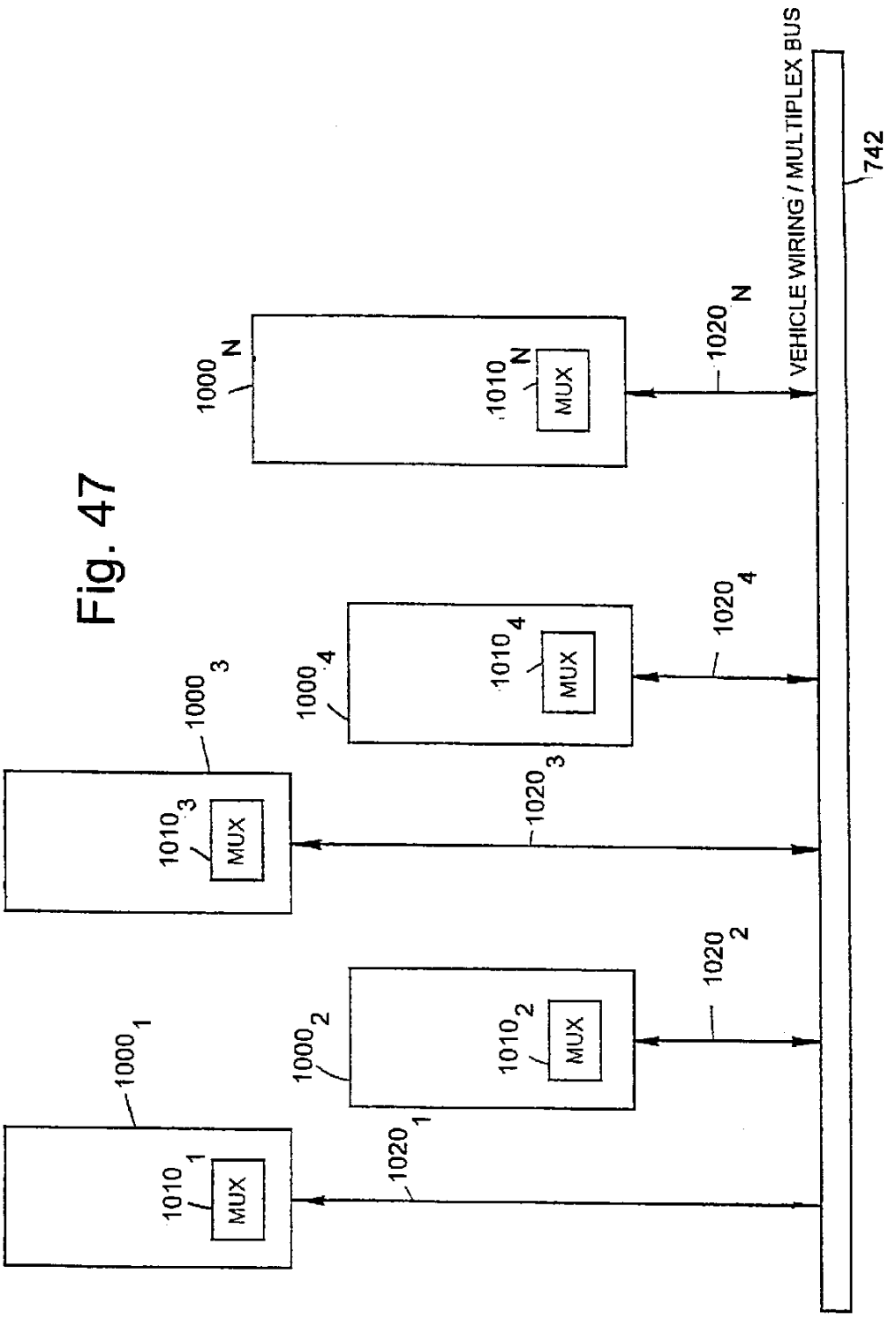

VEHICLE WIRING / MULTIPLEX BUS
742
1000 1
1010 1
MUX
1020 1
1000 2
1010 2
MUX
1020 2
1000 3
1010 3
MUX
1020 3
1000 4
1010 4
MUX
1020 4
1000 N
1010 N
MUX
1020 N

Fig. 47

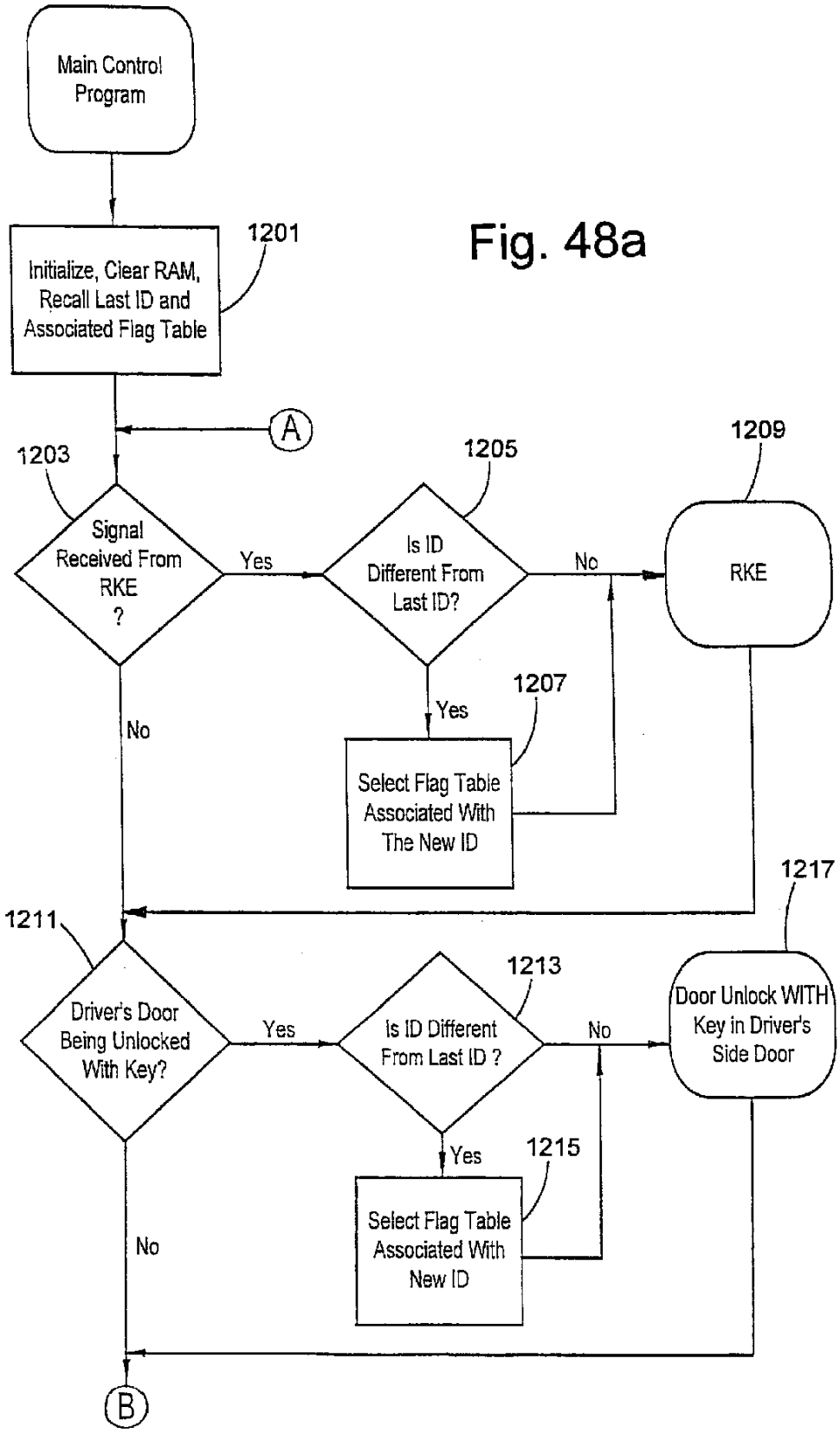

Main Control Program
Initialize, Clear RAM, Recall Last ID and Associated Flag Table
1201
A
1203
Signal Received From RKE ?
Yes
1205
Is ID Different From Last ID?
No
1209
RKE
Yes
1207
Select Flag Table Associated With The New ID
No
1217
1211
Driver's Door Being Unlocked With Key?
Yes
1213
Is ID Different From Last ID ?
No
Door Unlock WITH Key in Driver's Side Door
Yes
1215
Select Flag Table Associated With New ID
No
B

Fig. 48a

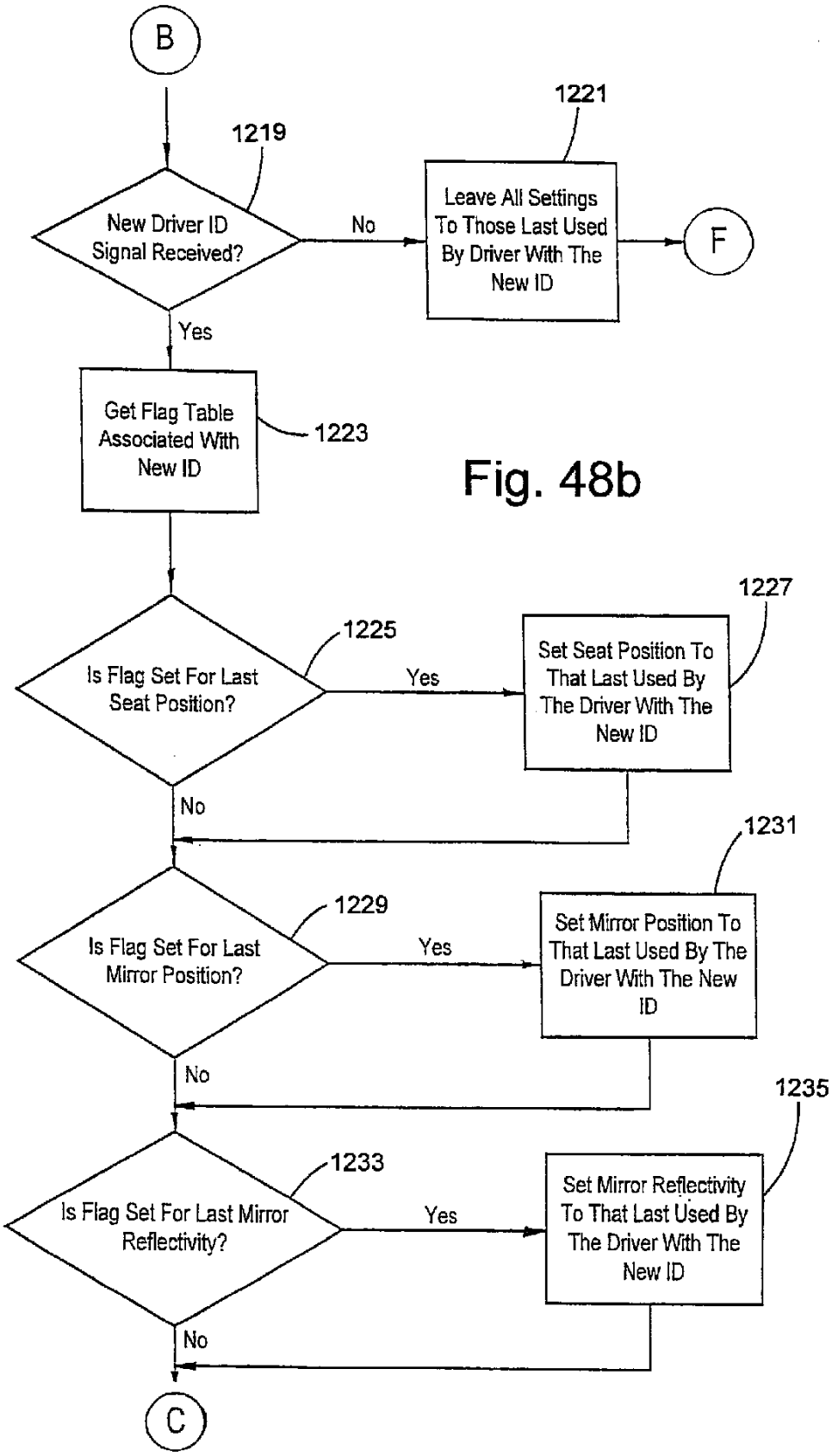

B
1219
New Driver ID Signal Received?
No
1221
Leave All Settings To Those Last Used By Driver With The New ID
F
Yes
Get Flag Table Associated With New ID
1223
1225
Is Flag Set For Last Seat Position?
Yes
1227
Set Seat Position To That Last Used By The Driver With The New ID
No
1229
Is Flag Set For Last Mirror Position?
Yes
1231
Set Mirror Position To That Last Used By The Driver With The New ID
No
1233
Is Flag Set For Last Mirror Reflectivity?
Yes
1235
Set Mirror Reflectivity To That Last Used By The Driver With The New ID
No
C

Fig. 48b

Fig. 48c

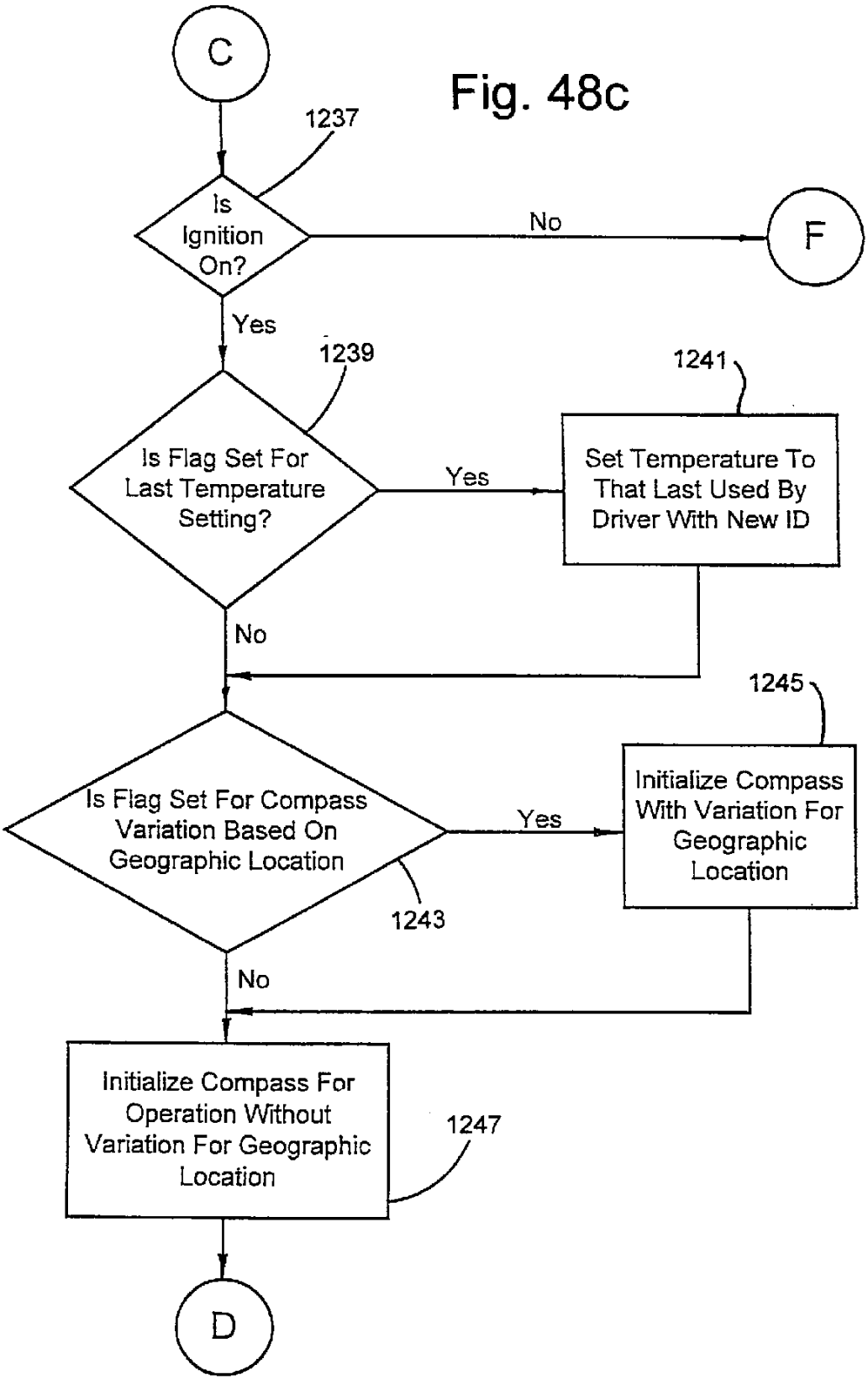
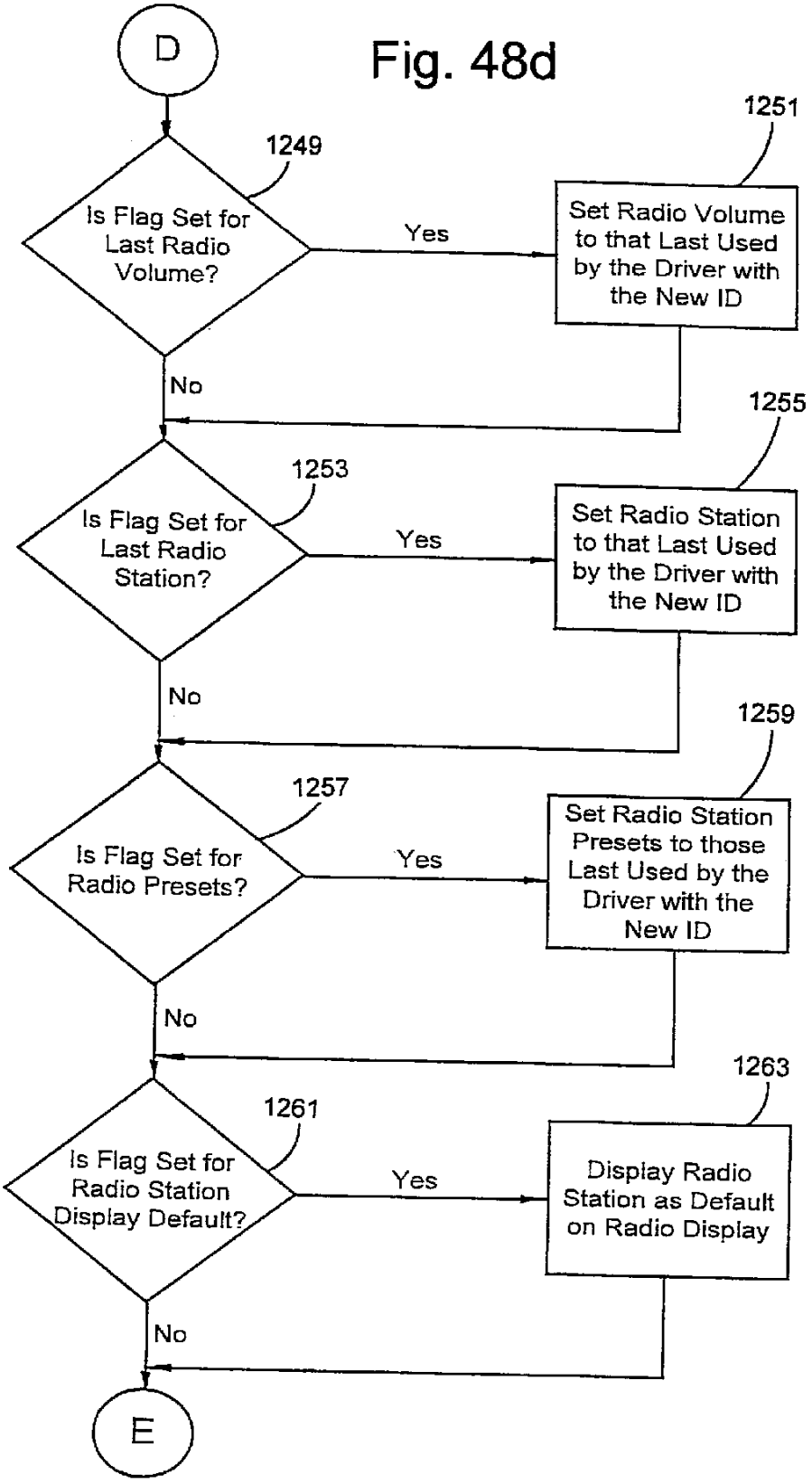
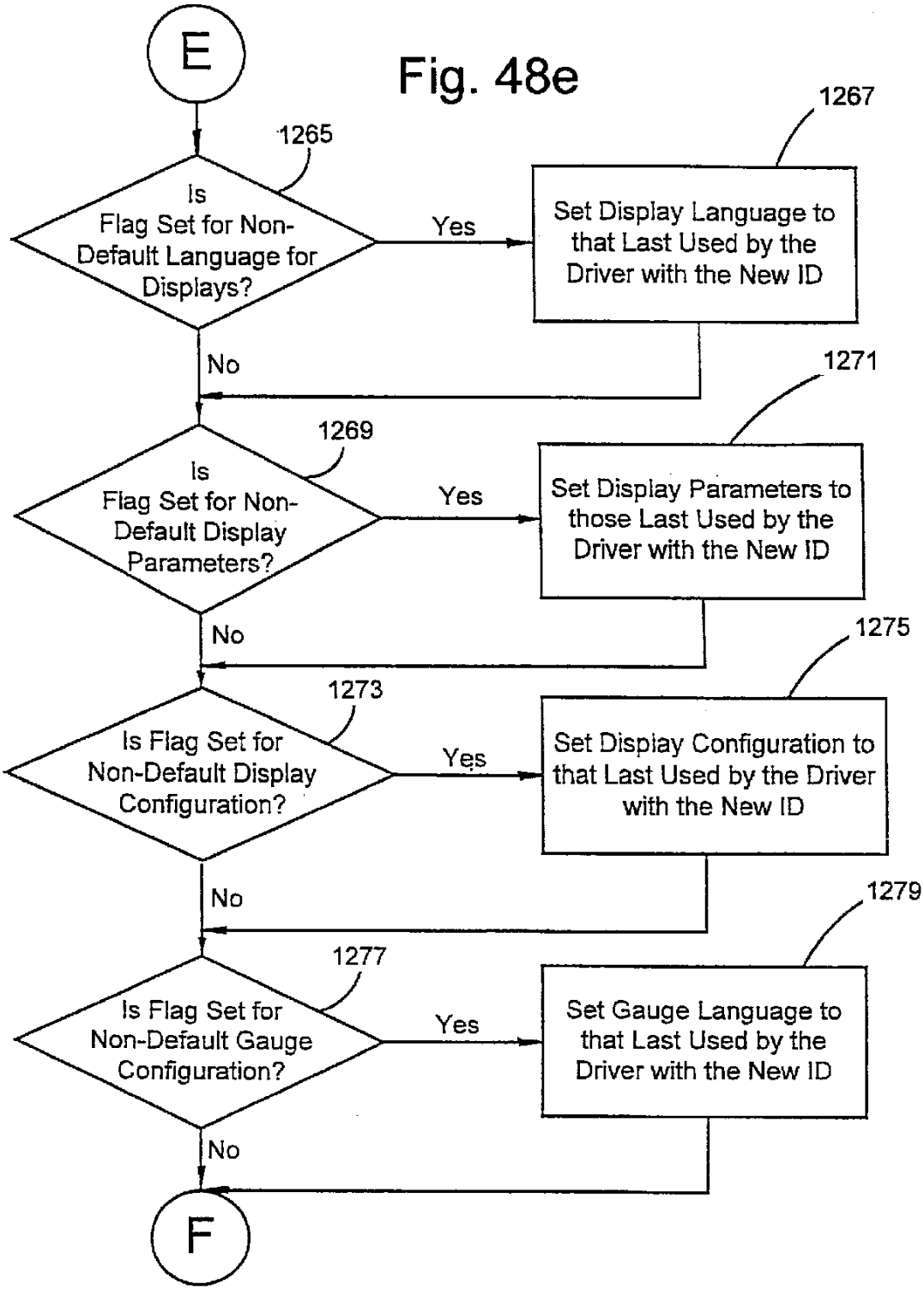

C
1237
Is Ignition On?
No
F
Yes
1239
Is Flag Set For Last Temperature Setting?
Yes
1241
Set Temperature To That Last Used By Driver With New ID
No
1245
Is Flag Set For Compass Variation Based On Geographic Location
Yes
Initialize Compass With Variation For Geographic Location
1243
No
Initialize Compass For Operation Without Variation For Geographic Location
1247
D

Fig. 48d


D
1249
Is Flag Set for Last Radio Volume?
Yes
1251
Set Radio Volume to that Last Used by the Driver with the New ID
No
1253
Is Flag Set for Last Radio Station?
Yes
1255
Set Radio Station to that Last Used by the Driver with the New ID
No
1257
Is Flag Set for Radio Presets?
Yes
1259
Set Radio Station Presets to those Last Used by the Driver with the New ID
No
1261
Is Flag Set for Radio Station Display Default?
Yes
1263
Display Radio Station as Default on Radio Display
No
E


E
Fig. 48e
1265
Is Flag Set for Non-Default Language for Displays?
Yes
1267
Set Display Language to that Last Used by the Driver with the New ID
No
1269
Is Flag Set for Non-Default Display Parameters?
Yes
1271
Set Display Parameters to those Last Used by the Driver with the New ID
No
1273
Is Flag Set for Non-Default Display Configuration?
Yes
1275
Set Display Configuration to that Last Used by the Driver with the New ID
No
1277
Is Flag Set for Non-Default Gauge Configuration?
Yes
1279
Set Gauge Language to that Last Used by the Driver with the New ID
No
F

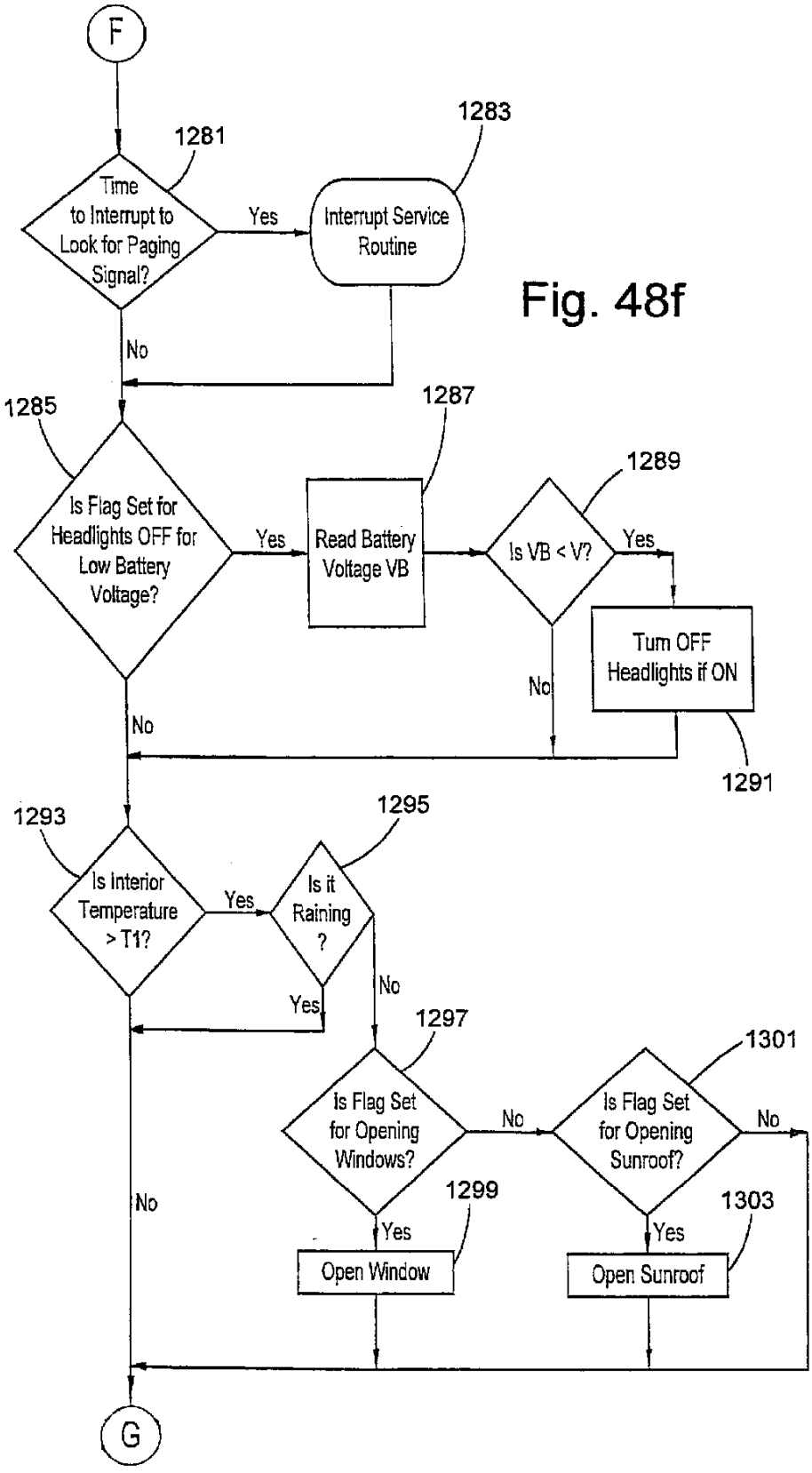

F
1281
Time to Interrupt to Look for Paging Signal?
Yes
1283
Interrupt Service Routine
No
1285
Is Flag Set for Headlights OFF for Low Battery Voltage?
Yes
1287
Read Battery Voltage VB
1289
Is VB < V?
Yes
Turn OFF Headlights if ON
No
No
1291
1293
Is Interior Temperature > T1?
Yes
1295
Is it Raining ?
Yes
No
1297
Is Flag Set for Opening Windows?
No
1301
Is Flag Set for Opening Sunroof?
No
No
Yes
1299
Open Window
Yes
1303
Open Sunroof
G

Fig. 48f

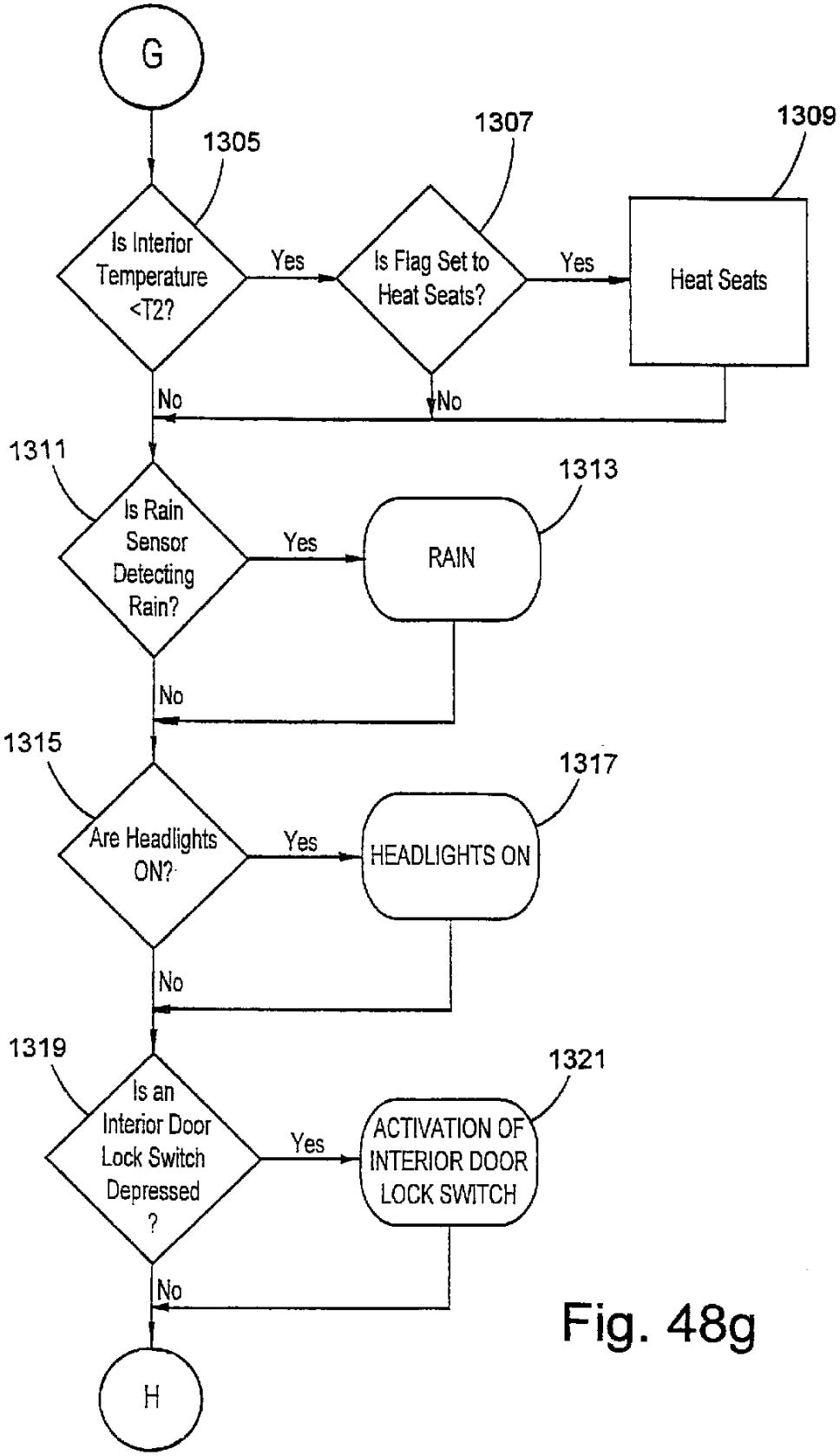

G
1305
Is Interior Temperature <T2?
Yes
1307
Is Flag Set to Heat Seats?
Yes
1309
Heat Seats
No
No
1311
Is Rain Sensor Detecting Rain?
Yes
1313
RAIN
No
1315
Are Headlights ON?
Yes
1317
HEADLIGHTS ON
No
1319
Is an Interior Door Lock Switch Depressed ?
Yes
1321
ACTIVATION OF INTERIOR DOOR LOCK SWITCH
No
H

Fig. 48g

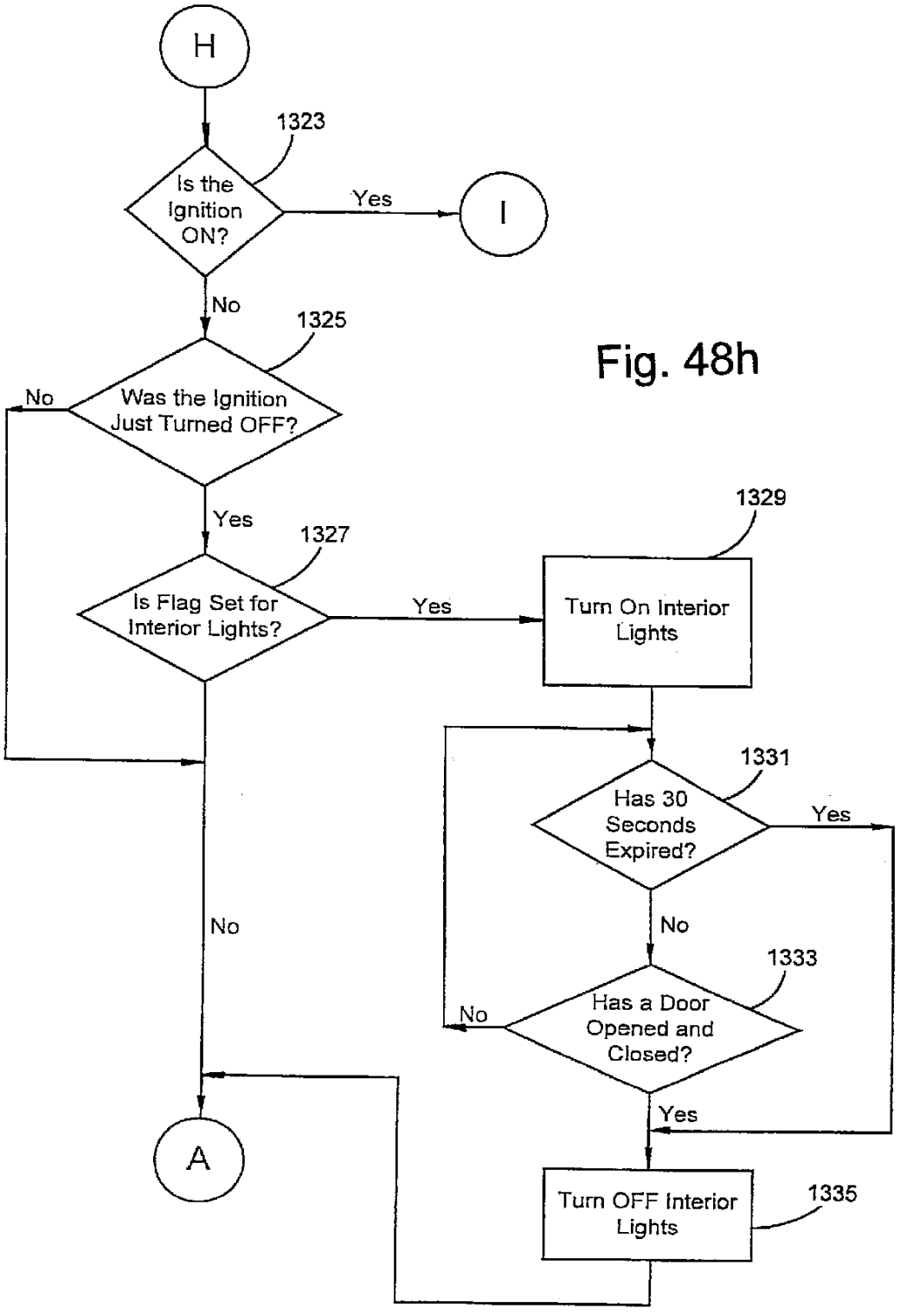

H
1323
Is the Ignition ON?
Yes
I
No
1325
Was the Ignition Just Turned OFF?
No
Yes
1327
Is Flag Set for Interior Lights?
Yes
1329
Turn On Interior Lights
1331
Has 30 Seconds Expired?
Yes
No
1333
Has a Door Opened and Closed?
No
Yes
No
A
Turn OFF Interior Lights
1335

Fig. 48h

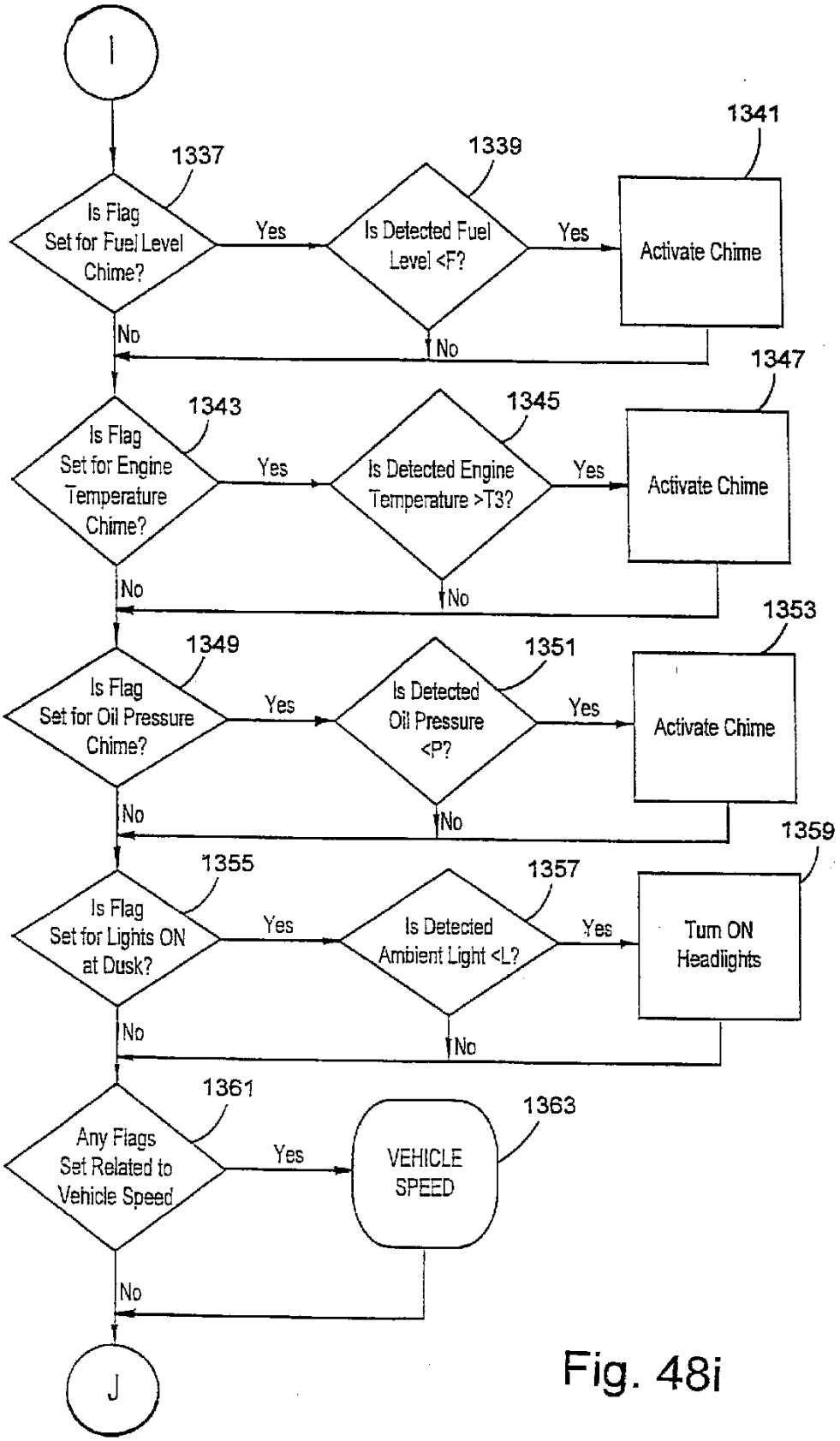

I
1337
Is Flag Set for Fuel Level Chime?
Yes
1339
Is Detected Fuel Level <F?
Yes
1341
Activate Chime
No
No
1343
Is Flag Set for Engine Temperature Chime?
Yes
1345
Is Detected Engine Temperature >T3?
Yes
1347
Activate Chime
No
No
1349
Is Flag Set for Oil Pressure Chime?
Yes
1351
Is Detected Oil Pressure <P?
Yes
1353
Activate Chime
No
No
1355
Is Flag Set for Lights ON at Dusk?
Yes
1357
Is Detected Ambient Light <L?
Yes
1359
Turn ON Headlights
No
No
1361
Any Flags Set Related to Vehicle Speed
Yes
1363
VEHICLE SPEED
No
J

Fig. 48i

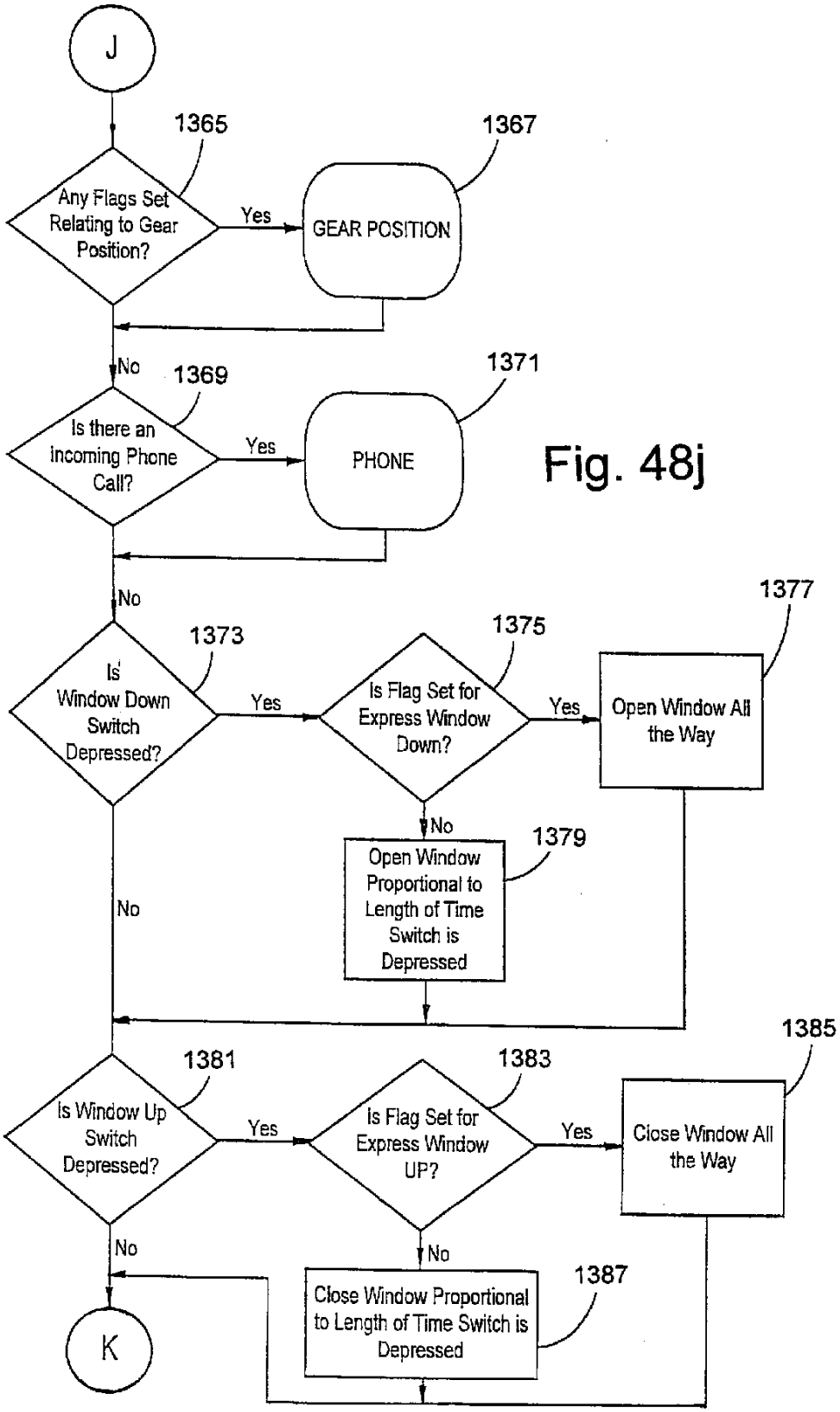

J
1365
Any Flags Set Relating to Gear Position?
Yes
1367
GEAR POSITION
No
1369
Is there an incoming Phone Call?
Yes
1371
PHONE
No
1373
Is Window Down Switch Depressed?
Yes
1375
Is Flag Set for Express Window Down?
Yes
1377
Open Window All the Way
No
1379
Open Window Proportional to Length of Time Switch is Depressed
No
1381
Is Window Up Switch Depressed?
Yes
1383
Is Flag Set for Express Window UP?
Yes
1385
Close Window All the Way
No
No
1387
Close Window Proportional to Length of Time Switch is Depressed
K

Fig. 48j

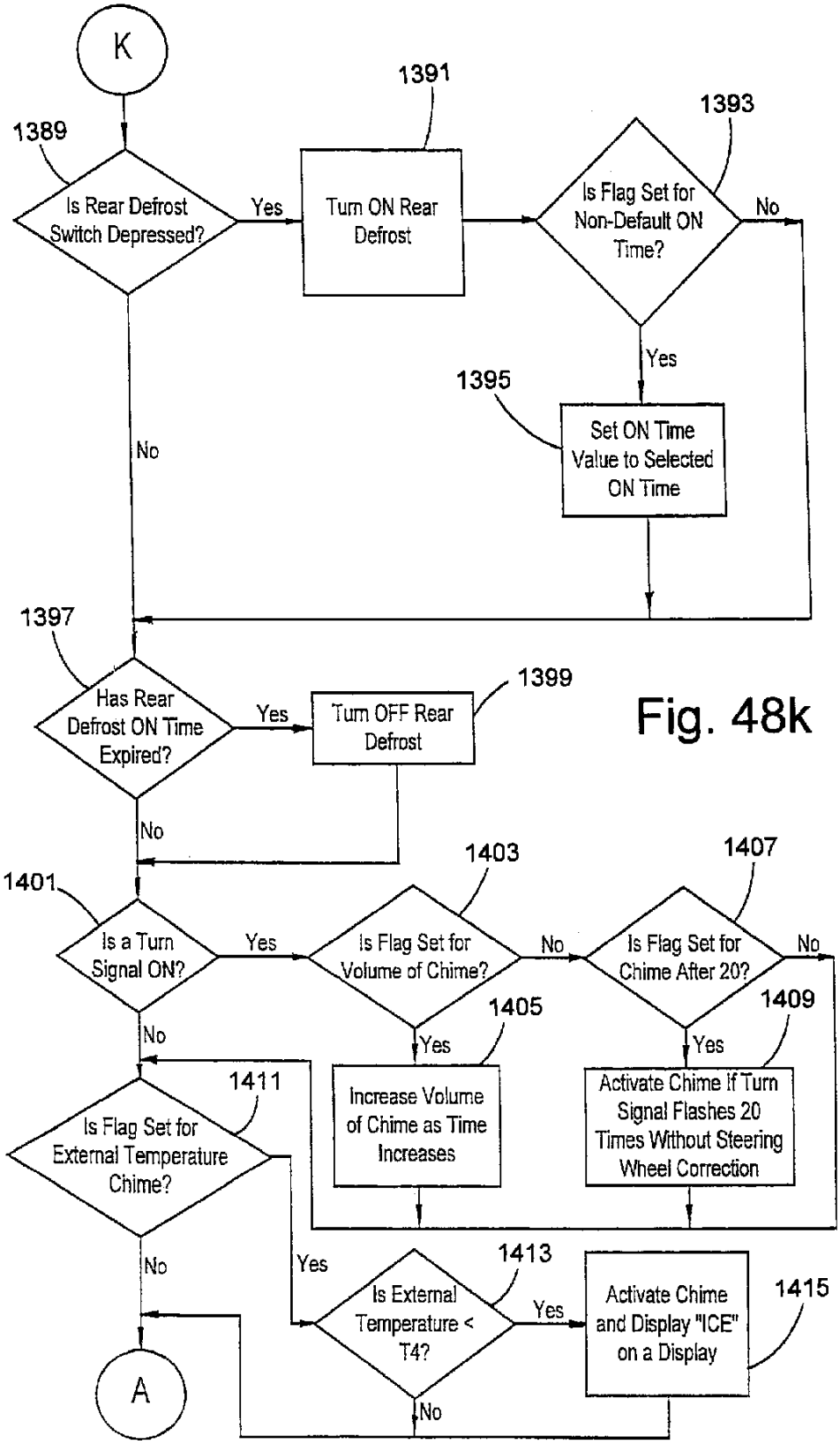

K
1389
Is Rear Defrost Switch Depressed?
Yes
1391
Turn ON Rear Defrost
1393
Is Flag Set for Non-Default ON Time?
No
Yes
1395
Set ON Time Value to Selected ON Time
No
1397
Has Rear Defrost ON Time Expired?
Yes
1399
Turn OFF Rear Defrost
No
1401
Is a Turn Signal ON?
Yes
1403
Is Flag Set for Volume of Chime?
No
1407
Is Flag Set for Chime After 20?
No
No
Yes
1405
Increase Volume of Chime as Time Increases
Yes
1409
Activate Chime If Turn Signal Flashes 20 Times Without Steering Wheel Correction
1411
Is Flag Set for External Temperature Chime?
No
Yes
1413
Is External Temperature < T4?
Yes
1415
Activate Chime and Display "ICE" on a Display
No
A

Fig. 48k

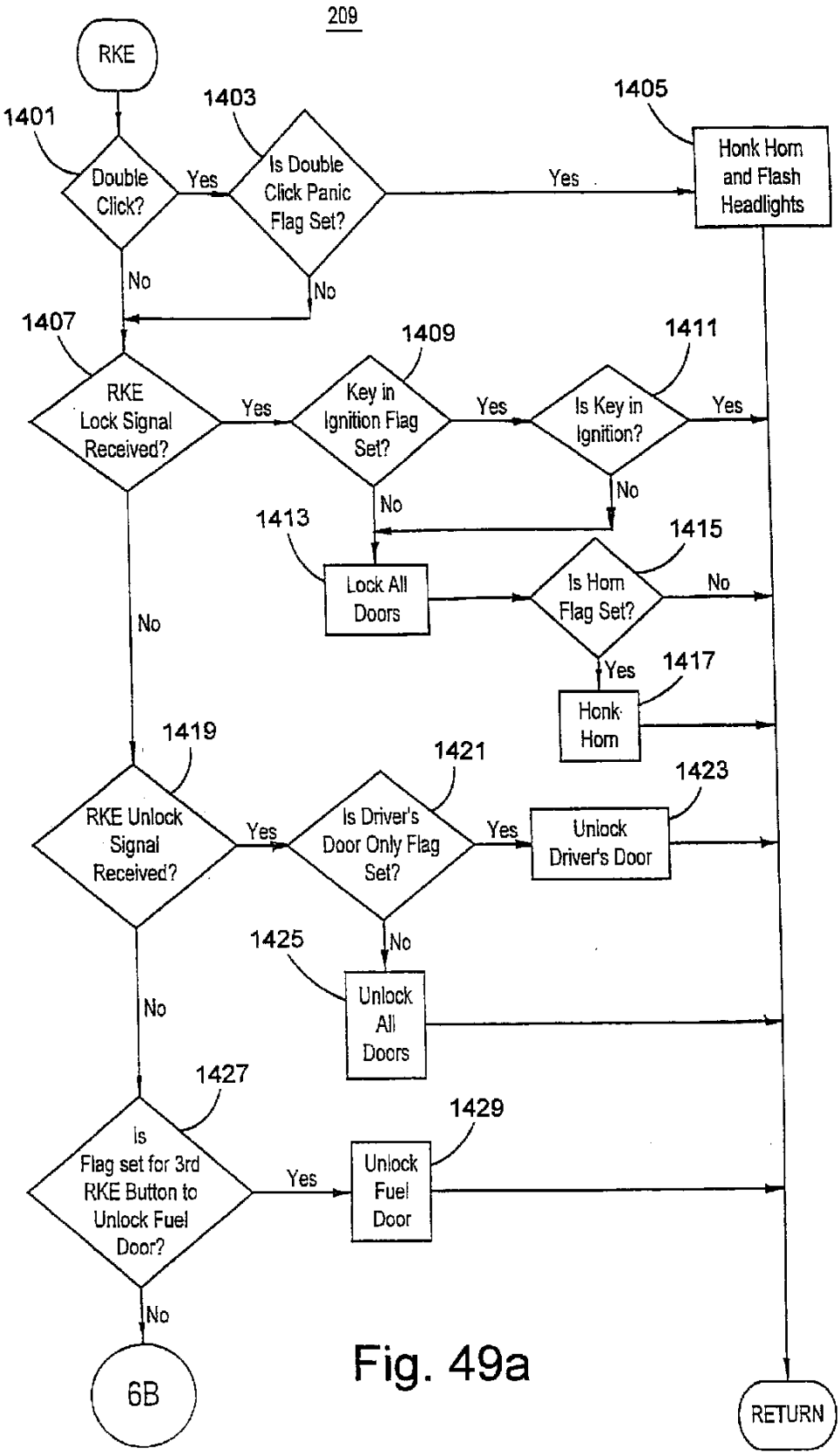

209
RKE
1401
Double Click?
Yes
1403
Is Double Click Panic Flag Set?
Yes
1405
Honk Horn and Flash Headlights
No
No
1407
RKE Lock Signal Received?
Yes
1409
Key in Ignition Flag Set?
Yes
1411
Is Key in Ignition?
Yes
No
No
1413
Lock All Doors
1415
Is Horn Flag Set?
No
Yes
1417
Honk Horn
No
1419
RKE Unlock Signal Received?
Yes
1421
Is Driver's Door Only Flag Set?
Yes
1423
Unlock Driver's Door
No
1425
Unlock All Doors
No
1427
Is Flag set for 3rd RKE Button to Unlock Fuel Door?
Yes
1429
Unlock Fuel Door
No
6B
RETURN

Fig. 49a

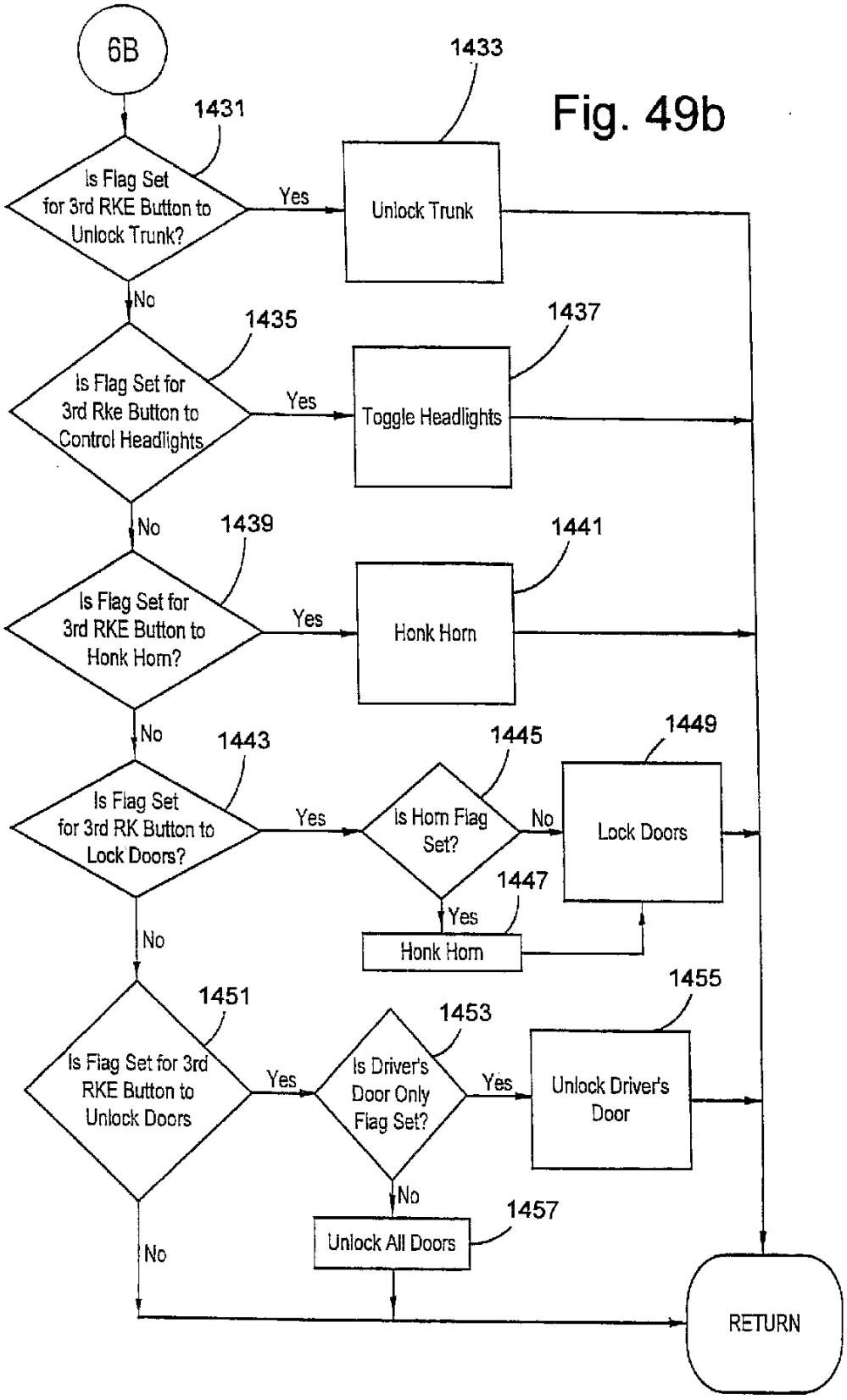

6B
1431
Is Flag Set for 3rd RKE Button to Unlock Trunk?
Yes
1433
Unlock Trunk
No
1435
Is Flag Set for 3rd Rke Button to Control Headlights
Yes
1437
Toggle Headlights
No
1439
Is Flag Set for 3rd RKE Button to Honk Horn?
Yes
1441
Honk Horn
No
1443
Is Flag Set for 3rd RK Button to Lock Doors?
Yes
1445
Is Horn Flag Set?
No
1449
Lock Doors
Yes
1447
Honk Horn
No
1451
Is Flag Set for 3rd RKE Button to Unlock Doors
Yes
1453
Is Driver's Door Only Flag Set?
Yes
1455
Unlock Driver's Door
No
1457
Unlock All Doors
No
RETURN

Fig. 49b

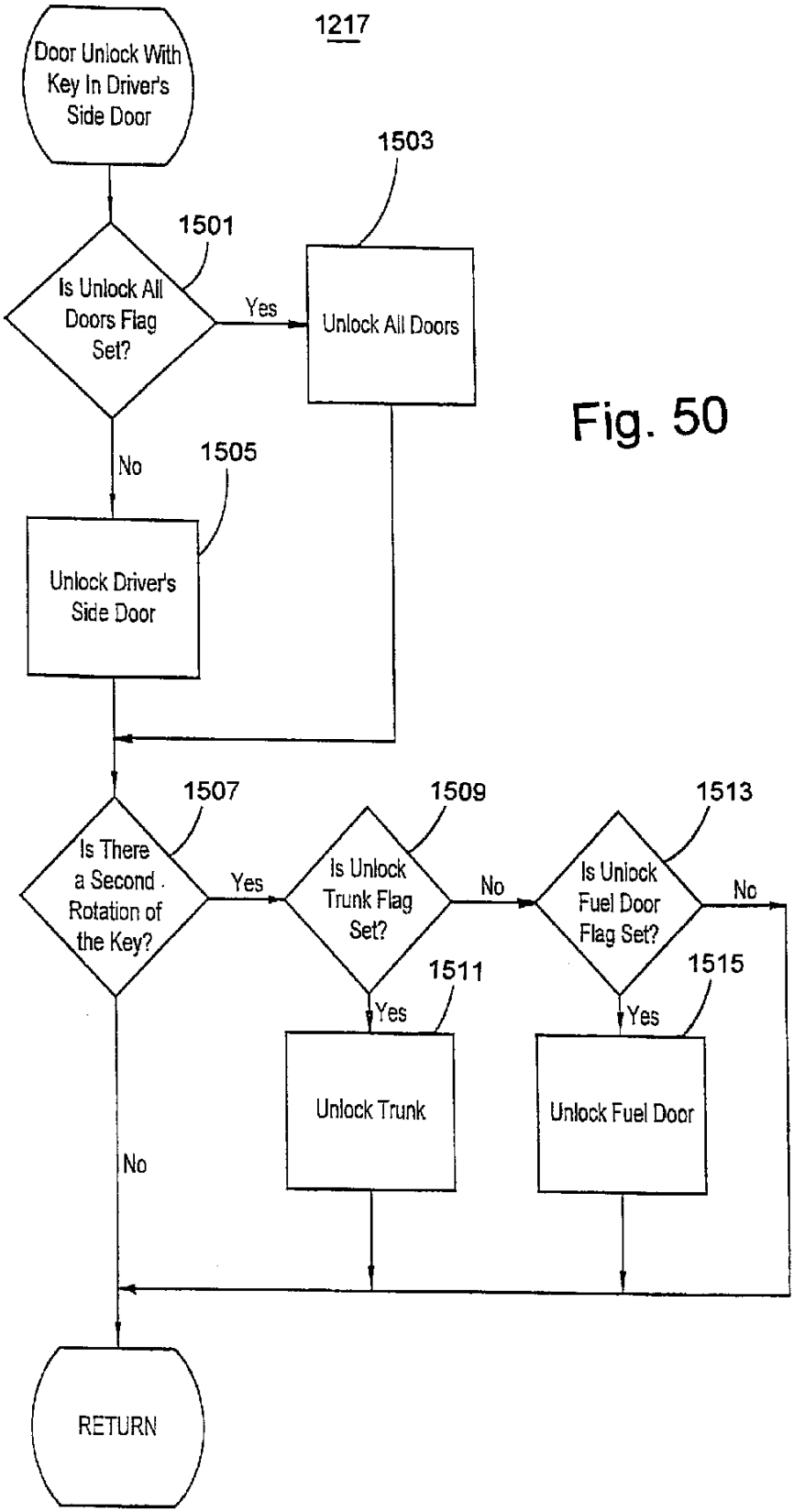

1217
Door Unlock With Key In Driver's Side Door
1501
Is Unlock All Doors Flag Set?
Yes
1503
Unlock All Doors
No
1505
Unlock Driver's Side Door
1507
Is There a Second Rotation of the Key?
Yes
1509
Is Unlock Trunk Flag Set?
No
1513
Is Unlock Fuel Door Flag Set?
No
Yes
1511
Unlock Trunk
Yes
1515
Unlock Fuel Door
No
RETURN

Fig. 50

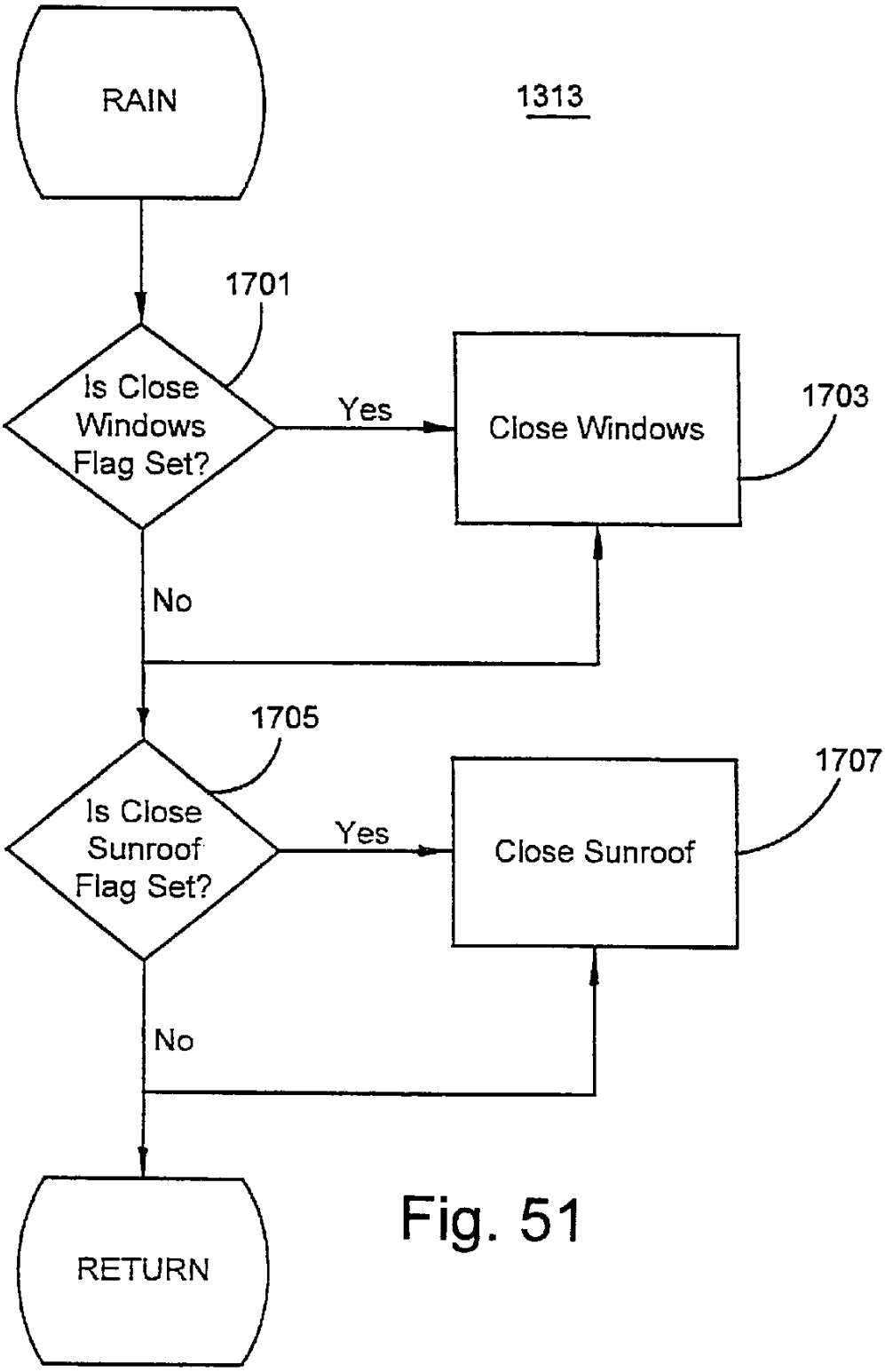

RAIN
1313
1701
Is Close Windows Flag Set?
Yes
Close Windows
1703
No
1705
Is Close Sunroof Flag Set?
Yes
Close Sunroof
1707
No
RETURN

Fig. 51

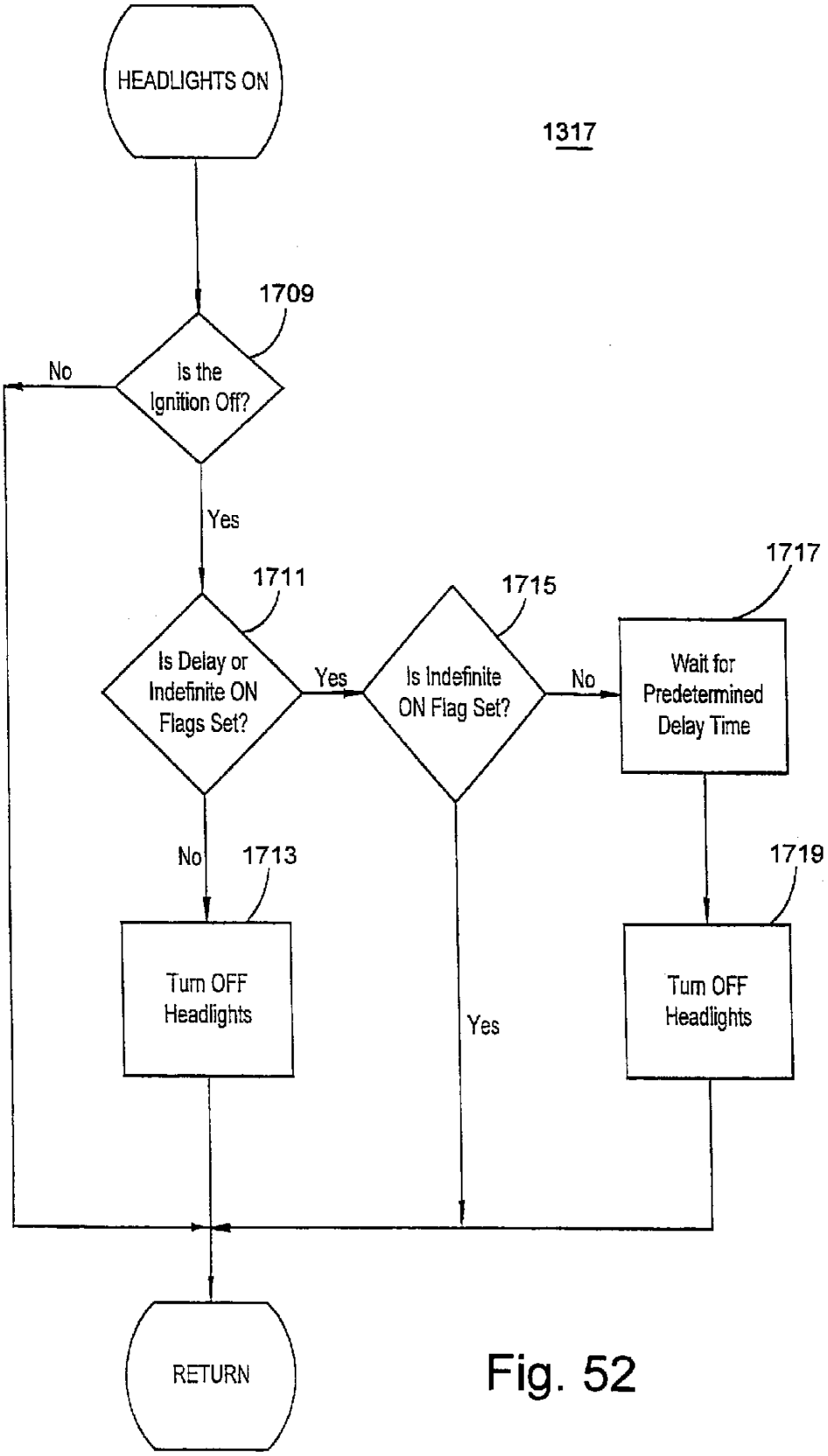

HEADLIGHTS ON
1317
1709
Is the Ignition Off?
No
Yes
1711
Is Delay or Indefinite ON Flags Set?
Yes
1715
Is Indefinite ON Flag Set?
No
1717
Wait for Predetermined Delay Time
No
1713
Turn OFF Headlights
Yes
1719
Turn OFF Headlights
RETURN

Fig. 52

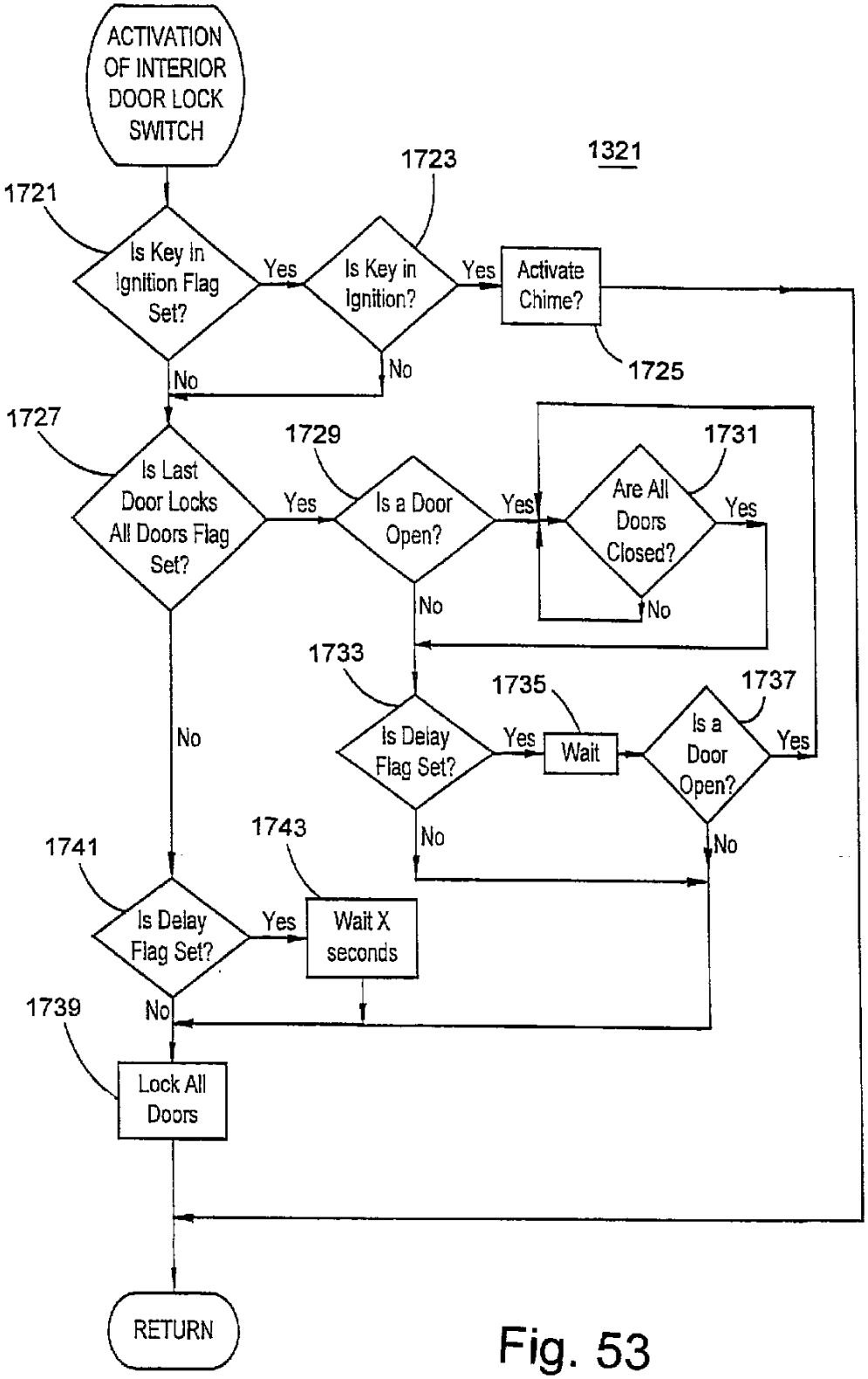

ACTIVATION OF INTERIOR DOOR LOCK SWITCH
1321
1721
Is Key in Ignition Flag Set?
Yes
1723
Is Key in Ignition?
Yes
Activate Chime?
1725
No
No
1727
Is Last Door Locks All Doors Flag Set?
Yes
1729
Is a Door Open?
Yes
1731
Are All Doors Closed?
Yes
No
No
1733
Is Delay Flag Set?
Yes
1735
Wait
1737
Is a Door Open?
Yes
No
No
No
1741
Is Delay Flag Set?
Yes
1743
Wait X seconds
1739
No
Lock All Doors
RETURN

Fig. 53

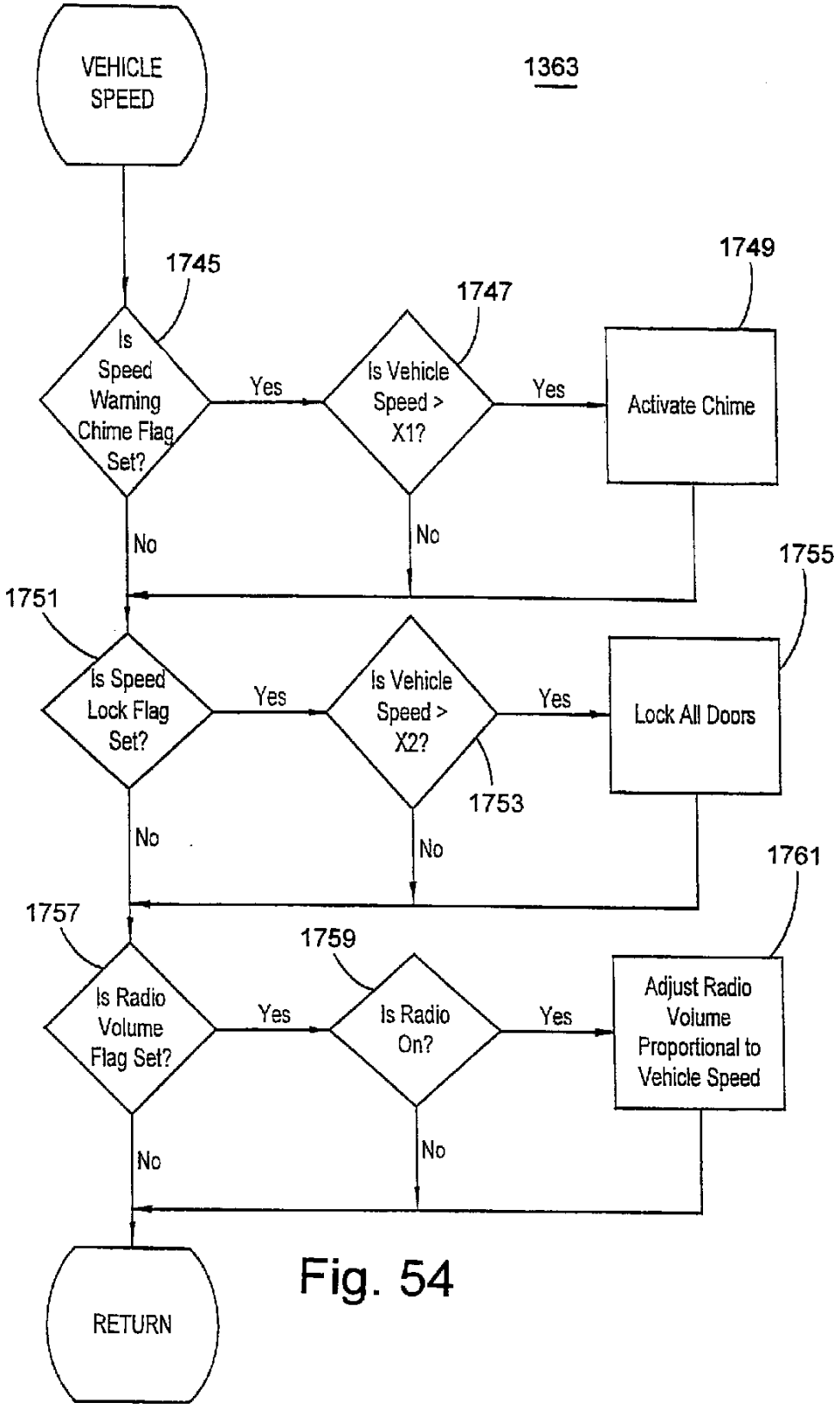

VEHICLE SPEED
1363
1745
Is Speed Warning Chime Flag Set?
Yes
1747
Is Vehicle Speed > X1?
Yes
1749
Activate Chime
No
No
1755
1751
Is Speed Lock Flag Set?
Yes
Is Vehicle Speed > X2?
Yes
Lock All Doors
1753
No
No
1761
1757
Is Radio Volume Flag Set?
Yes
1759
Is Radio On?
Yes
Adjust Radio Volume Proportional to Vehicle Speed
No
No
RETURN

Fig. 54

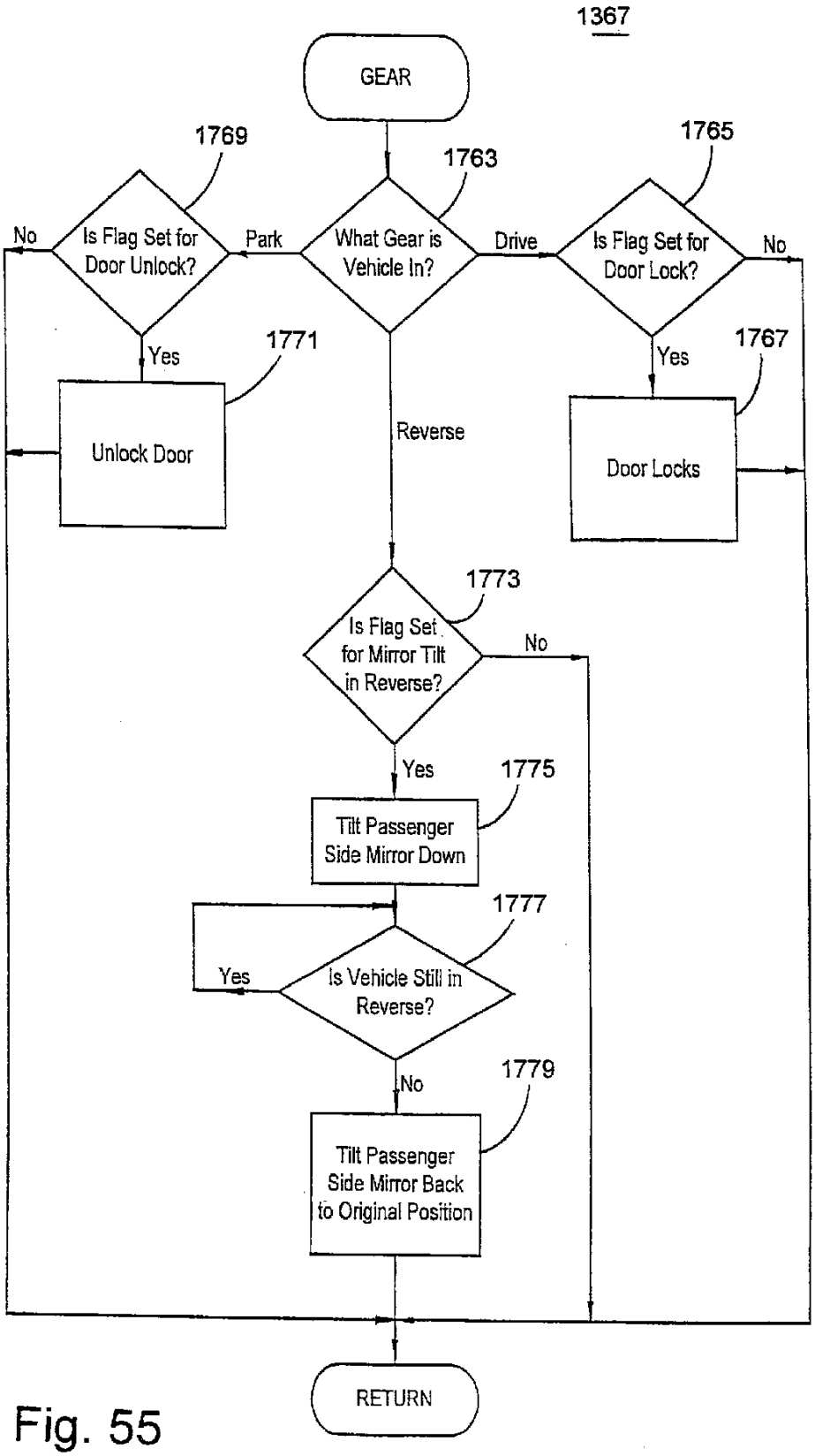

1367
GEAR
1769
1763
1765
No
Is Flag Set for Door Unlock?
Park
What Gear is Vehicle In?
Drive
Is Flag Set for Door Lock?
No
Yes
1771
Yes
1767
Unlock Door
Reverse
Door Locks
1773
Is Flag Set for Mirror Tilt in Reverse?
No
Yes
1775
Tilt Passenger Side Mirror Down
1777
Yes
Is Vehicle Still in Reverse?
No
1779
Tilt Passenger Side Mirror Back to Original Position
RETURN

Fig. 55

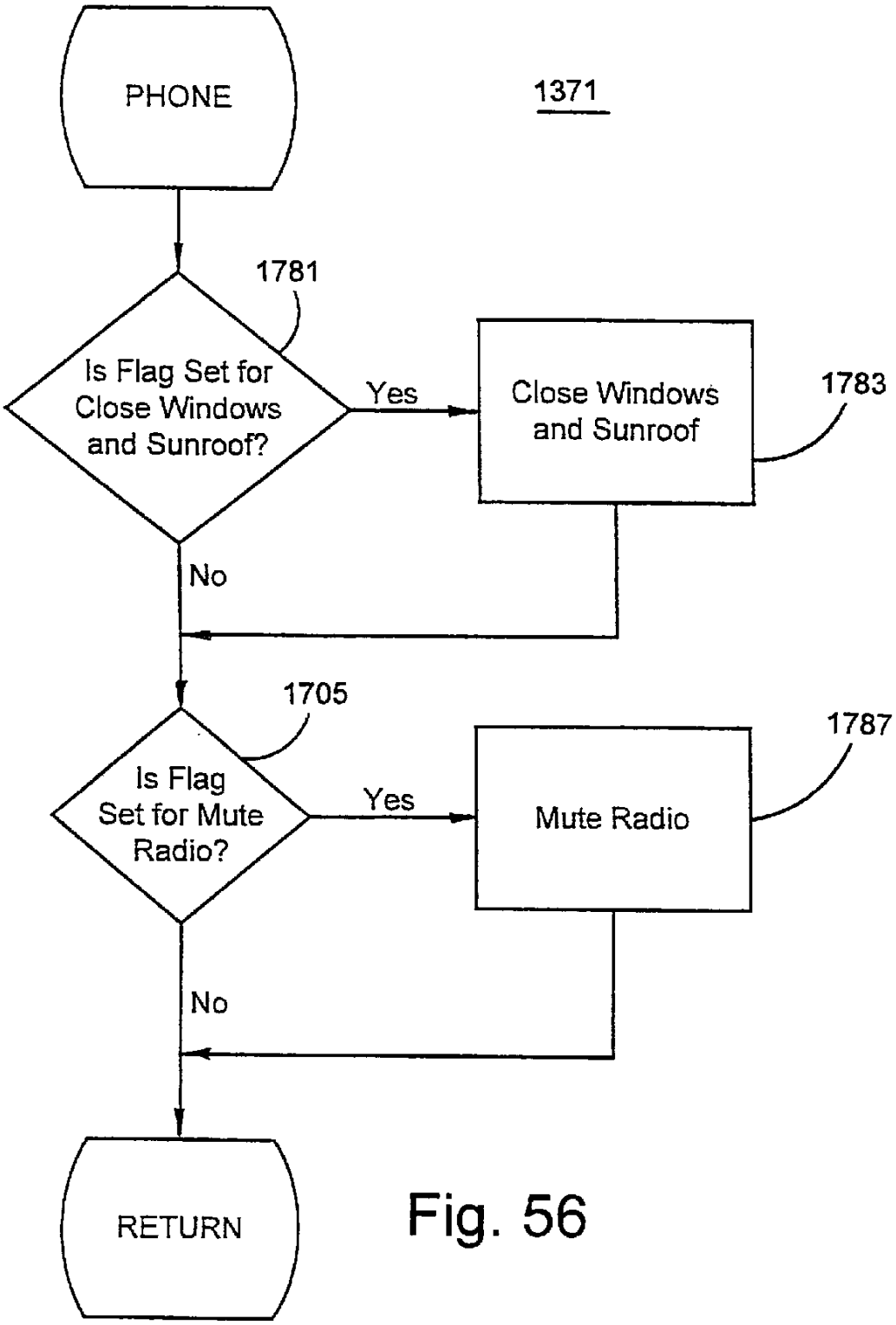

PHONE
1371
1781
Is Flag Set for Close Windows and Sunroof?
Yes
Close Windows and Sunroof
1783
No
1705
Is Flag Set for Mute Radio?
Yes
Mute Radio
1787
No
RETURN

Fig. 56

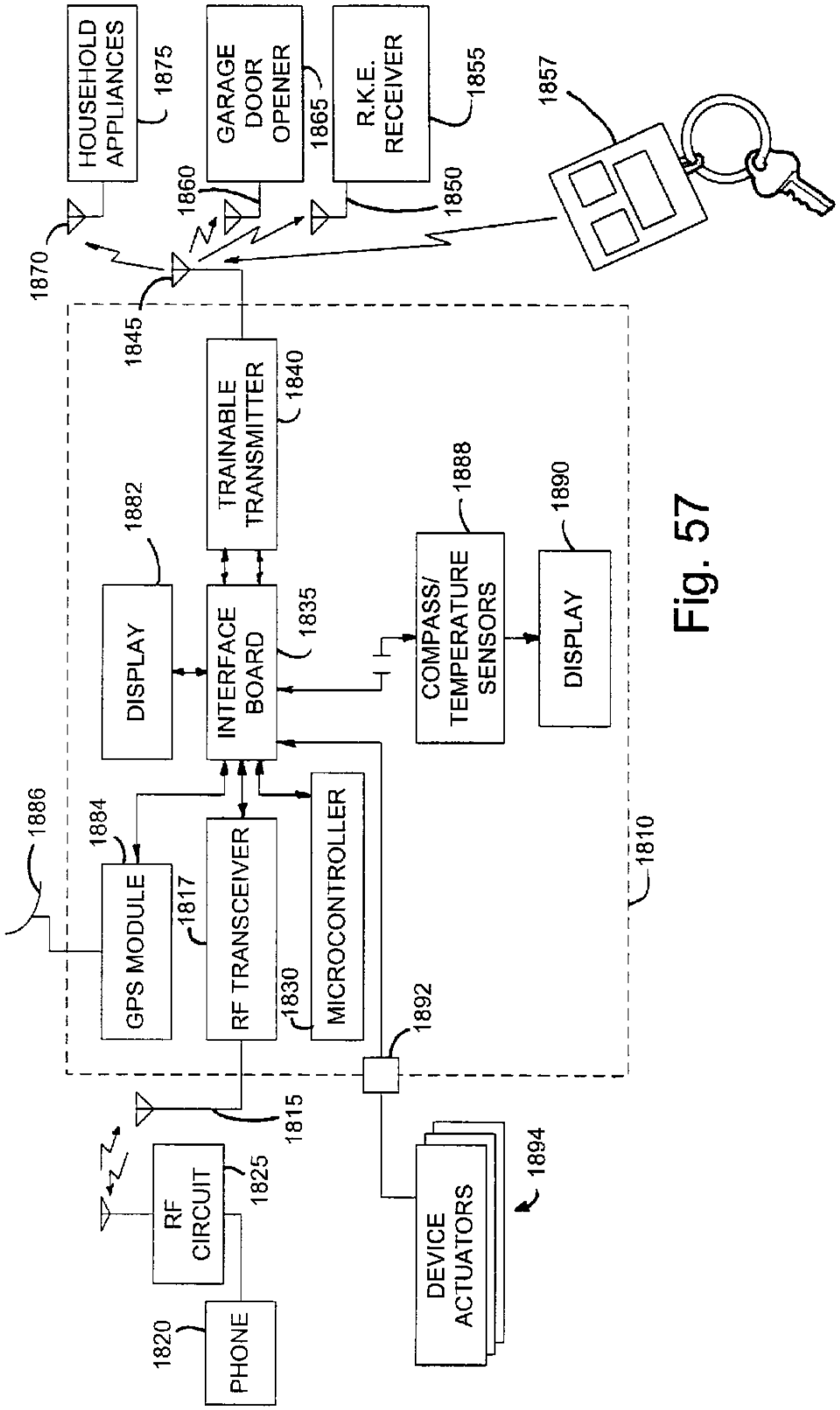

HOUSEHOLD APPLIANCES
1875
GARAGE DOOR OPENER
1865
R.K.E. RECEIVER
1855
1857
1860
1850
1870
1845
TRAINABLE TRANSMITTER
1840
1882
1888
1890
DISPLAY
INTERFACE BOARD
1835
COMPASS/ TEMPERATURE SENSORS
DISPLAY
1886
1884
1817
1830
1892
GPS MODULE
RF TRANSCEIVER
MICROCONTROLLER
1810
1815
RF CIRCUIT
1825
DEVICE ACTUATORS
1894
1820
PHONE

Fig. 57

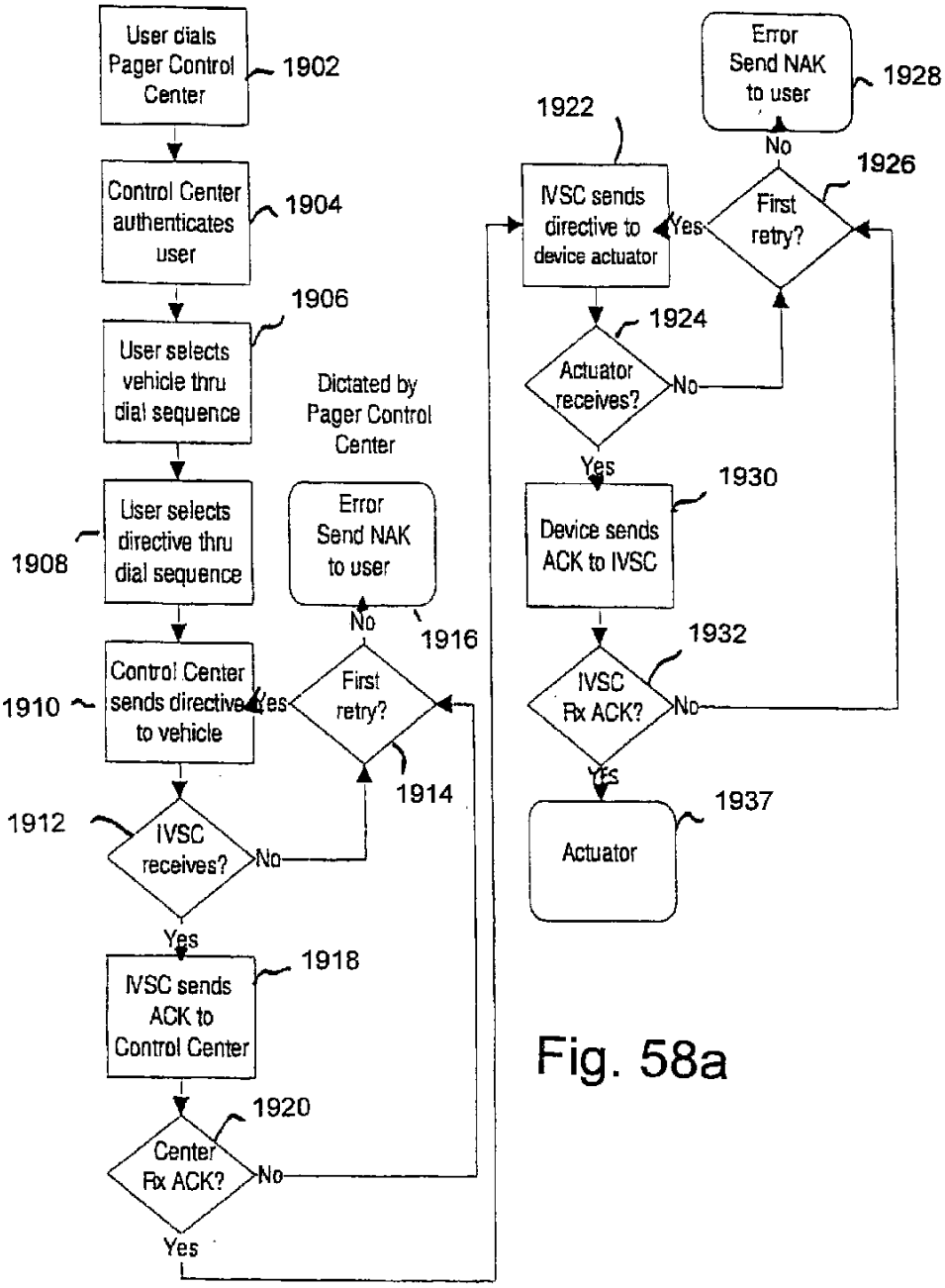

User dials Pager Control Center
1902
Control Center authenticates user
1904
User selects vehicle thru dial sequence
1906
Dictated by Pager Control Center
User selects directive thru dial sequence
1908
Error Send NAK to user
No
1916
Control Center sends directive to vehicle
1910
Yes
First retry?
1914
IVSC receives?
1912
No
Yes
IVSC sends ACK to Control Center
1918
Center Rx ACK?
1920
No
Yes
1922
IVSC sends directive to device actuator
Error Send NAK to user
1928
No
First retry?
1926
Yes
Actuator receives?
1924
No
Yes
Device sends ACK to IVSC
1930
IVSC Rx ACK?
1932
No
Yes
Actuator
1937

Fig. 58a

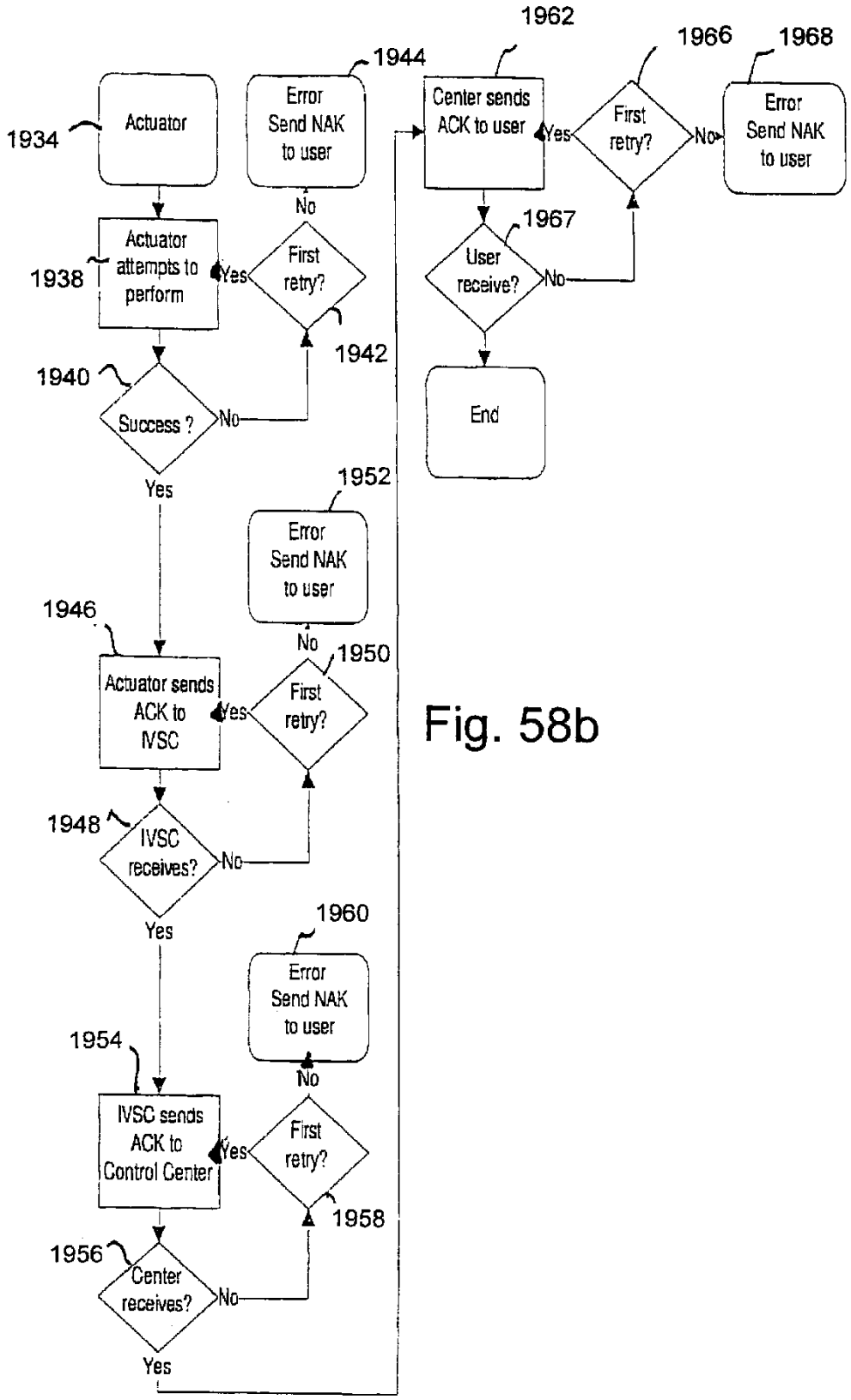

1962
1966
1968
1944
1934
Actuator
Error
Send NAK
to user
Center sends
ACK to user
Yes
First
retry?
No
Error
Send NAK
to user
No
1967
Actuator
attempts to
perform
1938
Yes
First
retry?
User
receive?
No
1942
1940
Success ?
No
End
Yes
1952
Error
Send NAK
to user
1946
No
1950
Actuator sends
ACK to
IVSC
Yes
First
retry?
1948
IVSC
receives?
No
Yes
1960
Error
Send NAK
to user
1954
No
IVSC sends
ACK to
Control Center
Yes
First
retry?
1958
1956
Center
receives?
No
Yes

Fig. 58b

VEHICLE COMMUNICATION AND REMOTE CONTROL SYSTEM

CROSS-REFERENCE TO RELATED APPLICATIONS

This application claims priority under 35 U.S.C. §119(e) on U.S. Provisional Patent Application No. 60/019,773 entitled VEHICLE COMMUNICATION AND REMOTE CONTROL SYSTEM, filed on Jun. 14, 1996.

BACKGROUND OF THE INVENTION

The present invention generally relates to a vehicle communication system having various message and control functions. More specifically, the present invention relates to a system for a vehicle capable of providing various combinations of automatic emergency response, theft deterrence, vehicle tracking and immobilization, two-way communication, remote vehicle accessory control, vehicle personalization, navigational guidance, and location-based information services.

Although various communication systems and various remote control systems have been disclosed for implementation in a vehicle, very few of these systems have, in fact, been integrated within a vehicle so as to provide both a two-way communication system and a remote control system that is capable of performing a large variety of functions. Because of the cost and complexity of the prior systems that have been proposed, many of the disclosed systems have never been actually implemented in a vehicle. In addition, given the cost that is passed along to the consumer, such systems must be capable of providing a large number of functions and yet be relatively easy to use. Further, most of these prior systems do not allow a vehicle owner to control, reprogram, and track their vehicle from a home or office personal computer (PC).

SUMMARY OF THE INVENTION

One aspect of the present invention is to provide a display and user interface in a vehicle-installed accessory such that the vehicle driver may easily manipulate the input keys and view the display with minimal distraction while driving. Another aspect of the present invention is to provide a two-way messaging system permanently installed in a vehicle and interfaced with the vehicle power supply, and preferably the vehicle system bus to allow for remote control and programming of vehicular components and accessories.

Yet another aspect of the present invention is to provide a system for providing quick access and communication with an emergency service center, such as 911, either by simply pressing a 911 button, or automatically upon deployment of an air bag. Such an emergency service system would also preferably provide information to the emergency service center indicating the vehicle's current location. Another aspect of the present invention is to provide a two-way communication system that will allow an occupant to request roadside assistance and to receive a confirmation that an assisting vehicle has been dispatched, and to provide an occupant with an estimation of when the assistance vehicle will arrive at the vehicle's current location.

An additional aspect of the present invention is to provide a system that will identify the location of the vehicle to the police, in the event that the vehicle is stolen. In this regard, the present invention preferably is passively activated when the vehicle's alarm is tripped. Further, the present invention may be used to immobilize and disable the vehicle in response to an appropriate command delivered in a radio frequency (RF) paging signal.

Yet another aspect of the present invention is to provide a vehicle locating system that allows the vehicle owner to determine the location of the vehicle when the vehicle has been loaned to a friend or family member. In this regard, the present invention may also be used by the manager of a fleet of commercial vehicles, such as taxis, police cars, trucks, or other delivery vehicles, to track the location of each vehicle in the fleet.

An additional aspect of the present invention is to provide a system capable of informing the vehicle occupants of the location of the nearest automatic teller machine (ATM), hospital, freeway on-ramp, etc., based upon the current location of the vehicle and to provide step-by-step audio or textual instructions on how to find such a location. In this respect, the present invention may also be used to provide a warning to the driver when the last exit is approaching from which the driver may obtain fuel before the fuel tank is empty. Further, the present invention may provide traffic reports, road conditions, and weather reports to the vehicle's occupants that are particularly relevant to the vehicle's current location.

It is an additional aspect of the present invention to provide a system allowing for remote control of vehicle functions and accessories using an RF signal. Thus, vehicle owners may lock their vehicle doors, roll up their windows, or activate an alarm system from any location in response to an RF signal. Further, the vehicle owner may use the system of the present invention to immobilize a vehicle to insure safe storage of the vehicle.

Still yet another aspect of the present invention is to provide vehicle personalization to be remotely affected by a service provider using an RF signal transmission system. In this regard, a vehicle owner wishing to reprogram a vehicle, calls the service provider who effects reprogramming of the control of an accessory by transmitting RF signals to the vehicle. Further, the present invention allows for vehicle personalization for each person who may operate the vehicle.

Additionally, it is an aspect of the present invention to provide a system that receives and displays text or audio messages providing step-by-step directions to reach a desired location based upon the current location of the vehicle whereby each step may be separately read from memory in response to each subsequent command, which may be generated by activation of a switch or by a global positioning system (GPS). Further, the present invention allows a user to inform the system that they are lost and to subsequently receive and display revised directions based upon the vehicle's current location. Additionally, the present invention may be used to suggest alternate routes based upon traffic delays between the current location of the vehicle and the desired destination. Further, the present invention may display or play back specific navigation steps corresponding to the current location of the vehicle.

Still another aspect of the present invention is to provide a system allowing for remote diagnostic evaluation of the vehicle by a service technician. Additional features and advantages of the present invention will be set forth in part in the description which follows and in part will be apparent from the description, or may be learned by practice of the invention.

To achieve these and other advantages, and in accordance with the purpose of the invention, the vehicle communication and remote control system preferably comprises various

combinations of the following: a two-way communication module for transmitting and receiving RF messages to/from a land-based transmitter/receiver station; a microprocessor coupled to the communication module for performing functions and generating messages in response to a received RF signal; a GPS module coupled to the microprocessor for receiving GPS signals and sending the location information signals to the microprocessor; a display interface and display coupled to the microprocessor for displaying messages and other information generated by the microprocessor to the system user; the compass module coupled to the microprocessor for providing and displaying vehicle heading information; a vehicle bus interface coupled between the vehicle's bus and the microprocessor for receiving information from and transmitting control signals to various accessories in the vehicle; a database stored in a memory coupled to the microprocessor for maintaining information pertaining to the vehicle and its occupants for manipulation by the microprocessor; and a driver interface coupled to the microprocessor for receiving input signals generated from various user interface buttons.

These and other features, advantages, and objects of the present invention will be further understood and appreciated by those skilled in the art by reference to the following specification, claims, and appended drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the drawings:

FIG. **1A** is a schematic diagram depicting a system including a land-based transmitting station in communication with a vehicle having a communication and control system according to the invention;

FIG. **1B** is a schematic diagram depicting a paging system including a land-based transmitting station in communication with a vehicle having a communication and control system according to the invention;

FIG. **2** is an electrical circuit diagram in block form of the land-based facility illustrated in FIGS. **1A** and **1B**;

FIG. **3** is an electrical circuit diagram in block form of a vehicle communication and control system constructed in accordance with a first embodiment of the present invention;

FIG. **4** is a pictorial representation of a rearview mirror constructed in accordance with one embodiment of the present invention;

FIG. **5** is an electrical circuit diagram in block form of a vehicle communication and control system according to a second embodiment of the present invention;

FIG. **6** is a pictorial representation of an overhead console constructed in accordance with one embodiment of the present invention;

FIG. **7** is a fragmentary perspective view of an armrest console embodying the data entry system of the present invention;

FIG. **8** is an enlarged front elevational view of the data entry switches shown in FIG. **7**;

FIG. **9** is a fragmentary perspective view of an overhead display incorporated in the system of the present invention;

FIG. **10** is a schematic circuit diagram of the data entry switches shown in FIGS. **7** and **8** and in block form;

FIG. **11** is a diagram showing the various displays of an embodiment of the invention;

FIG. **12** is a diagram showing the selectable displays for one of the subroutines shown in FIG. **11**;

FIG. **13** is a diagram of a display for the stereo features subroutine;

FIG. **14** is a flow diagram of the program subroutine for controlling the data entry circuit using the display method shown in FIGS. **13** and **14**;

FIG. **15** is a diagram of another display for the stereo features subroutine;

FIG. **16** is a diagram of a display for the phone subroutine shown in FIG. **11**;

FIG. **17** is a diagram of the display for the phone list of the phone subroutine;

FIG. **18** is a diagram of the display of information for the entry of data using another data entry technique according to the present invention;

FIG. **19** is a flow diagram for the program subroutine for data entry using the display format seen in FIG. **18**;

FIG. **20** is a diagram of another display used for the entry of data in the phone dial number subroutine;

FIG. **21** is a diagram of the displays for the messaging subroutine;

FIG. **22** is a fragmentary perspective view of the overhead console showing an example of a message being displayed;

FIG. **23** is a diagram of the displays used for the compass subroutine;

FIG. **24** is a diagram of the displays used for the navigation subroutine;

FIG. **25** is a fragmentary perspective view of the windshield area of a vehicle including a message display system according to another embodiment of the invention;

FIG. **26** is a block electrical circuit diagram of a vehicle message display system according to an embodiment of the invention;

FIG. **27** is a perspective view of a vehicle interior including a message display system located in the A-pillar of the vehicle according to an alternate embodiment of the invention;

FIG. **28** is a perspective view of a vehicle interior including a message display system in an overhead console according to another alternate embodiment of the invention;

FIG. **29** is a fragmentary perspective view of a vehicle including a visor embodying the system of the present invention;

FIG. **30** is a perspective view of the visor shown in FIG. **29**, shown with a display housing in a lowered use position;

FIG. **30** is an enlarged fragmentary view of the display shown in FIG. **30**;

FIG. **31** is a fragmentary perspective view of the visor shown in FIG. **30** with the display housing in a stored position;

FIG. **32** is a rear perspective view of the visor shown in FIGS. **29–31** with the display housing pivoted to a lowered position showing the display window formed through the visor;

FIG. **33** is a front perspective view of the visor of FIGS. **29–32** shown in a lowered use position with the vanity mirror cover in an open position;

FIG. **34** is an enlarged fragmentary, front elevational view of the visor display shown in FIG. **33**, showing the display information thereon;

FIG. **35** is an enlarged fragmentary cross section view of the visor display taken along section line VII—VII of FIG. **34**;

FIG. **36** is a front elevational view of the visor shown in a lowered use position with the mirror cover in a closed position;

FIG. **37** is an electrical circuit diagram in block form of the display system;

FIG. **38** is a fragmentary perspective view of a vehicle interior showing an alternative visor display with the visor in a lowered use position;

FIG. **39** is a fragmentary perspective view of the visor display shown in FIG. **38**, shown with the visor in a raised stored position against the vehicle headliner;

FIG. **40** is a enlarged fragmentary, cross-sectional view taken along section XII—XII of FIG. **39**;

FIG. **41** is a diagrammatic view of a vehicle and a highway map showing exits and service locations to be employed;

FIG. **42** is a fragmentary perspective view of the interior of the vehicle showing a rearview mirror including the system of the present invention;

FIG. **43** is a flow diagram of the software programming for the microprocessor employed in an embodiment of the system of the present invention;

FIG. **44** is an electrical circuit diagram in block form of the vehicle electrical circuit embodying the present invention which may be used in association with the system shown in FIGS. **2** and **3**;

FIG. **45** is an electrical circuit diagram in block form of an optional interface circuit associated with the electrical circuit shown in FIG. **44**;

FIGS. **46**A–**46**K are flow diagrams of the program employed with the microprocessor shown in FIG. **44**;

FIG. **47** is an electrical circuit diagram in block form of an optional interface circuit associated with the electrical circuit shown in FIG. **44**;

FIGS. **48**A–**48**K are flow diagrams of the main control program employed with the microprocessor shown in FIG. **44**;

FIGS. **49**A and **49**B are flow diagrams of a first subroutine that may be called by the main control program;

FIG. **50** is a flow diagram of a second subroutine that may be called by the main control program;

FIG. **51** is a flow diagram of a fourth subroutine that may be called by the main control program;

FIG. **52** is a flow diagram of a fifth subroutine that may be called by the main control program;

FIG. **53** is a flow diagram of a sixth subroutine that may be called by the main control program;

FIG. **54** is a flow diagram of a seventh subroutine that may be called by the main control program;

FIG. **55** is a flow diagram of an eighth subroutine that may be called by the main control program;

FIG. **56** is a flow diagram of a ninth subroutine that may be called by the main control program;

FIG. **57** is an electrical schematic diagram of an integrated vehicle systems controller constructed in accordance with another embodiment of the present invention; and

FIGS. **58**A and **58**B are flow diagrams illustrating the flow of operations utilizing the integrated vehicle systems controller shown in FIG. **57**.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

1. Preferred Configurations

Referring initially to FIG. **1**, there is shown a land-based system for communicating with the vehicle communication and remote control system of the present invention as implemented in a vehicle **20**. The system shown in FIG. **1** also allows remote control signals and other commands to be issued to and from a system of the present invention within vehicle **20** via its antenna **22**. In a preferred construction, the infrastructure that enables communications to be sent to and received from the vehicle communication system, utilizes a cellular/paging network **2** which includes a plurality of base stations **19** that transmit and receive RF signals to/from vehicle **20**. Further, in a conventional manner, communications may be initiated or received through a public-switched telephone network (PSTN) **1** for transmission to or from a vehicle through cellular/paging network **2**. Further, such communications may be routed through a computer network such as the Internet **3** which is typically accessed through PSTN **1**. Because infrastructure including PSTN **1** and cellular/paging network **2** are in existence and well-known in the art, the structure and function thereof are not discussed further.

Depending upon the form and nature of communication and any command signal sent to or received from the vehicle communication and control system of the present invention, different techniques for enabling transmission of such communications and control signals, may be employed. For example, if an individual wished to place a telephone call to the vehicle communication system in vehicle **20**, the individual could place the telephone call on any conventional telephone **15** such that the call is routed to the vehicle in the conventional manner used to route a telephone call to a cellular telephone. Similarly, a call originating from the communication system in vehicle **20** may be routed to telephone **15** in any conventional manner. If, on the other hand, a 911 emergency call is originated using the vehicle communication system in vehicle **20**, the call would preferably be initially routed to a network service center **11** where a service operator could utilize a computer **13** to identify the vehicle's location based upon a vehicle location signal generated by the vehicle communication system and transmitted with the 911 distress call. The service operator could then establish a two-way communication link with the vehicle occupants using a conventional telephone **12**, while at the same time placing a call through PSTN **1** to establish a conference call with an operator using a telephone **6** or computer **7** at a 911 dispatch center. Similarly, if the vehicle occupant requests roadside assistance, the initial call and vehicle location signal would be transmitted to network service center **11** where an operator would subsequently contact a dispatch center **8** to have the appropriate form of assistance dispatched to the vehicle at the location identified in the location signal.

If an individual wished to transmit a text message to the vehicle communication system in vehicle **20**, the individual could do so in a number of different ways. For example, the user could type in the message on a personal computer **5** and transmit it using the computer's modem through PSTN **1** and cellular network **2** to vehicle **20** for display via a cellular communication link. Such a message originated through computer **5** could also be sent to vehicle **20** via a server on the Internet **3** operated by a network service center **11** or the like. Yet another method would be to send the text message originating from computer **5** either directly through PSTN **1** to a computer **13** at the network service center **11** or through Internet **3**. Network service center **11** would then put together an appropriately-formatted text message for transmission through PSTN **1** and cellular/paging network **2** to the vehicle. This message could also be formatted as a paging signal that may be received and displayed on a display device of the vehicle communication system. Fur-

ther still, an individual could place a call on a conventional telephone **15** and reach a network service center operator on telephone **12** to request that a specific text message be transmitted to vehicle **20**.

By utilizing PSTN **1** and Internet **3**, various features of the Internet may be accessed in the vehicle. For example, a driver may access e-mail or may receive periodic stock prices or news items through the use of the present invention.

As will be apparent from the description of the various functionalities that may be performed using the vehicle communication and control system of the present invention in connection with the infrastructure disclosed in FIG. **1A**, various techniques may be used to establish the appropriate form of communication or signaling such that the desired function is ultimately performed.

As shown in FIG. **1B**, the land-based facility that sends and receives messages and commands to and from the vehicle may be directly connected to the cellular/paging network. The land-based facility can be a car dealership, for example, or an independent facility which includes a service department **11** for providing the transmission and reception of control and communication signals to and from vehicles subscribed to the system. The service department includes an operator **12** with access to a computer terminal **13** with a keyboard **14** (FIG. **2**). The terminal can be a typical PC with an RS-232 data output port coupled to a modulator **16***a*, which, in turn, is coupled to a transmitter **18***a* for transmitting address and control or message signals A by an antenna **19** (FIGS. **2** and **3**) to the receiving antenna **22** of a vehicle **20**. The terminal is also coupled to a demodulator **16***b* that demodulates signals received from receiver **18***b* via antenna **19**. It is understood that nationwide, there will be a sufficient number of land-based facilities to service vehicles in the system. As satellite communications improve, it will be possible for a single facility to send such information using DBS (Direct Broadcast Satellite) in which the vehicle antenna is a satellite receiving antenna. Alternatively, satellite communications can be used as one link through several land-based relay stations.

As but one example, in the system shown in FIG. **1B**, the service operator will receive a request from a vehicle owner, typically by a normal telephone request, that a certain vehicle option is either to be enabled or disabled. Such an operation may, for example, be the activation or deactivation of a "LAST DOOR LOCKS ALL DOORS" feature. The service operator responds to the request which identifies the vehicle either by owner or vehicle identification number (VIN) (or both) by entering in keyboard **14**, the vehicle code which is typically an address associated with the particular vehicle and a reprogramming command associated with the requested personalization of the vehicle option change for such vehicle. This information may be modulated onto an RF signal. This RF signal is transmitted by the service department **11** using the equipment shown in FIG. **2** and received and demodulated by the vehicle system as described in greater detail below in connection with FIGS. **44**, **45**, and **47**, which respond to the reprogramming command to carry out the reprogramming control function. Also, the land-based station may transmit messages including communications and other information to the vehicle. Further, signals may be received from the vehicle, in the form of requests for information, roadside assistance, emergency services, directions to a particular location, and for various other types of information or services.

A variety of modulation schemes can be used for the transmission of information between land-based facilities and vehicles, however, a cellular link is presently preferred. Also possible are standard commercially available GSC, POCSAG, or two-way paging systems. An example of a two-way paging system is described in U.S. Pat. No. 5,153,582, issued to Davis, the entire disclosure of which is incorporated herein by reference. In the FIG. **2** schematic diagram shown, a reprogramming command can be two 23-bit words in the standard GSC paging format which uniquely identifies each vehicle in the system. Following the address for the vehicle, the actual reprogramming command data is sent, which in this paging format can be up to eight words or fifteen bits each. Other paging formats such as the POCSAG format can also be employed which also provides address code words and message code words. A description of these two formats is set forth in detail in Appendix A to this Specification.

Because many of the features of the present invention described below require the ability to transmit information and requests for information or services from the vehicle using RF signals, two-way communication is preferred. However, depending upon the specific features and services that are selected, the present invention may be implemented using conventional one-way communication formats.

In the example shown in FIG. **1B**, the vehicle operator has requested that the memory seat be disabled and the necessary RF signal including the reprogramming command is transmitted to the vehicle electrical control system **730** as shown in FIG. **44**, which includes the vehicle antenna **22** and a receiver and demodulator shown by block **724** for receiving the vehicle address and reprogramming command and applying it to a microcontroller **735**. Once received and decoded, the reprogramming command is executed as described below, and an indication that the command has been received and executed is provided on an alpha-numeric display in the vehicle.

In the installation shown in FIGS. **1B** and **2**, the modulator **16***a* responds to the vehicle identification code and the reprogramming command signal or message entered on keyboard **14** and transmitted by conventional commercially-available modulator **16***a* and transmitter **18***a* to provide the desired address and reprogramming in the GSC or POCSAG paging formats or in a format that may be otherwise recognized by the vehicle-installed system. Transmitter **18***a* typically operates on a frequency within the 137–175 MHz (VHF band) or within the 405–513 MHz (UHF band), while the modulator provides FM FSK tone modulation for the RF carrier signal to provide a composite output signal at transmitting antenna **19** which provides the address and reprogramming information to vehicles which are part of the system. Typically, the vehicle receiver and transmitter will be integral parts of the vehicle when purchased, and the dealer can either include the options select control system as part of the vehicle cost or can provide it as a monthly subscription service to the vehicle owner. Access to the unique vehicle identification code address for controlling options, however, will typically only be available to the vehicle dealer or associated service centers.

Turning now to FIG. **3**, there is shown the electrical circuit of a first embodiment of the present invention which is mounted in vehicle **20**. The vehicle **20** includes a data bus line **42** which is coupled to a vehicle bus interface circuit **36**, which is a multiplex circuit coupled to a variety of system sensors and provides signals to a bus **24** coupling the circuits of the present invention. The bus interface circuit **36**, therefore, receives signals from, for example, the vehicle's fuel gauge, the speedometer input, the air bags, and other vehicle operating parameters. The vehicle itself may con-

ventionally include a computer for providing signals such as distance-to-empty signals on bus **42**, or such information can be easily calculated based upon the sensor inputs. The interface circuit **36** provides information in the form of serial data to a microprocessor **26** through a serial data line included on bus **24**. Bus **24** also includes a clock line, an enable signal line and power supply conductors for coupling power from supply **32** coupled to the vehicle's battery via conductors to the remaining circuit elements. The information on vehicle bus **42** may also be selectively displayed to the vehicle operator by a display **28**. As will be described in further detail below, display **28** may be a conventional alpha-numeric digital display mounted in either a vehicle overhead console, an A-pillar, a sun visor, a rearview mirror, or on the instrument panel. The display circuitry **28** may also include a suitable audible alarm for alerting the driver.

The vehicle control circuit also includes driver command control switches, such as a keyboard or push-button switches **46**, **48**, **50**, **52**, **54**, **56**, and **58** coupled to microprocessor **26** via a driver interface **44** and bus **24**. As shown in FIG. **4**, these switches may be employed on a rearview mirror **45** near a display **62** formed adjacent the mirror surface **64**. Such switches are commonly employed in vehicles for selecting and controlling the display and entry of data in a vehicle. The driver may thus select information to be displayed directly or enter a command to microprocessor **26** which responds to calculate and subsequently display the desired information. As will be described in greater detail below under the heading "Alternate Vehicle User Interface System," the switches may be located remotely from the vehicle accessory in which the display **28**, **62** is located.

In addition, the vehicle includes a compass module **30** such as the type disclosed in U.S. Pat. No. 4,953,305, which may include its own display or may be coupled by bus **24** as shown to provide a display through the vehicle display circuit **28**. The power supply **32** provides suitable operating power for the components, which may include plus and minus Vcc supplies for the electronic circuits employed. The microprocessor **26** can be any number of commercially-available microprocessors such as a Motorola 68HC11, which includes internal RAM and ROM memories for providing the program control functions including that of the present invention which is described below.

The vehicle communication and control system according to the first embodiment of the invention includes a pager module **34**, which is coupled to a two-way antenna **36** for receiving and transmitting digital paging messages and coupled to bus **24**. Such a paging module can be of the type disclosed in U.S. Pat. No. 5,153,582, the disclosure of which is incorporated herein by reference. As shown in FIG. **4**, it may be uniquely mounted in the vehicle rearview mirror housing **45** and utilizes display **62** for displaying incoming paging messages. Transmitted responses to incoming information requests can be sent automatically under the control of microprocessor **26** or by the operator actuation of one or a predetermined sequence of switches **46**, **48**, **50**, **52**, **54**, **56**, and **58**. The vehicle-installed pager **34** receives power from the vehicle's power source through supply **32**. The pager module **34** allows automatic or vehicle operator requested communication of various information including the locations of available service areas from a database at a central station to which the vehicle operator subscribes and which makes such information available to the vehicle operator and vehicle electronic system through the pager module **34**. In addition, the vehicle communication and control system includes a navigation module **38** coupled to a suitable receiving antenna **40**. In the preferred embodiment, module **38** is a commercially-available GPS module of the type manufactured by a number of suppliers including Motorola, Inc., Trimble Navigation, Ltd., or the like.

The serial data line of bus **24** is coupled to an SPI port for each of the circuit modules of FIG. **3**. Also, the clock line is coupled to each of the circuits of FIG. **3** for receiving clock pulses from microprocessor **26** to synchronize the transfer of data between the modules. Finally, an enable line is coupled to each of the circuits for receiving enabling signals from the microprocessor to initiate the synchronized transfer of serial data between the microprocessor and each of the modules. The connection and data flow scheme for such interconnection is conventional, as is the coupling of the microprocessor **26** to the vehicle bus line **42** through the interface **36**. The specifics of the coupling to the vehicle bus line **42** and the various vehicle accessories and input lines are described in more detail below.

FIG. **4** shows a construction of a rearview mirror **45** in which the present invention may be installed. Rearview mirror **45** is preferably a mirror having adjustable reflectivity levels, such as an electrochromic mirror, and has a control circuit for automatically varying the reflectivity of the mirror in response to an ambient light level detected by a sensor **60**. As shown, rearview mirror **45** includes a display surface **62** for displaying various information to the user. With reference to FIG. **3**, it can be seen that display **62** corresponds to display **28**. Rearview mirror **45** also includes various push-buttons to allow a user to enter information into the system and to otherwise interface with microprocessor **26**.

Some of the push-buttons that may be provided are a back arrow **48** and a forward arrow **50** used to move a cursor or selections in a display window back and forth. An "option" button **52** may be provided to cause various selectable options to be displayed. Also, a "yes" button **54** and a "no" button **56** may be provided to answer a yes or no inquiry displayed on display **62**. A "back" button **58** may also be provided to allow the user to back up to a previously-displayed message.

A second embodiment of the vehicle communication and control system of the present invention is shown in FIG. **5**. As shown in FIG. **5**, the second embodiment differs from the first embodiment in that it utilizes a two-way cellular telephone RF link rather than a paging link. More specifically, the communication and control system according to the second embodiment includes a first microprocessor **66** that works in communication and cooperation with a second microprocessor **67**, which monitors inputs and provides outputs in a user interface portion **69** of the system of the present invention. First microprocessor **66** and second microprocessor **67** may be connected by bus **68** that may be a serial or parallel common interface. Together, first and second microprocessors **66** and **67** monitor incoming messages and communications from a cellular telephone transceiver **70** and from various vehicle accessories and components coupled to microprocessor **67** via a vehicle bus interface **85** that is coupled to a vehicle bus **86**.

Cellular telephone transceiver **70** may be a standard cellular transceiver that receives and transmits RF signals to and from a conventional cellular telephone antenna **71**. Cellular telephone transceiver **70** is coupled to first microprocessor **66** for receiving control data and other data to be transmitted thereby.

Transceiver **70** is also preferably coupled to a handset connection port **72** to which a telephone handset **73** may optionally be connected. With the handset connected to port

72, a user may place and receive calls using handset 73 in a conventional manner. Handset connection port 72 is also preferably coupled to an audio multiplexer 74 which, in turn, is coupled to a DTMF decoder 75 and a cellular modem 76. Cellular modem 76 is provided for transmitting and receiving data and text messages through cellular telephone receiver 70. DTMF decoder 75 and cellular modem 76 are preferably coupled to first microprocessor 66.

Similar to the first embodiment, the second embodiment also includes a location identifying sensor, such as a GPS or differential GPS module 77 having a GPS antenna 78. The GPS/DGPS module 77 is coupled to first microprocessor 66 to provide an indication of the vehicle's location, which may be used for a variety of purposes as discussed below.

The system may further include a voice recognition unit (VRU) 79 which is coupled to audio multiplexer 74 for recognition of voice commands that may be delivered from handset 73, cellular telephone transceiver 70, or from a microphone 82 provided in user interface 69. By providing VRU 79, the system may be controlled by hands-free voice commands to perform its many and various functions.

By providing a speaker 81 along with microphone 82 in user interface 69, and by coupling microphone 82 to audio multiplexer 74 and coupling speaker 81 to audio multiplexer 74 through an amplifier 80, two-way voice communication may be provided without requiring handset 73.

User interface 69 may further include one or more switches that may perform various functions in different modes of operation or may perform discrete functions regardless of the mode of operation. For example, as shown in FIG. 6, the invention may be implemented with the user interface 69 provided in an overhead console 100 that includes a dedicated switch 104 for requesting emergency assistance, a dedicated switch 105 for requesting roadside assistance, and an information request switch 107 which is a dedicated switch for requesting information from an operator at a network service center. Also included in the exemplary interface shown in FIG. 6, a two-way toggle switch 94 that is provided for adjusting the volume of the audio output produced by a speaker 81 provided behind a grid 103 forming part of the exterior surface of console 100. Also provided is a two-way toggle switch 108 provided for playing either the previous or the next navigational step required to reach a selected destination. A record switch 96 and a play back switch 97 are also provided which are used to record and play back dictated memos. The manner by which this operation is performed is described below. Also provided is a switch 93 for deleting recorded messages. As shown in FIG. 6, overhead console 100 may further provide a pivotable cover 106, which may be transparent, translucent, or opaque, for covering up switches 104 and 105, which are used to request emergency or roadside assistance, so as to prevent inadvertent activation of one of these switches. Console 100 may also include map lamps 101*a* and 101*b* which are selectively illuminated using switches 102*a* and 102*b*, respectively. Additionally, other switches may be provided on overhead console 100, such as a sunroof open and close switch 95.

Referring back to FIG. 5, the system according to the second embodiment further includes a voice digitizing circuit 91 coupled to audio multiplexer 74 and also coupled to a memory 92 for receiving voice messages, digitizing them, and storing them in memory 92. Voice digitizer 91 and memory 92 are also preferably coupled to second microprocessor 67 which controls the recording and play back of voice messages.

User interface 69 may further include a display 84 which is coupled to second microprocessor 67 for the display of various control menus and received text messages. As stated above, a vehicle bus interface circuit 85 may be coupled to second microprocessor 67 to send control signals to various vehicle accessories and components coupled to vehicle bus 86 and for receiving signals from various components coupled to vehicle bus 86, to which microprocessor 67 is to respond. For example, second microprocessor 67 may receive a signal through bus 86 and vehicle bus interface 85 indicating that the vehicle's air bags have been deployed. Microprocessor 67 would then respond to this indication by instructing microprocessor 66 to transmit a distress signal through transceiver 70 that would include the vehicle's last known location as determined by GPS/DGPS module 77.

On the other hand, if a command message received through transceiver 70 and demodulated using cellular modem 76 instructs the system to lock the vehicle doors, first microprocessor 66 would recognize the command and instruct second microprocessor 67 to send the appropriate control signal through vehicle bus 86 to the door lock actuators to lock the doors. Given that a modem is provided within this system, it will be readily apparent to those skilled in the art that various control and communication functionalities may be implemented in a manner that would be similar to having two computers communicating via their modems.

The system may further include an electronic compass 87 coupled to second microprocessor 67 for providing the vehicle's heading that may in turn be displayed on display 84 or may be transmitted in a communication signal through transceiver 70.

Instead of connecting VRU 79 to audio multiplexer 74, a VRU 88 may optionally be coupled directly to microphone 82 and to second microprocessor 67 for again serving as a hands-free interface to initiate various control functions which the system is capable of performing.

The system is preferably powered by a power supply module 89 that receives its power from the vehicle's battery or alternator. Power supply circuit 89 may also be powered by an auxiliary battery 90 that is provided to power the system in the event that power is interrupted from the vehicle battery. This would allow the system to transmit a distress signal even when an accident has occurred that is so severe that it has interrupted the supply of power from the vehicle's battery.

It will be apparent to those skilled in the art that various other buttons or combinations thereof may be provided to enable a user to readily manipulate the information displayed and to enter data using these buttons. Some alternative approaches and graphic user interfaces are described in detail below.

2. Preferred System Functions

Preferably, one of the push-buttons described above includes a "911" button 46 or 104 that a user may push in the event of an emergency. Because many drivers have difficulty determining their precise location when calling 911 from a vehicle using a cellular telephone, and because most cellular telephones do not transmit any information pertaining to current location, emergency service vehicles may have great difficulty locating the vehicle from which a 911 call was made. By providing a GPS module 38 in the system of the present invention, microprocessor 26 or 66 may ascertain the precise location of the vehicle and transmit the location in a distress paging message from paging module 34 or transceiver 70. In this manner, emergency service personnel may use the received location information to generate a map having the location highlighted thereon and immediately dispatch an emergency vehicle to the

location. If the emergency vehicles also have the system of the present invention installed therein, the emergency service personnel receiving the distress message and dispatching the emergency vehicles may track the location of the available vehicles and dispatch that vehicle that is closest to the vehicle sending the distress signal. Further, the emergency service personnel may transmit a message back to the vehicle confirming that the distress signal was received and provide an estimate as to when the dispatched emergency vehicle will arrive.

With the second embodiment, two-way voice communication may be established using microphone **82** and speaker **81** so that the emergency dispatcher may speak with the vehicle occupants if they are conscious.

Because most cellular telephones are not interfaced with the vehicle's electronic control system, one of the vehicle occupants must be able to dial 911 on the cellular telephone to obtain emergency assistance. This may or may not be possible if they are rendered unconscious in an accident. To solve this problem, the present invention is connected to the vehicle bus **42** or **86** to receive a signal indicative of whether any of the vehicle's air bags have been deployed. If any of the air bags are deployed, microprocessor **26** or **66** will respond by generating and transmitting a distress paging message including the vehicle's current location in the same manner in which the system would operate when the 911 button **46** or **104** is actuated. Thus, the present invention can automatically summon an ambulance even when the vehicle occupants are unconscious, therefore increasing emergency service response time and increasing the likelihood that the occupants will survive an accident.

By proper manipulation of the provided buttons and any information displayed on display **28** or **84**, a vehicle occupant may also summon a tow truck or other roadside assistance vehicles by transmitting an appropriate signal to a nearby central service center. The request for roadside assistance is handled in a similar manner that a 911 request is handled, such that GPS module **38** may provide the vehicle's current location. Additionally, a service technician may access the vehicle's diagnostic database through the system's vehicle bus interface to ascertain what may be wrong with the vehicle, and thus, what parts and tools may be required. The system may also transmit the make, model, and model year of the vehicle to the technician.

The system of the present invention may further include a database **27** stored in the RAM of microprocessor **26** or **66** or in a separate memory module. This database may include information pertaining to the driver of the vehicle, such as medical information, and information identifying the vehicle, such as the vehicle's color, make, model, and license number. Thus, the present invention may transmit the medical information stored in database **27** to a responding ambulance or it may transmit the information identifying the vehicle to the police if the vehicle is stolen.

In the event a vehicle is stolen that incorporates the present invention, the police may transmit a signal to the vehicle, causing the vehicle to transmit a signal back to the police identifying its current location and heading. The current location may be provided by GPS module **38** or **77** and the heading may be provided from compass module **30** or **87** or from information obtained from GPS module **38** or **77** over a course of time utilizing a triangulation method. Thus, the police may pinpoint and track the location of a stolen vehicle and determine its speed using the system of the present invention. The police may also transmit information identifying the location of the stolen vehicle to their police cars in the area if they are equipped with the system of the present invention. Further, utilizing the interface to vehicle bus **42** or **86**, the present invention may immobilize the stolen vehicle upon receipt of a proper control signal sent from the police. Thus, the present invention provides significant improvements in vehicle security and retrieval of stolen vehicles. Preferably, microprocessors **26** and **66** are appropriately programmed to respond to an activation of the vehicle's alarm system via vehicle bus **42** and **86** so as to immobilize the vehicle or otherwise alert the police and/or owner if the vehicle alarm has been tripped.

For vehicle owners that loan their vehicle to friends and family members, the present invention offers the advantage of allowing the vehicle owner to track the location of their vehicle. Thus, a parent loaning their vehicle to a child may track the location of the vehicle and hence the location of the child using the vehicle location tracking features of the present invention. For example, an owner may send a signal to the vehicle's communication and control system via the owner's home or office PC **5** (FIG. 1A) and subsequently receive a signal back from the vehicle identifying its location. The location may then be displayed on a map on PC **5**.

The present invention further allows for the receipt and display of text messages on displays **28** and **84** and allows for responses to be transmitted back to the source from which they are generated. Predetermined responses such as "I am running late," "I am stuck in traffic," or "I will call you later," etc. may be stored in memory for ease of selection in responding to a text message. Further, voice messages recorded using the second embodiment may be played back in response to incoming text messages or telephone calls. Thus, in addition to the above features, the present invention provides a means of two-way communication at a lower cost than could be obtained with a cellular telephone. Further, one does not need to answer a telephone to receive a text message, and therefore, the present invention provides advantages over the use of a system that solely relies upon a cellular telephone for two-way communication. As will be described below, a paging system and a cellular telephone may be used in combination to obtain all the benefits of using each form of communication in a single system. For example, a paging or text message having a telephone number may be received at any time whereby the driver may subsequently press a single button causing the paging module to download the number to the cellular telephone over the vehicle bus **42** or **86** and cause the cellular telephone to automatically dial the number contained in the received paging message.

The present invention additionally allows for the receipt and transmittal of location-specific information services. For example, the driver may cause the system to transmit a message to a central service center requesting the location of the nearest ATM, hospital, or freeway on-ramp or exit, whereby the central service center determines the location of the nearest ATM, hospital, or freeway on- or off-ramp to the vehicle based upon the received vehicle location information provided through the use of GPS module **38** or **77** and pager module **34** or transceiver **70**. Further, the central service center may transmit step-by-step instructions on how to get to the nearest ATM or hospital based upon the vehicle's current location. Other location-specific information that could be relayed to the vehicle occupants includes traffic reports and weather and road conditions relevant to the vehicle's current location. Additionally, in the manner described in more detail below under the heading "Detailed Description of the Last Exit Warning Function," the vehicle's fuel level may be determined and the distance-to-empty mileage computed such that the system then transmits

the signal to a central service center identifying the vehicle's location and distance-to-empty and receives information back identifying the last exit on a highway at which fuel may be found before the vehicle's fuel tank is empty. Thus, the vehicle driver may be warned when he or she is approaching the last exit to obtain fuel.

The present invention may also be used for providing navigational information to the driver based upon the vehicle's current location and upon a desired destination. In this manner, the driver may identify the desired destination and transmit this destination in an RF signal that also includes the vehicle's current location derived from the GPS module **38** or **77**. A central service center receiving this message may then generate a step-by-step set of directions for reaching the desired destination and transmit this information to the vehicle in a return RF signal. The information may then be displayed one step at a time on display **28** or **84** in the view of the driver or if not in text form, may be played back over speaker **81**. This information may be continually updated by transmitting additional location identifying signals to the central service center so that the driver may be warned if he or she is about to miss a turn or exit. Alternatively, location codes may be transmitted with each step of the step-by-step instructions such that the steps may be displayed or played back when the vehicle has reached a location requiring a new instruction, such as "turn left here," as determined by GPS **38** or **77**. Further, in the event the driver is lost, the driver may inform the vehicle's system of this fact such that the system transmits an RF signal to a central service center which identifies the location of the vehicle and provides step-by-step instructions to the desired destination from the vehicle's current location. Additionally, the system may store the directions in memory such that upon selection by the user, the directions back from the vehicle's location to its original location will be displayed on display **28** or **84** or played back over speaker **81**. The system may further store directions for frequently traveled routes such that the driver may simply recall them from memory and have them displayed on display **28** or **84**. By obtaining traffic reports, the present invention may be used to warn the vehicle driver of traffic delays and to provide step-by-step alternate routes to any desired location.

As can be seen from the foregoing, the present invention provides many desirable features for businesses that have fleets of vehicles. Specifically, the ability to interactively receive traffic reports on demand and the ability to track the fleet's vehicles would provide a competitive advantage to businesses such as taxi cab companies. Further, by providing the vehicle systems with a remote assistance button that may be actuated in the event of an emergency, taxi cab drivers will feel more secure while driving in unsafe areas.

In the event the vehicle is provided with a self-diagnostic system that is connected to vehicle bus **42** or **86**, the present invention may be used to allow for remote diagnostics to be performed on the vehicle. Thus, for example, when a vehicle has broken down along side a remote highway, a service station may transmit an RF signal to the vehicle prompting the vehicle's system to transmit an RF signal back including any self-diagnostic information such that the tow truck responding to a request for roadside assistance may be properly equipped with the right tools to provide for the most-appropriate roadside assistance on the particular make and model vehicle requesting service.

The present invention may also provide for remote control of the vehicle's accessories in response to an appropriate RF signal. For example, in the event the driver has accidentally locked his or her keys in the vehicle, the driver may simply call the service center to have a control signal transmitted to their vehicle causing their doors to unlock. Further, if the vehicle owner has parked his or her vehicle in an airport parking lot and subsequently realized the doors were not locked, the owner may call the service center and have the center transmit an RF signal causing the doors to lock or possibly causing the windows to be rolled up in the event it begins to rain. Another remote control function that may be advantageous is to have a signal transmitted to the vehicle causing its horn to honk at periodic intervals to allow its owner to find it in a crowded parking lot. The detailed operation of the present invention for performing these functions is described below under the heading "Detailed Description of Vehicle Personalization and Remote Control Functions."

Yet another function performed by the present invention is to allow vehicle accessories to be reprogrammed in response to an RF signal such that the vehicle accessory operations may be personalized for each individual driver. For example, the vehicle may be programmed so as to recognize different drivers based upon a signal transmitted from a remote keyless entry (RKE) key fob and thereby move the seats and mirrors into a position last used for that particular driver. Due to the increasing number of available electronic options in vehicles, a large number of possibilities exist for controlling vehicle accessories and the need for personalizing the operation thereof dramatically increases. The manner by which the present invention reprograms the manner in which various vehicle accessories and functions are controlled is described below under the heading "Detailed Description of Vehicle Personalization and Remote Control Functions."

3. Alternative Display/User Interface Configuration

With the increasing use of microprocessors in vehicles for a variety of vehicle control functions, interaction between the vehicle operator and the microprocessor for programming options and the like is frequently necessary. Although a keyboard can be employed, it requires an excessive amount of space in a vehicle such as an automobile. If a numerical keypad is employed, such a data entry system requires the operator to understand for each command to be entered the corresponding numerical entry number or numbers to carry out the desired command. Further, the use of a keyboard or keypad, particularly if the vehicle in operation is very distracting, could result in inattentiveness to driving functions.

A voice-actuated control system has been proposed and is represented by U.S. Pat. No. 4,827,520 issued on May 20, 1989, and assigned to the present assignee. Although such a system provides hands-free control of a variety of vehicle options utilizing a microprocessor, it requires training to each one of the vehicle operator's voices and somewhat complicated and expensive electronics at current levels of technology.

The system of the present invention overcomes the difficulty of entering data or vehicle control commands for vehicle programming and operation by providing a visual display of either icons, alphabet letters, numerals or a combination of visual and alpha-numeric information and allows the user, by using a reversible control, to select an icon or other displayed control or data element and subsequently enter the element with a push-button switch. This information entry sequence thus provides a vehicle operator with a display of selectable information, allows the operator to easily select the desired information and subsequently enter such information for carrying out the associated function.

In an embodiment of the invention, the information displayed is provided in an overhead console and the operation information entry controls are located at the forward edge near the top of an armrest console where they are conveniently located and readily available to the operator. In one embodiment, a rotary left-right switch is provided to allow the operator to move a cursor or display information in a display window to select a desired command function before entering the command to be executed. In some embodiments of the invention, an array of icons or alpha-numeric displays are simultaneously displayed and the operator moves a cursor to the selected item after which an enter switch is actuated to carry out the command selected. In other embodiments, a window is provided in which different alpha-numeric characters are selectively displayed utilizing the rotary switch. When the desired window shows the command function to be carried out, the enter switch is actuated.

Central to each of the different types of data entry, however, is the utilization of a conveniently located control for selecting information which is displayed to the operator without the necessity of utilizing operator manuals or the like thereby providing a user-friendly data and command control entry system for vehicle programming such as personalization of accessories, telephone operation, reading of messages received from a paging system, the selection of compass and trip information or navigational instructions.

Referring to FIGS. **7** and **8**, there is shown the interior of a vehicle such as an automobile **110** including a centrally-located armrest console **112** having a switch assembly **120** which is conveniently located for use by the operator in selecting information to be displayed and entered in cooperation with the display **170** mounted in an overhead console **150** (FIG. **9**). The armrest console includes an upper arm supporting surface which may be in the form of a padded cover **114** pivotally mounted to the walls defining a storage compartment **115** located below cover **114**. The armrest console **112** is centrally located between the front seats of the vehicle. The armrest console may also include a collapsible cupholder assembly **116** shown in an extended use position and which slides into and out of the storage compartment **115** for use.

The armrest console integrally includes a forward housing **118** located at the front upper edge of the console **112** and which houses a switch assembly **120** comprising four switches **121**, **122**, **123**, and **124**. Housing **118** includes a forwardly and downwardly inclined wall **119** into which the switch assembly **120** is mounted. Each of the switches, which are shown in greater detail in FIG. **10**, include exposed switch control surfaces with switch **121** having a push-button **131** with the letters "ENT" for "enter" embossed thereon upside down so it can be read by the vehicle operator looking downwardly on the switch assembly **120** from above. The enter switch provides an enter command for currently displayed data or command information selected by the operator using switch **122**. Switch **122** is a rotary switch and includes a rotary knob **132** for controlling the motion of the switch to the left or right as viewed in FIG. **8** which in turn moves a cursor on the display **170** or otherwise changes displayed data or control information to be acted upon by the operator. Switch **123** includes a push-button surface **133** which is embossed by the letters "PREV" standing for "previous screen," the function of which is to control the display to display the previous screen as described in greater detail below. Finally, switch **124** includes a push-button surface **134** with "EXIT" embossed thereon for providing an exit command function for the system. The facing edges of switch contact surfaces **131** and **133** are concavely recessed at **135** as seen in FIG. **8** to provide greater accessibility to the disc-shaped control knob **132** for switch **122**.

As seen in FIG. **9**, the vehicle **110** also includes an overhead console **150** which is mounted to the roof **152** of the vehicle near the front windshield **113** and between the front window visors such as visor **111** which is the passenger side visor as seen in FIG. **9**. Console **150** includes a pair of covered storage compartments **154** and **156** with compartment **154** providing sunglass storage and compartment **156** housing, for example, a universal garage door opening transmitter. The console **150** may also include map reading lamps **153** and **155** and provides at its forward end a downwardly inclined bezel **160** housing a display **170** and a four push-button switch assembly **220** which parallels to some extent the switch assembly **120** on the armrest and can be used for the same or similar control functions interchangeably. Thus, a push-button select switch **222** is provided which moves a cursor of the display **170** only to the right as opposed to moving the display left or right as provided by the counter-part rotary switch **122**. An "enter" switch **221** corresponds to switch **121** for the entry of a selected command while to the right of the display **170** is a "previous" switch **233** and an "exit" switch **234**. The display is preferably a vacuum fluorescent or LCD display capable of providing alpha-numeric display information as well as providing graphic displays such as the icons shown in FIG. **9** or the text message shown in FIG. **22**.

In FIG. **9**, for example, there is displayed the "home" screen display which is five icons **161**–**165** with icon **161** corresponding to personalization, icon **162** corresponding to a telephone control subroutine, icon **163** corresponding to a page message reading subroutine, icon **164** corresponding to a compass and odometer display subroutine, and icon **165** corresponding to a navigation and route information subroutine. As can be seen in FIG. **9**, icon **165** which comprises a pictorial representation of the earth in a rectangular field has the background field illuminated indicating that this icon is currently being highlighted and therefore selected by the operator. Movement of switch **122** by the rotary knob **132** will cause the highlighted icon to change with movement of the switch **122** to the left or right scrolling around to the other end if passing the endmost icon. Switch **222**, if actuated, will continually move the icon highlighted to the right and which scrolls around to the left edge after icon **165**. Display **170** can provide the display not only of the icons programmed into memory to correspond to subroutines for computer operation but also alpha-numeric information describing the selected or highlighted icon as for example shown in FIG. **11**.

The electrical circuit for implementing this data entry system is disclosed in U.S. Pat. No. 5,555,172. Switch **122** is a rotary switch which provides sequential contact closure signals on conductor **125** (FIG. **10**) as the knob **132** is rotated to the left by the operator and sequential contact closure signals on conductor **127** as the knob **132** is rotated to the right. The knob can be continuously rotated to provide as many movement control signals for the cursor associated with display **170** as desired and as described below. Switch **122** can be a commercially-available Alps Model No. RK09710H. The display is a 32×128 pixel vacuum fluorescent display which has sufficient resolution to provide the display icons as shown in FIG. **9** as well as other data such as the text message shown in FIG. **22** and the other various screens as explained in greater detail below.

Turning now to FIG. **10** there is shown the switch assembly **120** which is mounted to the armrest **112** as seen

in FIGS. 7 and 8. The switch assembly includes momentary push-button switches 121, 123, and 124 corresponding to the "ENTER," "PREVIOUS," and "EXIT" commands and the rotary momentary make and break switch 122 which, depending on the direction of rotation, either provides a momentary left to ground circuit or right to ground circuit to the conditioning circuit and subsequently to a microprocessor. The microprocessor responds to command signals from switch assembly 120 to provide the desired information or control functions as now described in conjunction with the display screens and flow diagrams of FIGS. 11–24. The microprocessor provides stored display information written into a ROM memory when called upon. The program loops through the main program checking the closure status of each of the switches of switch assemblies 120 as well as checking for input data from either a compass circuit, text messages which may be received by the RF transceiver, or navigational data received through a navigation circuit module coupled to the microprocessor.

Upon receipt of operator inputted commands as described in connection with FIG. 16, the microprocessor outputs control signals for the operation of the cellular telephone. As one of these data interrupts occurs, the appropriate subroutine is called up for processing and storing the data. A compass circuit which can be employed with the microprocessor is disclosed in greater detail in U.S. Pat. No. 4,953,305 issued on Sep. 4, 1990, the disclosure of which is incorporated herein by reference. The personalization circuit and RF transceiver circuits and their programming are also disclosed in detail below.

Initially, the main program displays the home panel which is seen in FIG. 9 as the primary display with the five icons representing personalization, telephone, page, compass, and navigation. One of the icons will be backlighted or highlighted indicating that it is the selected icon which can be controlled by actuation of the "ENTER" switch 121. Rotation of the left/right switch 122 or alternatively depressing switch 222 causes the next adjacent icon on either side to be illuminated for selection upon actuation of the entry button.

Upon selecting one of the desired subroutines 300, 302, 304, 306, or 308 shown in FIG. 11, the program will move to the subroutine called for by actuation of the "ENTER" switch 121 or its corresponding switch 221 located in the overhead console 150. The subroutine performs the functions as controlled by the actuation of the switches in the switch assembly 120 with the display 170 providing prompting information to the operator with the use of icons or other alpha-numeric or symbolic displays. If, for example, the operator would like to select the personalization subroutine from the home panel display 290 (FIG. 11) which as seen in FIG. 9 is currently in the navigation selection position, rotary switch 122 can either be moved to the right to move the selected highlighted icon to the wrap-around position showing the personalization icon or moved to the left through the compass, pager, and telephone to the personalization icon. The "ENTER" switch 121 is then actuated to call up the personalization subroutine 300 (FIG. 11) shown in greater detail in FIG. 12.

Turning now to FIG. 12 which shows the display screen and an outline of the programming for the personalization subroutine 300, upon selection of the personalization icon from the home display 290, the program reads the stored information which is applied to display 190 to display the personalization selections indicated by block 310 in FIG. 12. This display information is stored in ROM memory and switch 122 is rotated to select either user 1, user 2, or the train fob icons which are displayed in display 190 as indicated by panel 310 of FIG. 12. Once the desired highlighted selection is made, the "ENTER" switch 121 is actuated to inform the computer which of the three subroutines to call up to train for personalization functions. These include in the embodiment shown, user 1 subroutine 312, user 2 subroutine 314, or training for use of the RF keyless entry fob 316. At this time, the display 190 will display the personalization icons identified in block 318 of FIG. 12 which may be, for example, graphic representations similar to that shown in FIG. 9 except displaying, for example for seat personalization, a pictorial representation of a seat, a lock for the door lock/unlock personalization function, a radio for the stereo select functions and a thermometer for the climate control functions.

Thus, actuation of the "ENTER" switch 121 when display 170 is displaying the selections shown in block 310 will advance the display to the next displayed screen 318 displaying to either user 1 or user 2, the selections available. The train fob subroutine 316 shown in FIG. 12 is selected if it is desired to train a keyless entry-type RF transmitting key fob such that various codes available by the actuation of switches on the key fob can be programmed to control various vehicle personalization functions. The programming for training the keyless entry fob and the various personalization functions can be done using a variety of conventional programming methods. One programming system for the personalization of the various vehicle options and training of a key fob is disclosed in U.S. Pat. No. 5,278,547 issued Jan. 11, 1994, the disclosure of which is incorporated herein by reference.

At any time during the programming of the vehicle personalization features, the programming can be terminated storing the selected features by pressing the "EXIT" switch 124 which returns the program to display the home panel 290 (FIG. 11). The data selections entered prior to such time by the actuation of "ENTER" switch 121 in response to displayed operational choices will have been stored in the computer RAM memory. Decisions which are made can be reversed by pressing the "PREV" switch 123 which allows the operator to return to a display prompted decision and enter the desired choice of data.

In response to the displayed icons at block 318, the operator, who may either be user 1 or user 2 in the embodiment disclosed, selects one of the four example categories by rotating select switch 122 or pressing its corresponding switch 222 on the overhead console to highlight the selected icon and then presses switch 121 for controlling the computer to move to the subroutine selected. The subroutines shown in the preferred embodiment include seat personalization 320, door lock and unlock 322, preset radio control functions (i.e. stereo features) 324, and climate control presets 326. Other personalization options such as rearview mirror, side view mirror controls and the like also can be incorporated in the system of the present invention utilizing conventional programming techniques. If the seat personalization subroutine 320 is called for, the computer will, upon receiving a command signal from the information corresponding to the highlighting of the seat personalization icon by movement of switch 122 and the entry command signal from the actuation of switch 121, display to the vehicle operator prompting information necessary to preset electrically operated and adjustable vehicle seats where desired.

Thus, display 170 may prompt the operator to manually adjust the seat by actuation of the normal electrical seat control switches to a desired position and once that has been accomplished actuate switch 121 to store the seat position information obtained from the movement of the seat to the

desired position in computer memory. When this is accomplished, the entry of the seat position information by the computer will allow the program to move back to the personalization loop looking for new input commands from switch assembly **120** while displaying display screen **318** to allow the operator such as user **1**, to select another item for personalization. As will be described herein in greater detail below, the data entry system available through the use of rotary switch **122** and display **170** however provides greater flexibility than merely highlighting an icon for entry and the subsequent entry of data selected.

The utilization of the rotary switch **122** also can be employed for providing specific alpha-numeric messages which can be stored in the computer and subsequently recalled, for example telephone numbers, addresses, and the like, for use in connection with the cellular telephone and navigation systems of the vehicle. As an example of the data entry available with the system of the present invention, for example with the stereo features subroutine **324** which can be called up from the personalization icon display **318**, preset frequencies can be entered into the system utilizing switch assembly **120** as described in connection with FIGS. **13–15**. Referring to FIG. **13**, there is shown one display for providing operator prompting information to the vehicle operator for selecting any programming preset frequencies in the vehicle's stereo system. Selection of the stereo features icon from block **318** of FIG. **12** will display a new menu of options to the operator including volume presets, bass and treble controls and other control functions including the frequency band and station presets illustrated in FIGS. **13–15**. Preset stereo system receivers are well-known and as is the presetting of a variety of frequencies therein, this system however provides for the use of the relatively easily operable rotary switch **122** and display system in connection with the data entry system for presetting AM and FM frequencies.

Referring initially to FIG. **13**, there is shown a typical operator prompting display for preset number **1** for receiver programming. The display prompts the operator to select AM or FM bands by providing at least one predetermined location on the display **170** defining a display window **328** which contains initially the letter "A" therein as called from the computer memory look-up table associated with the programming subroutine for the stereo receiver. As seen in FIG. **14**, this subroutine is started as indicated by block **332** and actuation of rotary switch **122** can move the alphabet characters up the alphabet (to the right) if rotated to the right as indicated by block **334** or down (to the left) as indicated by block **336**. Inasmuch as only two choices are required (an "A" or an "F") only these two letters need be available for this subroutine, it being understood that for other subroutines, the microprocessor memory provides for the scrolling through a selected window the entire alphabet. With "A" being displayed in window **328**, if the operator wants to select an FM band preset for position **1**, switch **122** is rotated in this case in either direction to display an "F" in window **328**. At this time, the operator actuates "ENTER" switch **121** and the program enters the selected data into memory and responds to the selected "F" to provide the next selected display screen of FIG. **15** for FM frequencies. The program subroutine for scrolling through the available or necessary letters or number is shown in FIG. **14** where the initial character to be selected is controlled by the operator actuated switch **122**.

The program looks for an alphabet right command **334** and when received, the next available letter is highlighted or entered into the window **328**. It then moves through the loop again looking for closure of one of the switch contacts for switch **122** in either direction or actuation of the "ENTER" switch **121** storing the highlighted letter or number. Thus, the program loops through decisional blocks **334–344** by which the program looks for the movement of rotary switch **122** to move the displayed letter of the alphabet either up or down in the alphabet and entering the selected letter or other character. When the desired letter is being displayed in block **328**, "ENTER" switch **121** is actuated as indicated by block **342** and this data is entered into the computer memory corresponding in the example to the first letter of the selected frequency band. In the case of the second letter, since it will always be an "M," "M" will be automatically displayed. Upon entry of the "A" or "F" in window location **328** and the subroutine will then move to the next subroutine setting forth the digital information corresponding to the FM frequency selection in a similar fashion prompting blocks of numbers corresponding to four-digits for FM or three-digits for AM are displayed. Thus, upon actuation of the "ENTER" switch **121**, the highlighted letter is entered into computer memory as indicated by block **344**, and the program exits the loop of FIG. **14** and goes to another similar subroutine for selecting the desired FM frequency and displays the selection screen shown in FIG. **15**.

In FIG. **15** four blocks of frequency indicating numbers are displayed and the subroutine prompts the operator to select an appropriate digit for each location in the display for subsequent entry into the computer in a manner similar to that described in connection with the band selection of FIGS. **13** and **14**. Thus, initially window **329** will be highlighted and switch **122** moved left or right to increase or decrease the digit displayed. Upon entry of the data by actuation of switch **121**, the next window **331** will be highlighted and the process repeated until data for the four possible frequency selection windows **329**, **331**, **333**, and **335** are selected. The program will provide a test to determine when the last frequencies digit has been entered and when completed increment a counter to initiate programming of preset number **2** by returning to the subroutine of FIG. **14**.

Thus, the select and entry system available with the use of rotary switch **122** provides a highlighted display window through which alpha-numeric or other character information can be scrolled by the actuation of switch **122** either by increasing or decreasing numbers displayed in the select block or by going up or down the alphabet for alphabetical information being displayed. Upon actuation of the enter switch, the selected information is entered into the computer memory for use either in controlling the desired operation or, for example, providing message information or, for example also, phone listing information, address information, or the like. Any desired alpha-numeric information may thereby be entered into the computer (i.e., the microprocessor memory **198**) using the data entry system and the select and enter method described in connection with FIGS. **13–15**. As will be described hereinafter, another operator prompting and data entry technique is also available employing the data entry system of the present invention.

As can be appreciated in connection with the entry of preset frequencies as shown in FIGS. **13–15**, once the selected frequency has been entered, the last digit entered will inform the computer to move to the next available preset address and once the last address is completed, the display prompt will so indicate to the operator and allow the selection of the other frequency band or ask if any of the presets need to be changed which, again, can be selected by scrolling through a display of a number corresponding to a particular preset or particular display frequency band.

Another of the selectable options from the home panel **290** shown in FIG. **11** is the phone control subroutine **302**. This subroutine is selected by the highlighting of the phone icon by rotating switch **122** and the actuation of the entry switch **121** or **221**. This causes the program to display to the vehicle operator either icons or words as indicated by block **350** of FIG. **16** either showing a list of telephone numbers or a telephone number to be dialed. Upon selection, for example, the phone listing icon, a subroutine **352** is called up which provides a pre-programmed listing of stored telephone numbers which can be automatically dialed by the microprocessor cellular telephone interface or which list can be initiated, added to, or deleted utilizing the other data entry technique now described in connection with FIGS. **17–20**.

The phone list may take the form of display as shown in FIG. **17** with the first three names and numbers being displayed on three lines of display in display **170**. Movement up and down of the display which may include any desired number of entries depending on the available memory, can be selected by rotating switch **122** to the right for scrolling down in the list or to the left scrolling up in the list or wrapping around for example entry **125**, the phone list can give the name of the person to be called as well as the calling number. By controlling switch **122** and highlighting number **1** and then pressing "ENTER," the first number on the list can be automatically dialed through the coupling of the microprocessor to the cellular telephone transceiver in a conventional fashion. Entry of numbers on the list can be achieved by the data entry system shown in FIGS. **18** and **19** which is somewhat similar to the data entry system described in connection with FIGS. **13–15** in terms of ease of operation but utilizes a somewhat different display and data entry technique.

As seen in FIG. **18**, display **170** will initially display a series of letters corresponding to adjacent sections of the alphabet. Rotation of switch **122** will move a cursor to highlight a desired letter for entry into the phone list. Thus, rotation switch **122**, for example, to the letter "J" for the first number on the phone list will cause a cursor to highlight the letter "J" and actuation of switch **121** will enter the letter J into the first position on the phone list which can be, upon entry, displayed below line **352** and on display line **354** shown in FIG. **18**. Subsequently, other letters are similarly highlighted and entered to complete the spelling of the name of the person to be called. Rotating switch control knob **132** for switch **122** to the right beyond the letter "K" as shown in FIG. **18** will cause the next successive letter or letters to appear at the right end while the preceding letters are dropped off of the left end of the displayed alphabet sequence. Actuating the "EXIT" switch **124** after the completion of the person's name will cause the display line **352** shown in FIG. **18** to display numbers corresponding to area code and telephone numbers with, instead of the alphabet being displayed the numbers **0–9** being displayed, and selectively highlighted and entered utilizing switches **122** and **121**, respectively. In this manner, the operator can relatively easily spell out a person's name and number for addition to the pre-programmed phone list for subsequent auto dialing. The software programming for providing the data entry function for the phone list or other subroutine is disclosed briefly in the flow diagram of FIG. **19**.

Turning now to FIG. **19**, the subroutine starts as indicated by block **360** by displaying the letters "A" through "K" in the order shown in line **352** of FIG. **18**. If it is desired to move the alphabet to the right or left, switch **122** is rotated as indicated by block **362** or **364**, respectively, which causes the highlighting of the next or previous letters as indicated by blocks **366** and **368**, respectively. Once the desired letter has been highlighted, the "ENTER" switch **121** is actuated as indicated by block **370** and that data corresponding to that selected letter is entered into the text as indicated by block **372**. The process is then repeated until the desired name is completed at which time the "EXIT" switch is actuated causing the program to exit to the next screen display where the number line is displayed for similarly selecting the desired telephone number. Upon completion of the desired number, the program will move to the next entry in the phone list so it can be similarly programmed.

If the operator, however, desires to directly enter a number for dialing without reference to the phone list, the subroutine shown in FIG. **16** as block **374**, if selected, allows the direct entry of a number utilizing a similar data entry system as shown in FIG. **20** in which the digits **0–9** are displayed on line **376** and the cursor highlights a selected number as, for example, number **6**, for entering into the number-to-dial line **378**. Once the desired number has been so entered, the "dial" icon can be highlighted and the enter switch actuated to effect dialing of the cellular phone for placing the desired call. The interface circuitry for coupling to the cellular telephone is well-known and conventional.

If desired, display **170** can be employed for displaying received text messages. Further, the vehicle may include a small dot matrix printer for providing a hard copy of a text message. If the operator selects the text messaging subroutine from the home panel **190** (FIG. **11**), the text messaging subroutine **304** shown in FIG. **21** is called up. This will cause the display **170** to display an initial current text message panel **382** which will list a number of text messages received by the RF transceiver and highlight whether or not the text message has been received. This can be done, for example, by blinking the paging number corresponding to an unread text message. The switch **122** can be rotated to highlight any one of the received text messages for reading. This is achieved by actuating the "ENTER" button to display the selected text message as indicated by block **384** in FIG. **21**. FIG. **22** is an example of a text message which has been received and is being displayed. Rotation of switch control knob **132** and actuating the enter switch provides the microprocessor with data as to which block of the program sequence is performed next. As indicated by block **382**, unread text messages can be indicated by the blinking of the text message number for such text messages.

Once the text message has been read, upon highlighting the desired icon shown in FIG. **22** and actuation of the "ENTER" switch, the text messaging option panel **386** allows the operator to delete the text message, which provides a redundant decisional display indicated by block **388** asking the operator a second time whether he or she wishes to actually delete the message. Thus, the text message will not be deleted unless two conscious decisions are made to delete the message. The operator may also opt to have the alpha-numeric message printed by a printer. Moving the cursor to highlight the icon of display panel **386** for the printer or the word "Print" and actuation of the "ENTER" switch **121** will effect the printing of the message by the printer which can also be installed in the console **112** near the switch assembly **120**.

As shown in FIG. **23**, the vehicle operator can select the compass subroutine **306** which allows the selection of compass, temperature, and trip display information as indicated by block **390**, calibration control as indicated by block **392** which may include prompting calibration messages as indicated by block **394** or variation correction as indicated by block **396** allowing for variation correction of the com-

pass according to a variation zone prompting message **398**. The compass selection primary display **305** allows the selection of these various subroutines.

Finally, the operator may select the navigation subroutine **308** shown in FIG. **24** which in its elemental form may include a route display selection **402**, a delete route selection **404**, or a print route selection **406**. The navigation circuitry **250** may include a suitable memory for storing navigation information and include, for example, a CD reader with CD stored maps and route information which can be selectively accessed using switch assembly **120** including the rotary switch **122** for controlling the displayed selection according to either of the two data entry techniques described above, that is providing a window through which either alpha or numeric information can be scrolled for selection or entry or by displaying a sequence of alpha-numeric information and moving the cursor to a selected one for entry to control subsequent information provided on the display or enter commands into the microprocessor for control or storage. The navigation system **250** may also include a GPS receiver so that the vehicle's actual location can be known and routing information to, for example, a selected address provided by entering the address in one of the manners set forth in FIGS. **13–17** to provide a desired route display as indicated by block **402**. If a route has been used and it is desired to delete the route, it can be deleted by selecting the delete route icon of block **400** and actuating the "ENTER" switch **121** for deleting the route which will require two actuations to make certain that the route is not inadvertently deleted. Finally, the directions for providing routing information can also be printed by selecting the print icon and actuating the "ENTER" switch to print the sequential directions for the route using printer **280**.

The data entry system of the present invention provides a user-friendly structure and method by which data can be selected for entry into a microprocessor for a variety of control and informational purposes. By providing a rotary switch or equivalent control, data can be more easily entered without the need for an alpha-numeric keyboard which would require excessive space in the vehicle for permanent installation and provides relatively easy and understandable operation for those who otherwise may not be familiar with data entry systems. It accomplishes this by providing a selectable prompting display and data entry in response to the display to provide control and informational data to and from a microprocessor for use in controlling and programming vehicle options and accessories. As described in the section immediately below, the display may be mounted in various other locations in the vehicle and may be a heads-up display that projects the displayed information in the driver's line of sight.

4. Alternative Display Configurations

It is desirable to provide the vehicle communication and control system with a message display system which is readily visible to the vehicle driver and does not interfere with the driver's field of vision. It is also desirable to provide such a display which is easy to read in all ambient light conditions. The present invention provides a message display system including a display positioned in the vehicle windshield area at a location which is readily visible to the vehicle driver while not interfering with the driver's field of vision.

According to one aspect of the invention, the message display system is provided in a housing adapted to be mounted in the windshield area of a vehicle. The system includes a display device positioned on a housing, a receiver which demodulates a detected RF signal, and a controller which generates display control signals responsive to the output of the receiver. The display device is responsive to the control signals for displaying the message.

According to other aspects of the invention, the display device is positioned on a rearview mirror housing, an A-pillar housing, an overhead console, or a visor. The display device may be implemented using a vacuum fluorescent display or a dot matrix display.

The message display system is thus adapted to be mounted in a vehicle such that the message is displayed in the area generally in front of the driver and does not interfere with the driver's field of view. The message display system may be provided as part of a vehicle accessory, such that the message display system is assembled to the vehicle with the accessory. The message display utilizing a vacuum fluorescent display is readily visible in all ambient light conditions.

Vehicle **412** includes a message display system **416** (FIG. **26**) in rearview mirror assembly **418** (FIG. **25**), which includes a housing **430**. The vehicle also, conventionally, includes an A-pillar **421**, a steering wheel **423**, an instrument panel **427**, a windshield **425**, sun visors **429**, **431**, and a headliner **438**. The mirror assembly **418** includes a support **437** which may be connected to a connector **434** in the vehicle roof structure.

The message display system **416** includes a RF receiver **420** (FIG. **26**) which demodulates the RF signal A from land station **410** and outputs a digital control signal. A microcontroller **422** is coupled to receiver **420** and is responsive to the digital control signals output from the receiver for generating display control signals when a message such as a paging message is received. A display source **424** is coupled to the microcontroller **422** and receives display control signals therefrom. Receiver **420**, microcontroller **422**, and display source **424** are mounted in housing **430** of rearview mirror assembly **418**. Accordingly, a message display system **416** is provided in rearview mirror assembly **418** to display a message for the driver.

The RF signals A are of the type conventionally utilized for RF signals transmitted from a land-based station **19** (FIG. **1A**). The message may include only numerical information if it is originated at a conventional telephone subscriber station **15**. Alternatively, if the message is generated at a telephone subscriber station **15** having an alpha-numeric input (e.g., a computer keyboard), the message may include alpha-numeric message information from the originating party. The RF signals A typically have a frequency range from 137 to 175 MHz (VHF band) or within the frequency range 405 to 513 MHz (UHF band). The signal format and land-based station are described in greater detail below under the heading "Detailed Description of the Vehicle Personalization and Remote Control Functions."

Receiver **420** (FIG. **26**) includes an antenna **426** which detects the RF signals from land-based station **19**. RF receiver **420** demodulates the signals detected by antenna **426** and conditions the demodulated signal to have digital levels appropriate for decoding in the microcontroller **422**. Microcontroller **422** is preferably implemented using a Motorola MC68HC05 microcontroller, which is commercially available from Motorola Corporation. However, any suitable microcontroller may be utilized. In general, microcontroller **422** receives and decodes the data signals output from the RF receiver **420**. If the message is a text message for the vehicle in which the system is mounted, the microcontroller is responsive to the text message for generating a serial display control signal which is communicated to display source **424** through a serial data link **428**. Additional details of RF receiver **420** and microcontroller **422** are

described below under the heading "Detailed Description of the Vehicle Personalization and Remote Control Functions." System **416** may be a two-way pager as described in U.S. Pat. No. 5,153,582.

Display **424**, according to this embodiment, is a vacuum fluorescent alpha-numeric display. The alpha-numeric display may be advantageously implemented using a commercially-available Noritake CU2055CPB-52A, which is a reconfigurable 20-character vacuum fluorescent display. The Noritake display includes a serial input and integral display driver components. Although the Noritake display includes integral display driver components, those skilled in the art will recognize that any suitable commercially-available vacuum fluorescent display may be utilized. If the display does not include an integral display driver circuit, a suitable commercially-available driver circuit may be used to generate appropriate signal levels for the display. A vacuum fluorescent display is preferred because it generates a particularly bright image which is clearly defined and readily decipherable in all ambient light conditions. However, other display devices could be utilized, such as LED and/or back-lit LCD displays.

With reference now to FIGS. **25** and **26**, RF receiver **420**, microcontroller **422**, and display source **424** are positioned in the housing **430** of rearview mirror assembly **418**. A particularly advantageous rearview mirror assembly which may be utilized is disclosed in U.S. Pat. No. 5,475,366, the disclosure of which is incorporated herein by reference thereto. This rearview mirror assembly may be advantageously implemented using the modular mirror connector disclosed in U.S. Pat. No. 5,455,716, the disclosure of which is also incorporated herein by reference. A detailed description of the rearview mirror assembly **418** is found in the above-incorporated patent. However, a general description of rearview mirror assembly **418** follows.

Assembly **418** includes at least one circuit board (not shown) positioned within the mirror housing **430** and on which receiver **420**, microcontroller **422**, and display source **424** are conventionally mounted. A reflective surface **432** is positioned above the display (e.g., the vacuum fluorescent display **424**) at an angle of approximately 45° with respect to the plane of the display surface of the display. The image from display **424** is reflected on surface **432** such that a driver looking at the reflective surface can read the reflected image. The paging message display system **416** mounted in housing **430** is connected through a wiring harness **434** to vehicle bus **436**, which is positioned in the vehicle roof structure above headliner **438**. If the mounting assembly disclosed in U.S. Pat. No. 5,455,716 is utilized, the rearview mirror assembly **418** includes a mirror support **437** removably connected to connector **440**. The mirror assembly is attached to the vehicle as an optional accessory by plugging the rearview mirror support **437** into connector **440**. Details of the mirror assembly and the electrical connector are found in the above-identified patents incorporated hereinabove by reference, and accordingly, they are not described in greater detail herein.

To assemble rearview mirror assembly **418**, RF receiver **420**, microcontroller **422**, and display **424** are mounted on at least one circuit board (not shown). The circuit board is assembled into the rearview mirror housing **430**. The wire harness **434**, including the control inputs and outputs of microcontroller **422** and power supply conductors connected to the vehicle power supply, are connected to the paging message display system **416**. The wiring harness is extended outwardly from rearview mirror housing **430** through mirror support **437** for connection with wiring in the vehicle roof structure when support **437** is connected to connector **440** in the vehicle roof structure. The rearview mirror assembly **418** is fully assembled to vehicle **412** when mirror support **437** is connected to connector **440**.

In operation, vehicle **412** may be paged from land-based station **19** (FIG. **1A**) by a person dialing the number for vehicle **412** (FIG. **20**) using telephone **15**. The page signal will be communicated from telephone **15** to land-based station **19** through the telephone system. Land-based station **19** transmits an RF signal A to vehicle **412**. Receiver **420** demodulates the RF signal A and outputs a control signal to microcontroller **422**. Microcontroller **422** is responsive to the demodulated page signal for indicating that a paging message is received. The driver may control when the message is displayed on display **424** using a READ switch **448** (FIGS. **25** and **26**) on rearview mirror housing **430**. Microcontroller **422** is responsive to actuation of the READ switch **448** to communicate a control signal to the alpha-numeric display such that the paging message is displayed. If the driver wishes to immediately call the party back, and vehicle **412** has a cellular telephone, the driver pushes the TRANSMIT switch **450**. Responsive to depression of the TRANSMIT switch, microcontroller **422** will control the cellular telephone to call the number indicated in the paging message. This process of control is described in greater detail below under the heading "Detailed Description of the Vehicle Personalization and Remote Control Functions."

According to an alternate embodiment of the invention, message display system **416** is provided in a housing **452** (FIG. **27**) mounted over a vehicle A-pillar **421** (FIG. **25**). The message display system **416** shown in the circuit of FIG. **26** is mounted to housing **452**. The RF receiver **420** (FIG. **26**), microcontroller **422** and display **424** also can be mounted in the housing by conventional means (not shown) such as snap connectors, threaded fasteners, adhesives, or the like. The A-pillar housing **452** including display system **416** the circuit board (not shown) is assembled to A-pillar **421** using suitable threaded fasteners, snap connectors, adhesive, or the like. The housing may be manufactured from plastic, metal, or other suitable materials conforming to the interior of the vehicle. The message display system **416** is located within the housing **452** at the lower end such that the display surface of the display **424** is readily visible to the vehicle driver. The alpha-numeric display may include two rows of ten characters or a vertically oriented display in this embodiment of the invention.

According to another alternate embodiment of the invention, message display system **416** is mounted in an overhead console **454**, as described above. The overhead console includes a housing **456** attached to the vehicle roof structure in a conventional manner. The overhead console housing may be of any suitable, conventional construction. The message display system **416** is mounted on a circuit board (not shown) which, in turn, is mounted in overhead console housing **456** by conventional means. Display **424** is positioned on overhead console housing **456** such that the display source image is directly visible to the vehicle driver. According to one advantageous embodiment of an overhead console pager display system, the display device may be implemented using the focus at infinity display system for an overhead console disclosed in U.S. Pat. No. 5,469,298, the entire disclosure of which is incorporated herein by reference thereto. If the focus at infinity display is used in the overhead console display, a mirror (not shown) is positioned in overhead console housing **456** and display source **424** is spaced from the mirror, as disclosed in U.S. Pat. No. 5,469,298.

It can thus be seen that a message display system is disclosed herein which is readily visible to the vehicle driver. The message display system is conveniently located in a housing in the windshield area of the vehicle so the vehicle driver can view the displayed message without taking his or her eyes completely off of the road for an extended period of time. The message display system may be integral with a vehicle accessory and is readily visible to the driver in all ambient light conditions.

Displays of vehicle parameter information and other information such as compass headings and the like have become commonplace with a variety of locations being employed for such displays, typically within the instrument panel of the vehicle itself. Displays have also been located in the A-pillar of a vehicle as, for example, described above and disclosed in U.S. Pat. No. 5,415,554 and in rearview mirrors as, for example, described above and disclosed in U.S. Pat. No. 5,475,366. Such displays usually provide the vehicle operator with information desired for the operation of the vehicle. An incidental display is employed on a visor-mounted telephone as disclosed in U.S. Pat. No. 4,870,676, which shows a telephone and its display viewable only when the visor is in a lowered position for use of the telephone.

It has been discovered that a visor provides a desirable location for the mounting of a trainable transmitter which is commercially available in many vehicles now on the market. Visors also provide a convenient location for the mounting of illuminated vanity mirrors of the type disclosed in U.S. Pat. No. 4,760,503.

In order to more fully utilize the beneficial location of the visor as well as its ability to move from a raised stored position to a lowered use position, the present invention may utilize the visor as a mounting location for a unique display for information such as text messages, compass and temperature information, vehicle operating parameter information, and the like. It is desirable, however, to have the display visible regardless of the visor position which can change depending upon its use for blocking sun for which it is primarily designed. Thus, in visor displays embodying the present invention, the visor body includes a window to which a display is movably mounted such that the display, when the visor is in one of a raised or lowered use positions, is visible through the window and, when the visor is moved to the other of the raised or lowered positions, the display can be moved to be directly visible.

In one embodiment of the invention, a visor display includes a display housing to which a display is mounted. Such housing is pivotally mounted to a visor body and movable from a closed position where the display is aligned with a window formed through the visor body to an open position where the display is visible when the visor window is adjacent the vehicle roof. In an another embodiment of the invention, the visor window was formed through a vanity mirror in an area of the vanity mirror which is otherwise covered with a reflective material to provide a mirror such that the display is viewed through the front surface of the mirror window. In another embodiment of the invention also, a visor body includes a housing which extends to opposite sides of the visor and presents a display on such opposite sides to be visible regardless of the visor position.

With the present invention, therefore, a single display, such as vacuum florescent display, can be employed and viewed through an illuminated vanity mirror with sufficient contrast to readily view the display with the visor in a lowered use position with the vanity mirror in use. The display is equally visible when the visor is in a raised stored position by pivoting the display housing downwardly to a position for direct viewing.

Referring to FIG. **29**, there is shown a vehicle **510**, such as an automobile, which includes a roof **512** of sheet-metal construction to which a molded composite headliner **514** is mounted for providing an attractive vehicle interior. Several pillars including an A-pillar **515** provide support for the roof **512**. Pillar **515** divides the windshield **516** from the driver's side window **518** of the vehicle. The vehicle typically will include a rearview mirror assembly **519** and a pair of visor assemblies with the driver's side visor **520** incorporating the present invention being shown.

Visor assembly **520** comprises a visor body which can be of a molded polymeric material such as polypropylene or other material such as fiberboard which can be preformed in a butterfly shape and folded over in a clam-shell design to complete the visor body construction. The visor body is mounted to the vehicle roof **512** by means of an elbow bracket assembly **530** which can be of conventional construction and includes a pivot rod **532** extending into the body of the visor. A torque fitting (not shown) mounted within the visor body engages the pivot rod **532** for allowing the visor to be held in a raised stored position as illustrated in FIG. **29** to a lowered sun-blocking use position as illustrated in FIGS. **33** and **34**. The bracket assembly also allows the visor to be moved from the front windshield position to a side window position in a conventional manner. A remote support clip **534** may be mounted to the roof near the rearview mirror **519** and receive auxiliary visor rod **536** for supporting the end of the visor body remote from the bracket assembly **530** to the vehicle roof as illustrated in FIG. **29**. The visor body may also include a pocket for receiving a slide-out auxiliary visor panel **521** as illustrated in FIGS. **29** and **30** for extending the effective width of the visor when in use.

For purposes of discussing the invention, the rear-facing surface **524** of visor **520**, when in the raised stored position shown in FIG. **29**, will be referred to as the rear of the visor with the opposite side of the visor being referred to as the front **522** of the visor. Formed in the rear **524** of the visor body is a pocket **526** as best seen in FIGS. **30** and **32** for storing a movably mounted display assembly **540** therein. Display assembly **540** includes a housing **542** which is pivotally mounted to the visor body on an edge of pocket **526** formed therein by means of a conventional pivot axle assembly **544** to be moved from a stored position substantially flush with the rear surface **524** of visor **520** as seen in FIG. **29**, with the outer surface **541** of display assembly **540** being textured with an upholstery material to conform to that of the visor. The inner surface of housing **540** includes a polymeric panel **543** having an elongated rectangular window **545** (FIG. **30A**) formed therein behind which there is mounted a digital display **546** which is electrically coupled to a display information source **548** (FIG. **37**) by means of suitable conductors **547** extending through the visor body and the hollow pivot rod **532** to the electrical circuit comprising the display information source **548**. The display information source **548** may be, for example, a digital compass such as disclosed below under the heading "Detailed Description of the Vehicle Personalization and the Remote Control Functions" and in U.S. Pat. No. 4,953,305, the disclosure of which is incorporated herein by reference; a paging receiver as disclosed in U.S. Pat. No. 5,479,157 the disclosure of which is incorporated herein by reference; or other vehicle information such as disclosed above.

For purposes of pivoting the display assembly **540** from its stored, concealed position shown in FIG. **29** to its

lowered use position as shown in FIG. **30**, a handle **549** is provided along the upper edge of the display. Display **546** can be any number of commercially-available digital displays such as a vacuum florescent display, an LCD display, an LED display, or the like, which provide an alpha-numeric or other suitable display of information to be displayed to the driver. It is conventionally mounted within the hollow body of housing **542** in alignment with window **545** such that information to be displayed is visible through the window.

The visor pocket **526** includes, as best seen in FIG. **32**, a rear panel **550** also having a rectangular window **552** extending therethrough and which is aligned with the display **546** when the display assembly **540** is in its stored position, as seen in FIGS. **29** and **31**. In one embodiment of the invention, the window **552** extends entirely through the visor body and is exposed on the front surface **522** such that when the visor is in its lowered use position, the display can be viewed through the window **552** in panel **550** of the visor. In the preferred embodiment of the invention, however, the front surface **522** of the visor includes an illuminated vanity mirror assembly **560**, as seen in FIGS. **33–36**. Vanity mirror assembly **560** can be constructed generally as disclosed in U.S. Pat. No. 5,428,513, the disclosure of which is incorporated herein by reference, with a modification to provide a window through the mirror of the assembly such that the display **546** can be viewed through the mirror when in the position shown in FIGS. **33** and **34**. A brief description of the visor assembly **560** follows.

Mirror assembly **560** includes a mirror frame **562** mounted to the visor body and including a mirror **564** mounted therein. Near the upper portion of the mirror, there is formed a generally rectangular window **566** of a shape substantially conforming to and aligned with window **552** in panel **550** (FIG. **32**). Window **566** is formed, as best seen in FIG. **35**, on the rear surface of mirror **564** by not coating the rectangular area of the rear surface of the mirror glass **561** with the normal reflective coating **563**. Alternatively, this coating **563** could be removed to define window **566**. Thus, the area defining window **566** provides clear glass **561** which is aligned with the display **546** mounted in display housing **540**, as seen in FIG. **35**. Therefore, the display assembly **540**, when in the position shown in FIGS. **29** and **31**, is within the pocket **526** in the rear surface **524** of visor **520**, and information displayed by display **546** is visible through the window **566** in mirror **564**, and window **552** in rear panel **550** form through the visor body. FIG. **34** illustrates how the information on display **546** appears through the mirror window. The mirror assembly **560** also includes a cover **568** which can be selectively moved from a closed position as shown in FIG. **36** to the open position shown in FIGS. **33** and **34** for exposure of the mirror **564** and display **546** therethrough. Illumination means **569** is mounted on the inside of cover **568**. The intensity of the illumination can be controlled by a variable resistance control **565** mounted to the frame **562** of the illuminated vanity mirror assembly.

The pocket **526** into which the display assembly **540** is pivotally mounted provides light shielding for the display **546** such that it is readily visible through the front surface of mirror **564** even when the illumination means **569** is in the high brightness position. The display is recessed in the darkened area of pocket **526** behind the reflective surface **552** of the mirror **564**. Thus, with the system of the preferred embodiment of the invention, a single display **546** is viewable either with the visor in a raised stored position, as illustrated in FIG. **30**, or when in a lowered position with the vanity mirror exposed, as seen in FIGS. **33** and **34**. In some embodiments, the vanity mirror will not have a cover so that the display is visible at all times instead of selectively as in the embodiment shown including a vanity mirror cover **568**.

In the alternative embodiment shown in FIGS. **38–40**, the same vehicle **510** is shown with corresponding parts bearing the same reference numerals as in the previous embodiment. The vehicle includes a pair of visors **570, 580** on the driver and passenger sides, respectively. The driver's side visor **570** includes a dual display assembly **590** (FIG. **40**) which includes a first display **592** which is visible when the visor is in a lowered position as seen in FIG. **38** and a second display **594** mounted to the visor to be visible and readable when the visor is in a raised stored position as shown in FIG. **39**. Displays **592** and **594** can be commonly coupled to the source of display information **548** (FIG. **37**) via conductors **547**. Displays **592** and **594** are mounted in a housing **596** which includes a front bezel **595** surrounding and receiving display **592** and an angled bezel **597**. Bezel **597** positions the face of display **594** to extend at an acute angle of approximately 45° to the planar surface **571** of visor **570** such that when the visor is in a raised stored position, as illustrated in FIG. **40**, the display is readily visible by the vehicle driver. Housing **596** is shaped to fit within an aperture **574** in the visor body. Displays **592** and **594** are positioned preferably in one corner of the visor which may include an illuminated vanity mirror package in the center area, if desired. Displays **592** and **594** may be of the same general type as display **546**. In some embodiments, the dual display can be provided utilizing a single display source located within housing **590** and suitable prismatic reflectors to provide the display surfaces **592, 594**. The visor display system of FIGS. **38–40**, therefore, also provides a display on opposite sides of the visor, such that the information is readily visible and accessible to the driver regardless of the operational position of the visor.

5. Detailed Description of the Last Exit Warning Function

Many vehicles currently include computers which calculate not only fuel economy but also, based upon the remaining fuel, a distance-to-empty estimation for preventing running out of fuel. Although the vehicle operator can readily select the distance-to-empty information for display, the operator may not be aware of the nearest service station at which fuel can be purchased nor the distance to such a service station. Therefore, and particularly when driving on limited access highways, the vehicle operator can still encounter an out-of-fuel crisis. This can be particularly troublesome in isolated areas where help is not readily available or in some urban areas where having a disabled vehicle is undesirable. Although motorist aids including frequent roadway signs and on-board navigational systems are available, there remains a need for a warning system which will notify the vehicle operator to exit, for example, a limited access highway to obtain fuel or other desired services prior to the time the vehicle is caught between two exits beyond the point of no return where insufficient fuel remains to reach the nearest service station.

The system of the present invention accommodates this need by providing a warning system which will automatically alert the vehicle operator to the fact that the next available exit should be taken for a desired or necessary service such as refueling.

In one embodiment of the invention, the system includes a source of information providing the current vehicle location as well as a source of information identifying the location of available selected service locations closest to each of the next two exits of, for example, a limited access highway. The system in a preferred embodiment includes a source of information indicating the available range of the

vehicle (distance-to-empty) and a microprocessor for calculating when the driver should take the next available exit to reach the desired service.

In most instances the service would be a service station for providing fuel, although the desired service may involve other parameters such as the time for stopping for lunch or dinner or checking into an available hotel. The system includes a suitable alarm which may be an audible alarm, a visual alarm, or both, to alert the vehicle operator that the next available exit should be taken. Such a system, therefore, provides the vehicle operator with the assurance that the vehicle will not run out of fuel prior to the availability of a service station at a forthcoming exit. Likewise, the vehicle parameter can alert the vehicle operator to exit to achieve a desired arrival time for certain other services, such as dining or checking into hotels, and forewarn the vehicle operator to exit for such facilities. In one embodiment, a vehicle mounted housing includes the electrical circuits of the invention which receive operating power from the vehicle's battery. Such circuits preferably include the two-way communication system of the present invention thereby permitting the vehicle operator to receive and transmit messages.

Referring initially to FIG. **41**, there is shown a map which pictorially illustrates a vehicle **20** traveling in the direction of arrow A along a limited access highway **612** having an exit A and an exit B spaced farther along highway **612**. Along exit A is a service facility S_1 which is located a distance from the current position of vehicle **20** of, for example, 7 miles. Exit B includes a service facility S_2 which is 32 miles from the vehicle's present location. Vehicle **20**, such as an automobile, conventionally includes a fuel computer which provides, on a vehicle data bus, distance-to-empty data which, in the example shown, indicates the distance-to-empty is 28 miles. Although the vehicle operator may be aware of the fact that exit A is, for example, 3 miles ahead and exit B is 20 miles ahead, the vehicle operator may not be aware of the fact that the only open service location S_2 is beyond the range of the vehicle and, therefore, the vehicle will run out of fuel prior to reaching service station S_2, which is the closest service facility from the otherwise reachable exit B. Thus, it is desired, in order to forewarn the vehicle operator of an impending out-of-fuel situation, to provide information to the vehicle operator as to the vehicle's present location and the locations of facilities S_1 and S_2 and their distance such that, prior to going beyond exit A, the vehicle operator receives a warning signal allowing the operator to exit at exit A and utilize the services of facility S_1.

Referring to FIG. **42**, there is shown a housing **611**, such as a rearview mirror housing, adapted to be attached to the roof structure **613** of a vehicle **610**. Mounted within the mirror housing are the electrical components of FIGS. **3** or **5**, which are electrically connected to the vehicle electrical system through suitable electrical conductors **615** for receiving operating power from the vehicle's battery. Housing **611** includes an alpha-numeric display **619** for selectively displaying messages from the RF transceiver (FIGS. **3** and **5**) and other information to the vehicle operator. Also, a plurality of control switches **621** are mounted to housing **611** at various locations for the operator to input control signals to the circuit shown in FIGS. **3** or **5**. The display and control switches are illustrated by blocks **28**, **46**, **48**, **50**, **52**, **54**, **56**, and **58** in FIGS. **3** or **5**. The details of construction of the rearview mirror assembly **617**, including the housing **611** and its mounting to the vehicle, are disclosed in detail in U.S. Pat. No. 5,455,716, the disclosure of which is incorporated herein by reference.

The operation of the system is best understood by reference to FIG. **43** which shows the subroutine for the last exit warning, which subroutine **650** is part of the overall programming for the microprocessor **626** which forms no part of the present invention. The subroutine **650** can be inserted at any suitable location in the program and includes an input **651** to test at block **652** whether the last exit flag is set. If it is not set, the subroutine is not called up and the main program proceeds from port **653** of block **652**. In the event the last exit flag is set, which can either be automatic, if desired, or can be operator enabled by the actuation of a control switch **621** in interface circuit **628**, the microprocessor first retrieves the current vehicle position as indicated by block **654**. It does this by interrogating the GPS module **638** which provides the current latitude/longitude information to the microprocessor, which then stores the current vehicle position.

Next, as indicated by block **656**, the microprocessor obtains location information for the next two exits of the limited access highway on which the operator is traveling for the desired services, as, for example, fuel availability. Such information will include not only the location of the service facility but also the availability of such facility (i.e., whether it is open at the time of the requested information). This information can be accessed in a variety of manners by, for example, a database **27** (FIG. **3**) contained on the vehicle in mass storage memory such as a CD-ROM, which includes the highway information on which the vehicle is traveling in memory, as well as the available services. The database **27** will thus include the data storage medium, a reader such as a CD-ROM drive, and a controller coupled to the microprocessor for transferring data to the microprocessor. The programming for the transfer of location data for, for example, service locations S_1 and S_2 based on the vehicle's current position, can be conventional. Such a system is described in U.S. Pat. Nos. 5,172,321 and 5,229,947, the disclosures of which are incorporated herein by reference. Preferably, however, microprocessor **26** or **66** obtains such service location information from an inquiry to a subscription service through two-way paging module **34** or transceiver **70**. It accomplishes this by initiating an information request utilizing paging module **34** or transceiver **70** and receiving such data from a centrally-located base station having a database of such information via a paging network service such as is commercially available from SkyTel Corp., located in Jackson, Miss. Both the paging module **34** and transceiver **70** can transmit the current vehicle location to the subscription service upon operator request or automatically on a repeating time cycle. Pager **34** or transceiver **70** receives the location information as, for example, S_1 and S_2 of FIG. **41**, and provides such information in a digital signal format to the microprocessor **26** or **66**, which is conventionally programmed to calculate the distance from the current vehicle location to the S_1 and S_2 available service facilities at the forthcoming two exits.

This information is stored by the microprocessor and compared with the distance-to-empty data which is retrieved as indicated by block **658** from the vehicle bus interface circuit **36**. The program then compares the distance from the vehicle's current location to each of the service areas S_1 and S_2 of FIG. **41** to determine if the remaining fuel is sufficient to reach the second service area S_2 represented by distance X in the test block **660** of FIG. **43**. If this distance is greater than the range available to the vehicle, a notification signal is sent to the driver as indicated by block **662**. This notification signal can take the form of an audible alarm tone, a visual message in alpha-numeric format on a vehicle digital

display contained within circuit **28**, or both. In the example of FIG. **41**, the notification signal alerts the driver that he or she should exit the limited access highway at exit A such that the first service area S_1 can be accessed prior to running out of fuel. Depending on the location information obtained as indicated by block **656**, it is possible that service area S_2, which is on the second exit, is actually closer than service area S_1, and assuming it is less than the distance-to-empty, no notification signal would take place and the testing cycle is repeated as indicated by the connecting line **664** as the vehicle continues to travel along the highway. A notification or alerting alarm would then be sent, most likely between exits A and B and before the vehicle passed exit B.

In place of the automatic system described, the vehicle operator may input specific desired services in addition to or in place of a distance-to-empty last exit service. Thus, for example, the operator may wish to exit the limited access highway to have dinner within a prescribed period of time or at a preferred restaurant. In such case, the system allows the operator to request the locations of such services as shown in phantom in block **655** of flow diagram **650**. The vehicle operator is requested to input information as to a desired available service through two-way pager module **34** or transceiver **70**. This can be done by the operator sequentially receiving one-line messages scrolled on display **619** and actuating a switch **621** when the desired service facility is identified to transmit such selection to the subscription database through pager **34** or transceiver **70**. The database would then send the service facility location back to the vehicle. The microprocessor stores this information and compares it with vehicle location information from GPS receiver **38** to alert the driver to exit when appropriate for the selected service facility. Such information is input to the microprocessor from its receipt from the pager module **34**, transceiver **70** or, alternatively, the on-board database **27** for such service location information as indicated by block **656**. The distance for the selected service can be calculated by the same calculations provided in block **660** to alert the driver as indicated by block **662** to exit the highway at the next exit.

With such a system, therefore, the microprocessor notifies the vehicle operator with a suitable warning that the service necessary or desired should be sought at the forthcoming exit in the case of a limited access highway, or the next crossroad, for example, on a non-limited access highway. As can be appreciated, the system has greater need in situations where a limited access highway is being traveled and exits are spaced at long distances. The system of the present invention automatically assists the vehicle operator in preventing the vehicle from ruing out of fuel and/or assists the vehicle operator in seeking desired services within a prescribed time or other parameter. The unique use of the GPS receiver in combination with an automatically operated or operator prompted two-way pager or transceiver allows location information to be communicated to and from the vehicle from a subscription service database to achieve such an alerting system.

6. Detailed Description of the Vehicle Personalization and Remote Control Functions

As vehicle electronic systems and options become more sophisticated, vehicle owners have many new options for vehicle accessories from which to choose. The rapidly increasing number of new options has led to a nearly infinite number of combinations of options for vehicle accessories that are available. This extremely large number of combinations of vehicle accessory options existing on any one vehicle makes it much more difficult for a buyer to find a vehicle on a dealer's lot having the exact combination of vehicle accessory options that the buyer desires. Further, this wide array of vehicle accessory options that may exist in a particular vehicle increases the likelihood that no two drivers who share the vehicle will be able to agree on which options the vehicle should have. These concerns have given rise to the need for a programmable vehicle personalization system that allows an operator to select accessory operation for that vehicle according to their preferences at any time following the manufacture of the vehicle. U.S. Pat. No. 5,040,990 issued on Aug. 20, 1991, discloses one such system in which selected vehicle options can be programmed by the vehicle operator. U.S. Pat. No. 5,113,182 also discloses a programmable vehicle personalization system. Although programmable vehicle personalization systems exist, there remains a need for a system that does not require extensive effort by the vehicle operator to reprogram the manner in which the vehicle's accessories are controlled.

The present invention provides vehicle personalization to be remotely effected by a service provider using an RF system such as a paging or cellular system. According to one aspect of the present invention, a vehicle owner wishing to reprogram a vehicle, calls the service provider who effects reprogramming of an option control by transmitting RF control signals to the vehicle from a land-based transmitter to a receiver mounted in the vehicle. Thus, because the service provider effects vehicle personalization, the vehicle owner need not have any technical knowledge as to how to operate the vehicle programming system. Another aspect of the present invention is to provide vehicle personalization for each person who may operate the vehicle.

To achieve these aspects and other advantages, the vehicle accessory control system of the present invention includes a plurality of electrically-operated vehicle accessories, a receiver to be mounted in a vehicle for receiving RF signals from a land-based transmitter, and a control circuit coupled to the receiver and to the vehicle accessories for controlling the operation of the vehicle accessories in accordance with a control program. The RF signals include an address uniquely identifying the vehicle and a reprogramming signal for reprogramming the operation of at least one of the vehicle accessories. The control circuit includes an input interface for receiving information regarding a plurality of sensed conditions, control means for controlling the operation of the vehicle accessories in accordance with the control program and in response to sensed conditions received from the input interface. The control circuit further includes reprogramming means for selectively reprogramming the control program in response to the detection of an RF signal including an address identifying the vehicle and the reprogramming signal, to selectively change the manner in which the control means controls the operation of at least one of the vehicle accessories.

Preferably, the vehicle electrical control system for performing the above functions is that described above and shown in FIGS. **3** or **5**. An alternative vehicle electrical control system **730**, is shown in FIGS. **44** and **45**, and include, as shown in FIG. **44**, a microcontroller **735** such as a Motorola MC68HC05, which receives demodulated signals from the receiver **724** shown enclosed within dotted lines in FIG. **44** via a data bus **727**. The receiver **724** may be the receiving portion of the two-way pager module described above or the receiving portion of cellular transceiver **70** (FIG. **5**), but may alternatively be a typical duo-conversion receiver having first and second local oscillators **721** and **723**, appropriate bandpass filters and amplifiers, and a demodulator circuit **725** which provides digital data output on a data bus **727** to an input of micro-

controller **735**. Microcontroller **735** includes an integral non-volatile memory for retaining data when the vehicle is not in operation. In vehicles including a single wire multiplex bus **742**, an output terminal **743** of microcontroller **735** is coupled to the input of a multiplex communication circuit **744** comprising a **728** pin integrated circuit which is coupled by output conductor **747** to a single wire data bus **742**. The average data rate for the multiplex circuit **744** is 10.4 kilobits per second. Microcontroller **735** communicates with circuit **744** through its SPI serial interface port **743**. When circuit **744** receives a message over the bus **742**, it interrupts the microprocessor, which in turn initiates communication with the circuit through its SPI port. Microprocessor **735** then reads the data from the SPI register and acts upon the information. The multiplexing scheme is set forth in SAE standard J1850 and is universally used in the automotive industry.

The vehicle control system **730** includes a power supply **732** which supplies regulated 5- and 12-volt DC to the various individual circuit blocks shown in FIGS. **44** and **45** with the conventional power circuit interconnections not being shown for the sake of simplification of the drawings. Circuit **730** also includes a power control circuit **734** which is coupled to power supply **732** and between the microcontroller and receiver **724** to selectively activate and deactivate the receiver periodically in order to save power as described in greater detail below in connection with the flow diagram of FIG. **46**. The vehicle electrical control circuit **730** further includes an alpha-numeric vacuum fluorescent-type display circuit **740** which is coupled to the microcontroller **735**. Display circuit **740** includes suitable driver circuits as well as the display itself. A push-button lead switch **741** is coupled to microcontroller and a transmit control push-button switch **745** is also coupled to microcontroller **735**. As will be described below, switches **741** and **745** are operator actuated switches which selectively scroll the information displayed on the display **740** and allow memory control of such information. In the case of an automatic telephone dialing system, the transmit switch **745** can be employed for activating a sequence of controls which cause a cellular telephone, if installed in the vehicle, to automatically dial a number displayed on the vacuum fluorescent display **740**.

Coupled to the microcontroller are a plurality of input/output ports **750–764** which provide control output signals or receive input status signals from a variety of vehicle interface controls and circuits identified in the drawings. Depending upon the specific microcontroller used, conventional interface circuits between the microcontroller and the input/output lines **750–764** may be required as is well-known in the art. In the system shown in FIG. **44**, the output terminals **750–764** can be coupled directly to one or more of the variety of control systems shown such as the electrical fuel pump system shown by data bus **762**, the ignition switch input **756**, and the like. Similarly, instead of directly coupling the microcontroller as shown through the data buses **750–764**, many vehicles will include a single wire data bus **742**, which as seen in FIGS. **45** and **47**, intercouples the same control information from microcontroller **735** in receipt of information through the data bus **742** instead of directly through conductors **750–764**. In this instance, many of the conductors **750–764** can be eliminated and the controls are accomplished through an interface microcontroller **770** of the type disclosed in U.S. Pat. No. 5,113,182, the disclosure of which is incorporated herein by reference. For the sake of comparison, the output conductors of microcontroller **770** corresponding to those of microcontroller **735** are identified by similar reference numerals carrying a superscript prime symbol. Thus, the vehicle control circuit **735** shown in FIGS. **44**, **45**, and **47** will be capable of communicating through the data bus **742** or directly from microcontroller **735** to the various interface controls. Microcontroller **770** is coupled by conductor **772** to bus **742** through a multiplex chip **773** of the same type as circuit **744** to provide two-way communication between the two microcontrollers. In the event it communicates through the data bus **742**, additional control circuits as now described are employed.

In the FIG. **45** embodiment of the control circuit **730**, a cellular telephone **775** (FIG. **45**) is mounted in the vehicle and communicates with bus **742** through a data link **774** and a multiplex interface chip **776**. Similarly, the vehicle includes an AM/FM radio **780** coupled to bus **742** through data line **782** and also includes a multiplex interface chip **786**. The vehicle may include a voice recognition system **790** of the type described in U.S. Pat. No. 4,827,520, issued May 2, 1989, and entitled VOICE ACTUATED CONTROL SYSTEM FOR USE IN A VEHICLE, the disclosure of which is incorporated herein by reference. In the event the system includes such a voice recognition and control system, data bus **742** is employed in connection with the voice recognition circuitry which operates in conjunction with microcontroller **770** to provide the desired control of the various vehicle functions. Voice recognition circuit **790** is coupled to a multiplex circuit **796** and conductor **795** to bus **742**. The vehicle may also include an electronic climate control system **792** which has a multiplex interface chip **797** which couples to bus **742** via the conductor **798**.

The software programming of the microcontroller **735** is shown in FIGS. **46A–46K**. The main program routine includes an interrupt timer which periodically interrupts the main program routine to run an interrupt service routine shown in FIG. **46A**. The interrupt service routine is initiated by block **800** upon expiration of the program timer and upon such event the power is applied to the receiver **724** as indicated by block **802** for sampling incoming signals for a period of 250 milliseconds. The demodulator looks for a preamble signal indicated by block **804**. The RF signaling formats preferably provide a preamble digital signal and if one is not detected by the microcontroller, the interrupt counter is reset as indicated by block **806** and the interrupt subroutine and the program returns to the main program as indicated by block **808**. The main program routine starts at block **852** as described below in connection with FIGS. **46E–46K**. In the event a preamble is detected, however, as indicated by an affirmative decision in block **804**, the receiver remains activated as indicated by block **810** for receiving one of two different vehicle addresses uniquely associated with the vehicle. If either of these addresses is received, as indicated by block **812**, a correction subroutine as shown in FIG. **46B** is conducted to assure that the address has been correctly received. The first vehicle address is one in which a vehicle option is to be changed by a subsequently-transmitted control signal. The second address is one which is followed by a telephone number or alpha-numeric message to be displayed. Each of these addresses is uniquely associated with a single vehicle.

The error correction routine is a standard subroutine for the different RF messaging systems. The bit error correction subroutine is initiated as indicated by block **813** of FIG. **46B**. The error correction subroutine **812** reads an address or message data block as indicated by block **814** and divides binary format constants indicated in block **816** for the respective paging formats and stores the remainder which is known as the syndrome as indicated by block **818**. Then a

test is conducted, as indicated by block **820**, to determine whether the syndrome is zero. If it is, the data is correct and the program returns to the interrupt service routine from the bit error correction subroutine as indicated by block **822**. If, however, the syndrome is not zero, the data is corrected by the bit indicated by the syndrome as shown by block **824** and the data is retested through the loop including blocks **816–820**.

Once the bit error correction subroutine has been completed and a correct preamble detected, the interrupt service routine proceeds to test as indicated in FIG. **46**C, block **830**, whether one of the vehicle's addresses has been detected. If no address is received for the particular vehicle into which the preprogrammed addresses of microcontroller **735** are installed, the program returns to port B of FIG. **46**A as indicated by block **832** and the interrupt counter is reset and the program returns to the main information display program described below.

If, however, one of the vehicle's addresses has been detected, the program tests, as indicated by block **834** (FIG. **46**C), whether the address is an information address or an option personalization address. If the vehicle owner or operator has called the service dealer asking that an option be activated or deactivated, the transmission of the address corresponding to the personalization code (i.e., first address) and the data corresponding to the activation of the option selected will be received and the control command decoded to provide a control signal to effect the option change as indicated by block **836** of FIG. **46**C. The signal is then either outputted by one of the conductors **750–764** shown in FIG. **44** of microcontroller **735** or through the multiplex circuit **744** to the multiplex bus **742** for subsequent receipt by the vehicle's microcontroller **770** shown in FIG. **45** to effect the change in the vehicle option. The details of changing a vehicle option are described below with reference to FIGS. **48–56**. In most instances, a bit or bytes are set into the NVM of microcontroller **735** to cause the vehicle option to respond as requested. Thus, for example, line **760** may send a control signal upon the selection of the "express window" feature to cause the driver's window to fully lower or raise in response to the activation of the window control switch for a predetermined period of time. This feature can be activated or deactivated by the setting of a switch in the microcontroller memory. As indicated by block **838**, the microcontroller also provides a display output signal which is applied to the alpha-numeric display **740** to indicate to the owner that the option requested has been changed as requested. The program then returns to the interrupt service routine input B of FIG. **46**A.

The anti-theft feature of the system operates in the same manner as one of the vehicle option changes. Typically, if a vehicle is stolen, the owner will call the service center **11** indicating the theft. The service center operator then will transmit the first vehicle address and an anti-theft control command signal which the microcontroller responds to by outputting a signal on line **762** (FIG. **45**) to deactivate the vehicle's fuel pump. For safety, the program responds to the anti-theft command to output the fuel pump disabling signal only after the ignition switch has been deactivated and thus the vehicle has come to rest. Alternative or additional anti-theft commands are also possible. Thus, a theft alarm signal output on line **759** (FIG. **45**) could be activated to enable the vehicle's audible alarm. Also, instead of deactivating the vehicle's fuel pump, the vehicle's ignition could be interrupted. In some areas, the police department may provide the anti-theft signal transmission facilities such that the owner can report the theft and take affirmative action to protect the vehicle from damage through one telephone call.

If the vehicle address received is not a first address for an option change or anti-theft control but instead is an address identifying a text message (i.e., a second address) as opposed to a vehicle option control signal, the test in block **834** indicates an address and the program receives and decodes a text message as indicated by block **840** in FIG. **46**C. Again, the bit error correction subroutine **812** of FIG. **46**B is rum to assure the accuracy of the incoming preamble and subsequent address and data as indicated by the block **812** subroutine. Once the subroutine of FIG. **46**B has been completed, the message of the incoming signal is placed in the memory as indicated by block **842** of FIG. **46**C. The program then proceeds to scan the text message to determine whether or not a telephone number has been received as indicated by block **842** of FIG. **46**D.

If a telephone number is detected in the incoming message as indicated by an affirmative response to the test of block **844**, the number is stored in the stack as described below and the number received flag is set as indicated by block **846**. The program then proceeds to block **848** and if a telephone number was present, it is displayed on the alpha-numeric display **740** of FIG. **44** in addition to being stored. This operation is indicated by block **848** of the flow diagram. Next, the microcontroller outputs a signal through the microcontroller indicated by block **850** to alert the owner that a message has been received. This can be a chime coupled to a vehicle multiplex bus **742** which is also used, for example, to alert the driver that a door is open with the key in the ignition, etc., or can be a flashing LED or the like. Subsequent to alerting the driver that a page has been received, the program proceeds to the interrupt routine at input B of FIG. **46**A as previously described. In the event a two-way communication system is used, the microprocessor will display any choices of responses that were transmitted with the message, and will allow the user to select one of the predetermined responses to transmit back to the service center and to the originator of the first message.

The microcontroller program includes a main program routine which provides a variety of informational displays and message storing, erasing and display features for the vehicle operator in addition to the automatic remote vehicle option control described above. Thus, in addition to the interrupt routine described in connection with FIGS. **46**A–**46**D, the main program routine for the microcontroller provides a variety of message storing, displaying, and controlling functions as now described.

Referring to FIG. **46**E, the main program routine of the microcontroller starts as indicated by block **852** upon power-up and initializes memory pointers and flags as indicated by block **854**. The input port A from the interrupt routine indicated in FIG. **46**A precedes the program test indicated by block **856** of the status of transmit and reads switches **745** and **741**, respectively (FIG. **44**). The program first tests to determine whether or not the transmit push-button switch was depressed as indicated by block **858** and if it was, it scans the information displayed to determine whether or not a telephone number exists. This is indicated by block **860** whereupon the program tests to determine whether a telephone number was found in the message as indicated by block **862** of FIG. **46**F. It is noted that in FIGS. **46**A–**46**K, the interconnections of the flow diagram ports are identified by corresponding letters.

If no telephone number was found, display **740** displays the no telephone number message as indicated by block **864** for three seconds and redisplays the current information, whereupon the program proceeds to input A of FIG. **46**E and recycles. If a telephone number was found, as indicated by

an affirmative test in block **862**, and the vehicle includes a cellular telephone which is coupled through the multiplex bus **742** to the microcontroller **735**, the vehicle operator can automatically dial the displayed telephone number. For this purpose, the program presents a dialing message to the vehicle operator as indicated by block **866**. If the operator wants to auto-dial the displayed number, the transmit or call button was actuated as previously indicated by the test of block **858** in FIG. **46**E and the detection and display of a telephone number in the message. The program then tests to determine whether or not telephone connection was made by the cellular telephone and if not, the program proceeds to block A of FIG. **46**E and cycles through the test loop again. If a telephone call was successfully placed, the call message is advanced to the old stack as described in connection with FIG. **46**G now described and the display pointer is reset thereupon the program returns to port A of FIG. **46**E.

FIG. **46**G illustrates the memory mapping for incoming messages. The program permits the vehicle operator to lock desired messages into a block of memory, for example, memory space for five alpha-numeric pages **871–875** is provided. These messages will be, depending upon the desired degree of sophistication for the system, numeric, or alpha-numeric messages having 24 characters. The information can displayed in the 20-character display **740** of FIG. **44** by sequentially displaying 12 characters at a time. This can be done automatically if desired, or the read switch **741** can be activated for scrolling to the second half of the displayed message. Incoming messages are displayed at the current memory location **876** while the system includes five old message memories in a first-in-last-out (FILO) storage system indicated by memory blocks **877–881**. Locked messages, as discussed below, will remain in memory for future reference regardless of the number of incoming messages while the old messages, unless locked, will be sequentially dumped from the last memory location **881** upon receipt of incoming messages which bump the incoming message from the previous message from block **876** to block **877**. This is indicated by block **870** of FIG. **46**F of the flow diagram.

Returning now to FIG. **46**E, if the transmit button has not been actuated as indicated by a negative decision on block **858**, the program tests to determine whether or not the read switch **741** of FIG. **44** has been actuated as indicated by block **882**. If the read switch was not depressed, the program cycles through tests **856**, **858**, and **882** with the periodic interrupt routine set forth in FIGS. **46**A–**46**D being conducted to the interrupt to this main routine and checks for incoming option control or messages. If the read switch has been actuated, a three-second counter for locking the message is reset as indicated by block **884**. The program then proceeds to port E of FIG. **46**H. How long the read switch is being depressed determines a variety of functions of the system. If the read switch is momentarily depressed (i.e., released within three seconds as indicated by the test of block **886**), the display stack pointer is incremented and the next message is displayed as indicated by block **888**. If, however, the switch is held down beyond three seconds, as indicated by a negative test at block **886** and a positive result of test block **890**, the program displays to the vehicle operator a lock message inquiry asking the operator if the message (i.e., displayed message) should be placed in one of the locked message memory locations **871–875** shown in FIG. **46**G. If upon receiving this prompt the vehicle operator releases the read switch, the previously-displayed message information will be placed in a locked message memory location. At the time the lock message is displayed, the three-second counter for a delete message is reset as indicated by block **894** and the program proceeds to port F of FIG. **46**I to determine whether or not the operator continues to depress the read switch. If the read switch has been released indicating the operator would like to lock the message into memory, test **896** of FIG. **46**I will be affirmative and the program proceeds to port G of FIG. **46**J.

The program then tests to determine if the locked stack (i.e., memory locations **871–875**) is full as indicated by block **898**. If not, the incoming message being displayed is stored in memory block **871** and the remaining locked memory messages are shifted downwardly as indicated by block **900** (FIG. **46**J). The program then returns to port A of FIG. **46**E. If the locked message memory stack is fall, an affirmative test at block **898** causes the message locked memory full to be displayed as indicated by block **902** to the vehicle operator and then the program returns to port A of FIG. **46**E. This all occurs within the three- to six-second interval while the vehicle operator is holding the read button in a depressed condition.

If the read switch remains depressed beyond six seconds, as indicated by block **904** of FIG. **46**I, the program tests to see if the previously reset three-second timer has timed out, if not, it continues testing to determine whether or not the read switch has been released. If the three seconds (now six seconds total) has expired, the delete message indicator is displayed on the display **740** as indicated by block **906**. This presents the vehicle operator a three-second interval between the six-and nine-second time period in which to, as described below, delete the message from the memory. Initially, the three-second counter for the "cancel" message is reset as indicated by block **908**. The program proceeds to input H of FIG. **46**K. At this time, the operator has held the read switch in for a period of six seconds and a message "delete message" is being displayed. If the read switch is released, as indicated by block **910** of FIG. **46**K, the displayed message is deleted from memory and the remaining memory messages are advanced as indicated by block **912** and the program proceeds to port A of FIG. **46**E. If the displayed message is not desired to be deleted, the operator can hold the read switch down, as indicated by block **914**, until the six- to nine-second time period has been exceeded and the three-second timer again times out presenting a "cancel" message to the vehicle operator as indicated by block **916**.

At this point in time, the vehicle operator can release the read switch **741** as indicated by block **918** and the current message is again displayed and the program returns to port A of FIG. **46**E thus allowing the vehicle operator to cycle through the memory to determine whether or not the operator desires to insert a message into a locked memory location if the memory is full. Thus, by using a single switch **741**, the vehicle operator can sequence through stored messages of display information including locked messages and insert messages into the locked message memory as desired. By only momentarily depressing the read button, the sequence of messages shown in FIG. **46**G are displayed to the vehicle operator and, if desired, any telephone number contained in any of such messages can be automatically dialed by actuating the transmit button when the message is currently displayed on display **740**.

Thus, the system of the present invention provides a vehicle with a receiver for receiving a vehicle option control address and command signals for changing a vehicle option remotely and one which can also receive a paging address and paging message. In one embodiment, the system is capable of both functions and the receipt of alpha-numeric

messages which can be employed for automatically dialing a cellular telephone if the vehicle has a telephone installed and connected to the multiplex bus or otherwise directly wired to a serial data port such as an RS-232 port of microcontroller **735**. Cellular telephones typically include input ports for such purpose. Similarly, the microcontroller interfaces with a plurality of vehicle accessories indicated by conductors **750–764** or through the multiplex computer **770** of FIG. **45** to such systems for activation or deactivation of a variety of vehicle options.

As shown in FIG. **47B**, the vehicle may also include a plurality of other control modules $\mathbf{1000}_1$-$\mathbf{1000}_N$ each associated with a controlled vehicle accessory and having a multiplex interface chip $\mathbf{1010}_1$-$\mathbf{1010}_N$ coupled to bus **742** via conductors $\mathbf{1020}_1$-$\mathbf{1020}_N$, respectively. Control modules $\mathbf{1000}_1$-$\mathbf{1000}_N$ may be associated with one or more of the following vehicle accessories in various combinations thereof. The associated vehicle accessories may include: a door locking actuator for each door; a window opening actuator for each movable window; a sunroof actuator; vehicle headlights; horn; seat position actuators; seat heaters; mirror position actuators; a rearview mirror reflectivity adjusting circuit; a compass; vehicle gauges; vehicle displays; interior lighting; a rear defrost circuit; a fuel door locking mechanism; a trunk locking mechanism; and various circuits for producing an audible chime within the vehicle's interior.

In addition to those inputs to microcontroller **735** or microcontroller **770** as shown in FIGS. **44**, **45**, and **47**, respectively, various other input signals may be provided including input signals from the following: each of the window switches; a circuit for detecting whether a key is in the ignition; a speedometer; an RPM detecting circuit; a battery voltage detecting circuit; a fuel level sensor; the turn signal circuit; ambient light sensors; a reverse gear switch input; a drive gear switch input; a park gear switch input; a rain sensor; an interior thermometer; an exterior thermometer; an engine temperature sensor; an oil pressure sensor; a rear defrost switch; door open/closed sensors; a driver's exterior door lock sensing circuit; and a headlight switch. As will be apparent from the following description of the operation of the foregoing system, microcontroller **735** and microcontroller **770** utilize various combinations of these input signals to control the various vehicle accessories associated with the control modules connected to multiplex bus **742** in a manner defined by a control program stored in a non-volatile memory of the respective microcontroller.

FIGS. **48–56** show an example of a main control program and its various subroutines that may be used to control the operation of various combinations of vehicle accessories. Upon reading this Specification, those skilled in the art will recognize that such a control program may be implemented in many different forms taking into account the large number of possible combinations of vehicle accessories that the main control program is responsible for controlling. Further, those skilled in the art will recognize that various functions of the exemplary main control program may be delegated to microcontroller **770** and/or the various control modules associated with the vehicle accessories. It should be noted that the previously-described main pager program routine described above with respect to FIGS. **46A–46K**, may be incorporated into the main control program described below as an integral part or called subroutine.

In general, the main control program utilizes a modifiable data structure to determine which of several possible subroutines to execute in response to a given input signal. As exemplified in the main control program as described below, such a data structure may take the form of a plurality of tables, each associated with one of several vehicle operators, including a plurality of entries corresponding to flags read from these tables by the main control program to determine the desired accessory control operations to be executed in association with the current vehicle operator.

Referring to FIG. **48A** during system initialization, microcontroller **735** begins the execution of the main control program by clearing its RAM, recalling the last user ID by reading the same from the non-volatile memory, and reading a flag table associated with the last ID (step **1201**). Initially, the associated flag table may be set in the factory or by the dealer to specify default values. As described below, the flags in the flag table may subsequently be modified by a reprogramming signal included in either a paging signal or a cellular RF control signal having the vehicle's ID.

Following initialization, microcontroller **735** periodically wakes from a sleeping state to turn on its RF receiver to determine whether a signal is received from an RKE transmitter (step **1203**). If the RKE transmitters associated with the vehicle each transmit different user IDs, microcontroller **735** may be programmed to read the ID from the signal transmitted from the RKE transmitter and compare the received ID with that stored in memory in association with the last user ID (step **1205**). If a new ID has been received, microcontroller **735** selects the flag table associated with the new ID and sets a new ID flag for subsequent reference (step **1207**) prior to executing an RKE subroutine (step **1209**). On the other hand, if the received ID is the same as the last ID, or if the transmitted signal does not include a user ID, microcontroller **735** proceeds directly to the steps defining the RKE subroutine **1209**.

Referring to FIGS. **49A** and **49B**, which show the steps performed in RKE subroutine **1209**, microcontroller **735** first will determine whether the person activating RKE transmitter double-clicked any of the RKE transmitter buttons (step **1401**). If microcontroller **735** detects a double-click, it then checks a predefined location within the flag table associated with the user ID to determine whether a flag has been set to instruct microcontroller **735** to perform a panic routine in which microcontroller **735** responds to a double-click by honking the horn and flashing the headlights (step **1405**) prior to returning to the main control program at step **1211** (FIG. **48A**). If microcontroller **735** does not detect a double-click, or if the double-click panic flag is not set, microcontroller **735** determines whether the signal received from the RKE transmitter corresponds to a door lock signal (step **1407**).

In the example shown in FIG. **49A**, there are two options that may be set to change the manner by which the microcontroller **735** controls the vehicle accessories in response to an RKE lock signal. The first option prevents the user from locking the vehicle when a key is detected in the ignition. To implement this option, the RKE subroutine **1209** first checks whether the associated flag has been set in the flag table (step **1409**) and then checks whether an input signal is received from an ignition key sensor (step **1411**). If a key is in the ignition, microcontroller **735** will not lock the doors and will proceed to step **1211** in the main control program. If a key is not in the ignition, or if the flag is not set for this option, microcontroller **735** proceeds to lock all the doors of the vehicle (step **1413**).

The second option associated with an RKE lock signal is to honk the horn after the doors have been locked as a confirmation to the vehicle operator. Thus, after locking all the doors in step **1413**, microcontroller **735** next determines whether the flag associated with this second option has been

set (step **1415**). If the flag has not been set, microcontroller **735** proceeds to execute step **1211** in the main control program and the routine for honking the horn after locking all the doors would remain a dormant subroutine which could not be executed unless the flag associated with this option has been set in the flag table associated with the user.

If in step **1407** microcontroller **735** determines that the transmitted RKE signal is not a lock signal, it will then determine whether the receive signal is an unlock signal (step **1419**). If the receive signal is an unlock signal, microcontroller **735** determines whether a flag has been set to instruct microcontroller **735** to unlock the driver's door (step **1421**). If the flag has been set, microcontroller **735** only unlocks the driver's door in response to the RKE unlock signal (step **1423**). However, if this flag has not been set, microcontroller **735** unlocks all the doors in response to a received RKE unlock signal (step **1425**).

RKE subroutine **1209** provides for several selectable control routines that microcontroller **735** may execute in response to receiving an RKE signal from a third button on the RKE transmitter. Thus, if in steps **1407** and **1419**, microcontroller **735** determines that the received RKE signal is not a lock or unlock signal, it assumes the receive signal is associated with a third RKE button and determines in steps **1427**, **1431**, **1435**, **1439**, **1443**, and **1451** which control operation is to be performed in response to the received RKE signal by checking the associated flags at predetermined locations in the flag table. In response to a signal corresponding to the third RKE button, microcontroller **735** may unlock the fuel door (step **1429**), unlock the trunk (step **1433**), turn on and off the headlights (step **1437**), honk the horn (step **1441**), lock the doors (step **1449**), or unlock either the driver's door (step **1455**) or all the doors (step **1457**). If the flag is set for the third RKE button to lock the doors, microcontroller **735** may determine whether the flag is set (step **1445**) to honk the horn (step **1447**) to confirm that all the doors have been locked (step **1449**). Further, if the flag is set for the third RKE button to unlock the doors, microcontroller **735** can determine whether to unlock only the driver's door or all the doors by checking whether a flag is set in the flag table (step **1453**).

Referring back to FIG. **48**A, if microcontroller **735** determines in step **1203** that a signal has not been received from an RKE transmitter, or following completion of the RKE subroutine **1209**, microcontroller **735** checks whether an input is received from a circuit detecting whether the driver's door is being unlocked from the exterior with a key (step **1211**). If a user ID may be input from a keypad on the exterior surface of the door or from a key itself, microcontroller **735** determines whether a detected ID is different from the last ID stored in memory (step **1213**). If the ID is not different, microcontroller **735** selects the flag table associated with the last ID stored in memory and proceeds to execute subroutine **1217**. Otherwise, microcontroller **735** selects a flag table associated with the new ID (step **1215**) prior to executing subroutine **1217**.

Subroutine **1217** is shown in FIG. **50** and begins with step **1501** in which microcontroller **735** checks whether an unlock all doors flag has been set. If this flag has been set, microcontroller **735** unlocks all the vehicle's doors (step **1503**) in response to a door unlock signal received through the keyslot or keypad on the exterior of the driver's door. Alternatively, if the unlock all doors flag is not set, microcontroller **735** unlocks only the driver's door (step **1505**).

In association with the keyslot on the driver's door, three different options may be selected upon a detection of a second rotation of the key in the keyslot (step **1507**). If an unlock trunk flag is set (step **1509**), microcontroller **735** unlocks the trunk (step **1511**). If the unlock trunk flag is not set, but an unlock fuel door flag is set (step **1513**), microcontroller **735** may unlock the fuel door (step **1515**). If neither the unlock trunk nor the unlock fuel door flags are set, microcontroller **735** may do nothing in response to a detection of a second rotation of the key in the keyslot. If a second rotation is not detected, or after the preprogrammed function has been executed, microcontroller **735** proceeds to execute step **1219** in FIG. **48**B.

In step **1219** of FIG. **48**B, microcontroller **735** checks whether a new driver ID signal has been received. Because various mechanisms may be used to input a driver's ID such as a keypad or a user ID dedicated push-button, it may be appropriate for microcontroller **735** to monitor such input mechanisms to determine whether a new driver ID signal has been received. If a driver ID signal is received that is the same as the last user ID stored in memory, or if no new driver ID signal is received, microcontroller **735** leaves all the settings in the vehicle to those last used by the driver with the last ID stored in memory (step **1221**) and the program advances to step **1281** shown in FIG. **48**F. If a new driver ID signal is received, microcontroller **735** executes a routine (steps **1223**–**1279**, FIGS. **48**B–**48**E) to initialize various vehicle accessories to those preferred and set by the driver with the received new driver ID utilizing the flag table associated with this new ID (step **1223**).

A first vehicle accessory that may be initialized is the position of the driver's seat. Thus, if the driver with the new ID has selected the last seat position memory feature, microcontroller **735** will determine in step **1225** that the associated flag has been set and will set the seat position to that last used by the driver with the new ID by reading seat positioning parameters stored in non-volatile memory the last time this driver used the vehicle (step **1227**). Next, microcontroller **735** will check whether a flag is set for a last mirror position feature (step **1229**) which, if selected, causes microcontroller **735** to set the mirror positions to that last used by the driver with the new ID (step **1231**). If this flag is not set, the routine for setting the mirror positions is dormant with respect to the driver with the newly detected ID.

If the vehicle includes mirrors with electronically adjustable reflectivity, microcontroller **735** may check whether a flag has been set for a last mirror reflectivity feature (step **1233**). If the flag has been set for this feature, microcontroller **735** sets the mirror reflectivity to that last used by the driver with the new ID in step **1235**.

In step **1237** (FIG. **48**C) microcontroller **735** determines whether the vehicle ignition is on. If the vehicle ignition is not on, microcontroller **735** advances to step **1281** in FIG. **48**F and skips the remaining portion of the new user initialization routine. If the ignition is on, microcontroller **735** proceeds in step **1239** to determine whether a flag has been set for a last temperature setting feature. If the flag has been set for this feature, microcontroller **735** will set the interior temperature for the climate control system to that last used by the driver with the new ID by retrieving the last used temperature setting from the non-volatile memory (step **1241**).

If the vehicle includes a compass that allows for selection of a feature that computes variations in heading based on the geographic location of the vehicle, microcontroller **735** may determine in step **1243** whether the flag associated with this feature has been set. If the flag has been set, the compass will be initialized for variation based on geographic location (step **1245**). Otherwise, the compass will be initialized for operation without variation for geographic location (step **1247**).

Next in step **1249** (FIG. **48**D), microcontroller **735** may check whether a flag has been set for a last radio volume feature (step **1249**). If the last radio volume feature has been selected by the user with the detected ID, microcontroller **735** sets the radio volume to that last used by the driver with the new ID (step **1251**).

If a flag has been set for a last radio station feature, microcontroller **735** will detect if the flag has been set (step **1253**) and set the radio station to that last used by the driver with the new ID (step **1255**). Similarly, if microcontroller **735** detects that a flag has been set for a radio preset memory feature (step **1257**), microcontroller **735** sets the radio station presets to those last used by the driver with the new ID (step **1259**).

If the vehicle radio includes a display that displays either the radio station or the time of day, a vehicle operator may wish to select what is displayed on the radio display as a default condition. Thus, microcontroller **735** may look for a flag corresponding to a radio station display default in step **1261** and display the radio station as a default on the radio display (step **1263**) if the flag is set. Otherwise, the time of day will be displayed on the radio display as a default.

As vehicle sophistication improves, more and more vehicles will include alpha-numeric displays to convey information to the vehicle operator. Because such vehicles may be used in countries having different primary languages, it is advantageous to allow for different languages to be displayed on the vehicle's alpha-numeric display. Moreover, it would be even more advantageous to provide for a vehicle alpha-numeric display that can be programmed to display different languages for different drivers that may use the vehicle. To this end, the main control program includes a step (**1265**) that causes microcontroller **735** to check whether a flag for a non-default language (i.e., English) has been selected for the vehicle displays. If the flag has been set, microcontroller **735** sets the display language to that last used by the driver with the new ID (step **1267**) by setting a pointer to a set of memory addresses at which the selected language display messages are stored.

A related feature provided by the present invention permits the vehicle operator to select display parameters such as Fahrenheit or Centigrade, miles or kilometers, miles per hour or kilometers per hour, and/or gallons or liters, to be displayed in the vehicle's gauges and other display screens. Thus, in step **1269**, microcontroller **735** first checks whether a flag has been set for a non-default display parameter and then sets the display parameters to those last used by the driver with the new ID (step **1271**) if the flag has been set.

The present invention further allows each vehicle operator to customize the vehicle's displays by reconfiguring message screens and, if desired, the message screen location. Thus, if a vehicle includes several message screen displays, a vehicle operator may reconfigure these displays such that a compass heading is displayed on a different message screen than that used in a default condition. Therefore, if microcontroller **735** determines in step **1273** that a flag is set for a non-default display configuration, it will set the display configuration to that last used by the driver with the new ID (step **1275**).

If the vehicle employs a reconfigurable instrument panel display, the present invention allows for the vehicle operator to reconfigure the display gauges on the instrument panel display by changing their location, size, color, or existence as displayed on the instrument panel. To allow various vehicle operators to select their desired preference, microcontroller **735** determines in step **1277** whether a flag has been set for a non-default gauge configuration and sets the gauge configuration to that last used by the driver with the new ID in step **1279** if the flag has been set.

After completing steps **1277** and **1279**, microcontroller **735** has completed the steps associated with initializing the vehicle for a driver having a new ID that is different from that of the last ID stored in memory. It will be appreciated by those skilled in the art that the settings associated with the last driver will be maintained and utilized during initialization provided a new user ID is not received. Following this initialization process, microcontroller **735** monitors a timer to determine when to interrupt the main program to look for an RF signal (step **1281**). If it is time to interrupt the main program, microcontroller **735** executes interrupt service routine **1283**, which is described above with reference to FIGS. **46**A, **46**B, and **46**C.

If an RF signal is received and the detected address corresponds to a personalization address, microcontroller **735** receives and decodes the RF signal and corrects errors therein using the bit error correction subroutine and subsequently defines the function in the reprogramming signal that is to be changed (step **836**). Microcontroller **735** may determine from the received reprogramming signal which function is to be changed by accessing a look-up table and identifying which flags correspond to the commands included in the reprogramming signal. After identifying the flags corresponding to these commands, microcontroller **735** modifies the data structure it utilizes in determining the manner in which to control vehicle accessories by setting or resetting the flags in the flag table corresponding to a user ID also transmitted in the personalization RF signal. In this manner, microcontroller **735** reprograms the main control program as used to control vehicle accessories for a particular vehicle operator.

As apparent from the foregoing and following description of the control program, the main control program includes both active and dormant subroutines which may be activated or deactivated by the setting or resetting of its associated flag. Upon reading this disclosure, those skilled in the art will recognize that various other data structures or mechanisms may be employed to reprogram the manner in which a vehicle accessory control system controls the operation of the vehicle accessories in response to detected conditions, parameters, or vehicle operator initiated activation signals. For example, the various selectable routines defining manners in which a vehicle accessory can be operated may be separately stored and executed by the control module associated with that vehicle accessory whereby the main control program either alters the data structure used by the routines in the control module or relays the reprogramming signal to the appropriate control module, which alters the data structure used by its associated control routine. In such a case, the various control modules may directly receive and act upon a sensed condition, parameter, or vehicle operator initiated activation signals. Thus, the various routines and subroutines of the main control program may be separated and delegated to the various accessory control modules and be independently executed. Alternatively, the main control program could modify the data structure it uses itself to determine a particular command to issue to a vehicle accessory control module to activate the desired one of the subroutines stored in the control module.

If it is not time for the interrupt service subroutine to be executed or if the interrupt service routine has been executed, microcontroller **735** proceeds to execute step **1285** in FIG. **48***f*. In step **1285**, microcontroller **735** checks whether a flag has been set to turn off the headlights if the

battery voltage is low. If the flag is set, microcontroller **735** reads the detected battery voltage VB and compares the detected battery voltage VB to a threshold voltage V to determine whether the battery voltage is below a low voltage threshold (step **1289**). If the battery voltage is below this threshold, microcontroller **735** will turn off the headlights if they were on (step **1291**) to prevent further drain on the vehicle's battery.

Another feature that may be selected is to open the windows or a sunroof if the temperature in the interior of the vehicle exceeds a threshold temperature T1 to keep the interior of the vehicle relatively cool. Although this feature may be desirable for some individuals, it may be undesirable to other individuals who, for example, may frequently park their vehicles in a high crime area. Thus, the present invention provides the flexibility for each vehicle operator to select how microcontroller **735** will respond when (in block **1293**) the interior temperature of the vehicle exceeds a threshold temperature T1. To prevent the windows or sunroof from being opened when it is raining, microcontroller **735** may first determine whether rain is sensed by a rain sensor in step **1295**. If it is raining, microcontroller **735** will not open the windows or sunroof. However, if it is not raining, microcontroller **735** will then check whether a flag has been set to open the windows when the interior temperature exceeds the threshold (step **1297**). If the flag has been set, microcontroller **735** will open the windows by a predetermined amount (step **1299**). If the flag for opening the windows has not been set, microcontroller **735** will check whether the flag has been set to open the sunroof (step **1301**). If the flag has been set, microcontroller **735** will issue the appropriate signal via multiplex bus **742** to an actuator for opening the sunroof (step **1303**). If the flag has not been set, microcontroller **735** will proceed to step **1305** (FIG. **48**G) without opening the windows or the sunroof.

If the interior temperature of the vehicle is below a lower, second temperature threshold T2, as may be the case during winter time (step **1305**), microcontroller **735** checks whether a flag has been set to heat the vehicle seats when the interior temperature falls below the second threshold T2 (step **1307**). If the flag has been set, microcontroller **735** will cause the vehicle's seats to heat (step **1309**). If the flag is not set, the routine associated with heating the seats is effectively disabled and the program advances to step **1311** where microcontroller **735** determines whether the rain sensor has detected rain. If rain is detected, microcontroller **735** executes a rain subroutine **1313** which will now be described in detail with reference to FIG. **51**.

If rain is detected, microcontroller **735** checks whether a flag is set to close the windows (step **1701**). If the flag is set, microcontroller **735** will issue the appropriate control signals to the window actuators to close the windows (step **1703**). Then, microcontroller **735** will check whether a flag has been set to close the vehicle's sunroof (step **1705**). If the flag has been set, microcontroller **735** will issue the appropriate command to close the sunroof (step **1707**). Following execution of the rain subroutine **1313**, microcontroller **735** executes step **1315** (FIG. **48**G) to determine whether the vehicle's headlights are presently on. If the headlights are on, microcontroller **735** executes a headlights ON subroutine **1317**, which is described in detail below with reference to FIG. **52**.

In the headlights ON subroutine **1317**, microcontroller **735** first tests whether the vehicle ignition is off (step **1709**). If the ignition is off, microcontroller **735** exits the headlights ON subroutine and returns to step **1319** (FIG. **48**G) of the main control program. If, on the other hand, the vehicle ignition is off and the headlights are on, microcontroller **735** determines in step **1711** whether a delay flag or an indefinite ON flag has been set. If neither flag has been set, microcontroller **735** turns off the headlights (step **1713**) and returns to the main control program. If one of these flags are set, microcontroller **735** then determines whether the flag that is set is the indefinite ON flag (step **1715**). If the indefinite ON flag is set, microcontroller **735** returns to the main control program without turning off the headlights. If the indefinite ON flag is not set, microcontroller **735** assumes that the delay flag has been set and waits for the predetermined delay time (step **1717**) before turning off the headlights (step **1719**) and returning to the main control program.

The next step in the main control program instructs microcontroller **735** to determine whether an interior door lock switch has been depressed (step **1319**). If an interior door lock switch has been depressed, microcontroller **735** executes an associated subroutine **1321**, which is described below with reference to FIG. **53**.

The subroutine **1321** associated with the activation of an interior door lock switch begins with step **1721** which causes microcontroller **735** to determine whether a flag has been set for a feature preventing the doors from being locked when a key is in the ignition. If this flag is set, microcontroller **735** determines whether there is a key in the ignition (step **1723**). If a key is in the ignition, microcontroller **735** activates a chime (step **1725**) and returns to the main control program without locking the doors in response to the activation of the interior door lock switch. If the key is not in the ignition or if the flag associated with this feature has not been set, microcontroller **735** next determines whether a flag has been set for a last door locks all doors feature (step **1727**). If this flag has been set, microcontroller **735** determines whether a door is presently open (step **1729**). If a door is presently open, microcontroller **735** will wait until all the doors are closed (step **1731**) before advancing to step **1733** in which microcontroller **735** determines whether a flag is set to delay the activation of the locks for a predetermined time after all of the doors are closed. If this flag has been set, microcontroller **735** will wait for this predetermined time period (step **1735**) and again check whether a door has subsequently been opened (step **1737**). If a door has been reopened, microcontroller **735** returns to step **1731** where it waits until all doors are closed. Once all the doors are closed and remain closed for the predetermined time period, microcontroller **735** locks all the doors (step **1739**) and returns to the main control program. If, in step **1733** the delay flag is not set, microcontroller **735** immediately proceeds to step **1739** and locks all the doors without rechecking whether a door is subsequently opened.

If, in step **1727** microcontroller **735** determines that the flag for the last door locks all doors feature has not been set, microcontroller **735** then checks whether a flag has been set to delay the locking of the doors following the activation of an interior door lock switch (step **1741**). If the delay flag has not been set, microcontroller **735** immediately locks all doors (step **1739**). On the other hand, if the flag has been set, microcontroller **735** waits a predetermined time period (step **1743**) before locking all doors (step **1739**) and returning to the main control program.

The main control program resumes at step **1323** (FIG. **48**H) where it is determined whether the vehicle ignition is on. If the vehicle ignition is on, the main control program advances to step **1337** in FIG. **48**I and if the ignition is off, microcontroller **735** determines whether the ignition was just turned off (step **1325**). If the ignition was not just turned

off, the main control program returns to its beginning at step **1203** in FIG. **48**A as denoted by connection port A.

If the vehicle ignition was just turned off, microcontroller **735** checks whether a flag has been set for controlling the interior lights in response to the vehicle ignition being turned off (step **1327**). If the flag has not been set, the main control program returns to step **1203** (FIG. **48**A) of the main control program. If, however, the flag has been set, microcontroller **735** turns on the vehicle's interior lights (step **1329**) and starts a timer. The interior lights remain on until one of the following events takes place—the expiration of a predetermined time period of, for example, thirty seconds (step **1331**) or the detection that a door has been opened and subsequently closed (step **1333**). Once one of these events has occurred, microcontroller **735** turns off the interior lights (step **1335**) and the program returns to step **1203** at the beginning of the main control program.

As described above, if the vehicle ignition is detected as being on in step **1323**, the main control program advances to step **1337** in FIG. **48**I where microcontroller **735** determines whether a flag has been set for a low fuel level warning chime. If this flag has been set, microcontroller **735** checks the fuel level on the associated input line and determines in step **1339** whether the detected fuel level is below a low fuel level threshold F. If the fuel level is low, microcontroller **735** will activate a warning chime (step **1341**) which may chime once or at a predetermined interval of, for example, once every five minutes.

Next, microcontroller **735** checks whether a flag has been set for an engine temperature warning chime (step **1343**). If this flag has been set, microcontroller **735** obtains the detected engine temperature from the associated input terminal and determines whether the engine temperature exceeds a threshold temperature T3 (step **1345**). If the detected engine temperature T3, microcontroller **735** will activate a warning chime (step **1347**) once or at periodic intervals.

Another warning chime that may be set corresponds to a low oil pressure. Because this feature is optional, as are the other features relating to warning chimes, microcontroller **735** first determines whether the flag has been set for the oil pressure warning chime (step **1349**). If the flag has been set, microcontroller **735** reads the detected oil pressure from the associated input terminal and determines whether the detected oil pressure is less than a predetermined threshold P (step **1351**). If detected oil pressure is less than this threshold pressure, microcontroller **735** activates a warning chime (step **1353**).

Yet another feature that may be selected is to have your headlights automatically turn on at dusk or whenever an exterior ambient light level falls below a threshold level. To perform this feature, microcontroller **735** first checks whether a flag has been set for this feature (step **1355**) and retrieves the detected ambient light level from an associated input terminal and determines whether the detected ambient light level is below a threshold level L (step **1357**). If the detected level is below threshold L, microcontroller **735** will turn on the vehicle's headlights (step **1359**).

The present invention allows various accessories to be controlled in response to a detection of the vehicle speed. Thus, as the next step, microcontroller **735** may check whether any of the flags have been set that are related to the vehicle speed (step **1361**). If any of these flags have been set, microcontroller **735** will execute a vehicle speed subroutine **1363**, which is described below with reference to FIG. **54**.

The vehicle speed subroutine **1363** begins at step **1745** at which microcontroller **735** determines whether a flag has been set for a speed warning chime. If this flag has been set, microcontroller **735** reads the vehicle speed from the associated input terminal and determines whether the speed exceeds a first speed threshold X1 (step **1747**). If the vehicle speed exceeds this threshold, which may be set manually to correspond to the speed limit, for example, microcontroller **735** activates a warning chime (step **1749**), which chimes periodically until the vehicle speed falls back below the first speed threshold X1.

Next, microcontroller **735** may check whether a flag has been set for a feature by which the doors lock when the speed of the vehicle exceeds a threshold level (step **1751**). If the flag has been set, microcontroller **735** reads the vehicle speed from the associated input terminal and determines whether this speed exceeds a second speed threshold X2 (step **1753**). If the second speed threshold X2 is exceeded, microcontroller **735** proceeds to lock all the doors of the vehicle (step **1755**). Typically, the second speed threshold X2 will be set at a relatively low speed to insure the safety of the vehicle's occupants.

As the vehicle's speed increases, the interior noise level within the vehicle will also increase. Therefore, another feature that may be selected adjusts the radio volume proportional to the vehicle's speed. If, in step **1757** microcontroller **735** determines that the radio volume flag has been set, it will then determine whether the radio is on in step **1759**. If the radio is on, microcontroller **735** will obtain the vehicle speed from the appropriate input line and adjust the radio volume proportionally to any changes in vehicle speed and will return to the main control program at step **1365** in FIG. **48**J.

In step **1365**, microcontroller **735** checks whether any flags have been set relating to gear position. If any such flags have been set, microcontroller **735** executes a gear position subroutine **1367**, which is shown in detail in FIG. **55**. In the gear position subroutine **1367**, microcontroller **735** first determines what gear the vehicle is in (step **1763**). If the vehicle is in drive, microcontroller **735** next determines whether a flag has been set for a feature in which the doors are automatically locked when the vehicle is put in drive (step **1765**). If the flag has been set, microcontroller **735** locks all the doors (step **1767**) before returning to step **1369** (FIG. **48**J) of the main control program.

If the vehicle is in park, microcontroller **735** checks whether a flag has been set to automatically unlock the doors (step **1769**). If this flag has been set, microcontroller **735** automatically unlocks the doors when the vehicle is in park (step **1771**).

If the vehicle is in reverse, microcontroller **735** determines whether a flag has been set to automatically tilt the passenger side exterior mirror downward when the vehicle is in reverse (step **1773**). If this flag has been set, microcontroller **735** tilts the passenger side mirror downward to a predetermined angle (step **1775**) and determines whether the vehicle is still in reverse (step **1777**). When the vehicle is no longer in reverse, microcontroller **735** tilts the passenger side mirror back to its original position (step **1779**) before returning to the main control program. This mirror tilting feature is particularly suited for vehicle operators who frequently parallel park their vehicles next to a curb.

At the next step in the main control program, microcontroller **735** checks whether there is an incoming telephone call (step **1369**). If there is an incoming telephone call, microcontroller **735** executes a phone subroutine **1371** that identifies several selectable features relating to vehicle accessory operation in response to an incoming telephone call. Phone subroutine **1371** is shown in FIG. **56** and begins

with microcontroller **735** determining whether a flag is set for a closed windows and sunroof feature (step **1781**). If this flag has been set, microcontroller **735** will close the windows and sunroof in response to an incoming telephone call (step **1783**). By automatically closing the windows and sunroof when an incoming telephone call is received, the vehicle operator will not have to fumble around to close all the windows and sunroofs to cut down on the interior noise so that the vehicle operator may subsequently answer the incoming telephone call.

Another option that may be selected to make receiving a telephone call much easier for a vehicle operator is a feature which automatically mutes the radio when an incoming telephone call is received. If microcontroller **735** determines in step **1785** that the flag is set for this feature, microcontroller **735** will automatically mute the radio (step **1787**) in response to the detection of an incoming telephone call.

After determining that there is no incoming telephone call or executing the phone subroutine **1371**, microcontroller **735** continues in the main control program by determining whether a window down switch has been depressed (step **1373**, FIG. **48J**). If the vehicle operator has depressed the window down switch, microcontroller **735** will check a flag to determine the manner in which the window actuator is to be controlled in response to this vehicle operator-initiated activation signal associated with a window down function (step **1375**). If the flag has been set for an express window feature, microcontroller **735** will automatically open the window all the way without regard to the length of time the button is depressed (step **1377**). If the flag has not been set, microcontroller **735** opens the window an amount proportional to the length of time the switch is depressed (step **1379**). Similarly, if a window up switch is depressed (step **1381**), microcontroller **735** determines whether a flag has been set for an express window up feature (step **1383**). If this flag has been set, microcontroller **735** closes the window all the way (step **1385**). Otherwise, microcontroller **735** will close the window an amount proportional to the length of time the switch is depressed (step **1387**).

The main control program then advances to step **1389** in FIG. **48K**, in which microcontroller **735** determines whether the rear defrost switch has been depressed. If this switch has been depressed, microcontroller **735** will turn on the rear defrost and start a timer (step **1391**) and will check whether a flag has been set for a non-default ON time (step **1393**). If the flag has been set, microcontroller **735** will set and store an ON time value to the selected ON time (step **1395**). Otherwise, the stored and set ON time value will correspond to the default ON time for the rear defrost circuit. Then, microcontroller **735** will check whether the rear defrost ON time has expired (step **1397**) and will turn off rear defrost if the time has expired (step **1399**).

Next, microcontroller **735** checks whether a turn signal is on (step **1401**) and checks the flags for features associated with the turn signal. The first feature that may be selected increases the volume of a chime associated with the turn signal as the time the turn signal is on increases. Thus, if the associated flag is set for this feature (step **1403**), microcontroller **735** will increase the volume of the chime as the length of time that the turn signal is on increases in order to alert the driver if the turn signal did not turn off following a turn or lane change. If the flag is not set for this feature, microcontroller **735** will check whether a flag is set for a feature which activates a chime after a turn signal has flashed twenty times without a steering wheel correction being made (step **1407**). If this flag is set, microcontroller **735** will count the number of times the turn signal has flashed and will activate a chime after twenty flashes without a steering wheel correction being made (step **1409**).

Next, microcontroller **735** checks a flag associated with a feature for activating a chime upon the detection of a low exterior temperature (step **1411**). If the flag has been set, microcontroller **735** reads the external temperature from the associated input terminal and determines whether this temperature is less than a threshold **T4**, which may be, for example, 32° F. or 0° C. (step **1413**). If the external temperature is less than threshold **T4**, microcontroller **735** will activate a chime and display "ICE" on one of the vehicle's displays (step **1415**). The control application then returns to step **1203** in FIG. **48A** as denoted by connection port A.

Those skilled in the art will recognize that the main control program described above may be modified to include or eliminate or rearrange various steps associated with the control of the vehicle's accessories to accommodate various combinations of vehicle accessories and their control options. Further, the control program may be reprogrammed by invoking a program editing routine in response to a reprogramming signal, which edits the main control program by adding or deleting command lines in the main control program that call the various subroutines relating to selectable control functions. Also, a vehicle owner may personalize his or her vehicle using a home or office PC that is connected to the Internet or programmed to allow the owner to select certain options in a user-friendly manner.

7. Alternative Integrated Vehicle Systems Control

In some vehicles, not all devices and accessories are connected to the vehicle system bus and in these and other vehicles, it is conceivable that the circuitry of the present invention as described above will not have access to the vehicle system bus. If the system of the present invention does not have access to the vehicle system bus, or if the door locks cannot be activated via the vehicle system bus, there would be no way to remotely lock or unlock the vehicle's doors from a remote location using a paging signal or cellular RF signal. Thus, in this event, if the vehicle owner accidentally locked their keys in the car, or if the vehicle owner wished to make sure the vehicle's doors are locked from a remote location, the present invention as described above would be incapable of serving these needs. To this end, an alternative embodiment of the present invention includes a trainable transmitter coupled to the above-described system that may be used to learn the frequency and code of the signal transmitted from an RKE transmitter, such that upon reception of an appropriate RF command signal, the trainable transmitter may be instructed to transmit the RKE control signal to the RKE receiver in the vehicle causing the doors to lock or unlock depending upon the instructions provided in the RF control signal.

The integrated vehicle systems controller constructed in accordance with this alternative embodiment of the present invention includes an RF receiver or transceiver module **1817** coupled to an antenna **1815** for receiving RF signals sent over a telephone **1820** via a transmitter station **1825**,

and for transmitting signals back to the transmitter station **1825** provided the receiver module is a two-way transceiver. Receiver module **1817** may be coupled to a microprocessor **1830** via an interface board **1835** for sending received RF messages to microprocessor **1830**. A trainable transmitter **1840** is coupled to receiver module **1817** and microprocessor **1830** via interface board **1835**. Thus, when an RF control signal is received by receiver module **1817**, instructing the system to lock or unlock the doors, microprocessor **1830** sends a control signal to trainable transmitter **1840** causing it to transmit a control signal having learned characteristics via antenna **1845** to an antenna **1850** of a RKE receiver/actuator **1855**. When RKE receiver/actuator **1855** receives this control signal, it unlocks or locks the vehicle's doors in accordance with the control signal in the same manner that it would operate when receiving the control signal from a key fob transmitter **1857**.

Trainable transmitter **1840** preferably is constructed in accordance with the teachings of U.S. Pat. No. 5,661,804 entitled TRAINABLE TRANSMITTER CAPABLE OF LEARNING VARIABLE CODES, filed on Jun. 27, 1995, the disclosure of which is incorporated herein by reference. Alternatively, trainable transmitter **1840** may be the trainable transmitter disclosed in U.S. Pat. No. 5,442,340, U.S. Pat. No. 4,479,155, or U.S. Pat. No. 5,475,366, the disclosures of which are incorporated herein by reference. Because the trainable transmitter may be used to learn and transmit RF signals to garage door openers, gates, house light modules, house appliances, and any RF actuated door locks, the integrated vehicle system's controller may be used to remotely close or open a garage door or turn lights on or off in response to an RF cellular or paging signal, provided the vehicle is parked in the near vicinity of these devices.

As shown in FIG. **57**, the integrated vehicle system's controller **1810** may further include a display **1882** for displaying received messages, a GPS module **1884** connected to a GPS antenna **1886** and to interface board **1835**, a compass/temperature circuit **1888**, which may optionally include its own display **1890**. Integrated vehicle systems controller **1810** may optionally include a vehicle system bus interface **1892** to couple the device other vehicle accessories and devices **1894** coupled to the vehicle system bus. Optionally, microprocessor **1830** may be eliminated by programming the microprocessor in the trainable transmitter **1840** to perform the functions recited above in the preceding sections.

If receiver module **1817** is a two-way communication transceiver, a confirmation signal may be transmitted back to transmitting station **1825** after trainable transmitter has transmitted the control signal to the RKE receiver/actuator. Further, if the remotely actuated device is capable of transmitting a confirmation signal back to the trainable transmitter, a microprocessor in the trainable transmitter may be programmed to look for such a confirmation signal after transmitting a control signal and to cause a confirmation RF signal to be transmitted back to the transmitting station **1825** to confirm that the desired function has been carried out.

The integrated vehicle systems controller circuit **1810** may be mounted in a rearview mirror, sun visor, overhead console, or other accessory. As such, the integrated vehicle systems controller **1810** may be sold as an after-market device and allow for the remote locking and unlocking of the vehicle's doors using an RF signal provided the vehicle is equipped with an RKE receiver.

Having described the structure of this alternative embodiment of the present invention, a more detailed description of the operation thereof is provided below.

The process begins in step **1902**, when a user dials the service control center to request, for example, that the vehicle's doors be unlocked. The control center would first authenticate the user's identity (step **1904**) and the user would subsequently select the vehicle to which the RF signal is to be transmitted through a dialing sequence (step **1906**). Then, the user selects a directive (i.e., unlocking the vehicle's doors) through a dialing sequence in step **1908**. The control center then sends the directive to the vehicle (step **1910**) via the transmitting station **1825**. Upon receiving this RF control signal, the integrated vehicle systems controller **1810** would transmit back an acknowledgement that the RF control signal was received (steps **1912** and **1918**). If, on the other hand, the integrated vehicle systems controller did not receive the RF control signal and no acknowledgement is received by the control center between a predetermined time period, the control center will retry to transmit the control signal in step **1910** provided that it is a first attempt to retry to transmit the signal (step **1914**). If the control center unsuccessfully attempts to transmit the RF control signal more than twice, the control signal will send an error signal indicating that no acknowledgement was received to the user (step **1916**). Also, if the integrated vehicle system controller **1810** sends the acknowledgement to the control center, but the center does not receive the acknowledgement (step **1920**), the control center will retransmit the control signal to the vehicle. After transmitting an acknowledgement to the control center, the integrated vehicle system controller **1810** sends a directive to the device actuator **1855** (step **1922**). If the actuator **1855** receives the directive (step **1924**), the device actuator sends an acknowledgement back to the integrated vehicle system controller **1810** (step **1930**). If the actuator does not receive the directive or if the acknowledgment is not received by the integrated vehicle system controller, the integrated vehicle system controller will attempt to retransmit the directive (step **1922**) provided it has not already attempted to retransmit the directive (step **1926**). If, after a second attempt, the actuator device does not receive the directive or an acknowledgement is not received back from the actuator device, the integrated vehicle system controller sends the signal back to the control center informing the control center that an acknowledgement had not been received (step **1928**).

If the actuator device receives the directive and selectively sends the acknowledgement back to the integrated vehicle system controller, the actuator attempts to perform the directive (step **1938**), and if successful (step **1940**), the actuator sends a second acknowledgment signal back to the integrated vehicle system controller (step **1946**). If the actuator device is unsuccessful in performing the directive, it will reattempt to perform it (step **1938**) provided it is only the second attempt to do so (step **1942**). If it is subsequently unsuccessful in performing the directed function, the actuator transmits a signal to the integrated vehicle system

controller representative of this fact whereby the integrated vehicle system controller then sends a signal to the control center indicating that no acknowledgement has been received. If, following step **1946**, the integrated vehicle system controller does not receive a second acknowledgement from the actuator that it performed its function (step **1948**), the actuator will attempt to resend the acknowledgement to the integrated vehicle system controller in step **1946** provided it is only its second attempt to do so (step **1950**). Again, if it is unsuccessful in transmitting this acknowledgment to the integrated vehicle system controller, the end user is informed that an error occurred in step **1952**.

If the integrated vehicle system controller receives the second acknowledgement that the actuator device successfully performed the directed function, it sends the acknowledgement to the control center (step **1954**). If the control center does not receive this acknowledgement signal (step **1956**), the integrated vehicle system controller will again send the acknowledgement to the control center (step **1954**) provided it is not its second attempt to do so (step **1958**). If the control center does not receive an acknowledgement within a predetermined time period, it notifies the end user that an error has occurred (step **1960**). On the other hand, if the control center receives this acknowledgement signal (step **1956**), the control center sends an acknowledgement to the user (step **1962**) which the user may then acknowledge receiving. If the user does not acknowledge receiving this acknowledgement (step **1964**) the control center will resend the acknowledgement to the user provided as a first attempt to do so (step **1966**), otherwise it may send an error signal to the user (step **1968**).

8. Transceiver Wake-Up System

Vehicle communication systems such as that described above with reference to FIGS. **3**, **5**, and **57** and cellular telephones include transceivers that consume significant amounts of energy while in a standby mode. To conserve power, these transceivers may be shut down completely when the vehicle ignition is turned off. However, a party sending a paging message or making a call to the cellular telephone will not know whether the vehicle's ignition is on or off and will send the message regardless of whether the transceiver is capable of receiving the message. Thus, a trade-off exists between keeping the receiver in a standby mode at all times to receive all messages that are sent, or to tarn off the receiver with the vehicle ignition to conserve energy and prevent undue drain on the vehicle's battery.

It is therefore an object of the present invention to provide a transceiver wake-up system that prevents the transceiver from unnecessarily consuming power when no one is in the vehicle to receive the message while operating in such a manner that any messages that originated during such period are not lost. Additional features and advantages of the present invention will be apparent from the following description.

To achieve these features and advantages, the transceiver wake-up system includes at least the microprocessor **26**, vehicle bus interface **36**, pager module **34**, antenna **22**, power supply **32**, and bus **24** of the system shown in FIG. **3**. As will be appreciated by those skilled in the art, the additional elements shown in FIG. **3** may also be included in this system. In operation, microprocessor **26** selectively connects and disconnects power supply **32** from pager module **34** depending upon the mode of operation. Specifically, a sleep mode is entered when microprocessor **26** determines that the vehicle ignition has been turned off for a predetermined time period or that all of the vehicle occupants have exited the vehicle and closed the doors. Alternatively, the sleep mode could also be entered when the vehicle alarm is activated. Microprocessor **26** would receive signals representing the occurrence of these events over the vehicle bus via vehicle bus interface **36**.

In the sleep mode, microprocessor **26** disconnects power supply **32** from pager module **34** via any appropriate switching mechanism. Microprocessor **26** then monitors inputs received from vehicle bus interface **36** to determine whether one of the vehicle's door handles has been moved. If one of the vehicle's door handles has been moved, microprocessor **26** wakes up pager module **34** by supplying power from power supply **32** through the pager module **34**. By keying upon these inputs, microprocessor **26** may disable the pager module when it is unlikely that there is anyone in the vehicle to receive a paging message while activating the pager module just prior to someone entering or attempting to enter the vehicle. Thus, any transmitted messages will be received and available to the vehicle occupant as the occupant enters the vehicle.

In the event a third party attempts to transmit a paging signal to the sleeping pager module **34**, the pager transmitting station **19** (FIG. **1A**) will initially attempt to transmit the paging signal while awaiting an acknowledgment signal from the two-way paging module **34**. If such an acknowledgement signal is not received, transmitting station **19** will store the paging message for later retrieval and transmission to pager module **34**. Subsequently, upon being woken up by microprocessor **26**, pager module **34** transmits a signal to transmitting station **19** to inform it that the pager module **34** is now awake. Upon receiving such a signal, transmitting station **19** retrieves and transmits any stored messages to pager module **34**.

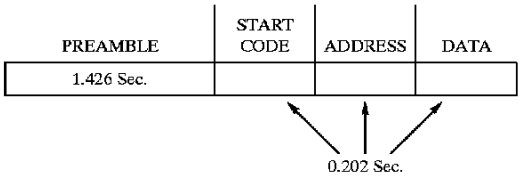
In an alternative implementation, microprocessor **26** would instruct pager module **34** to transmit a paging signal to transmitting station **19** to inform transmitting station **19** that pager module **34** is about to enter a sleep mode prior to disrupting the power supply to pager module **34**. Transmitting station **19** would then store all messages received until a paging message is subsequently received indicating that pager module **34** is no longer in a sleep mode. In the event that pager module **34** is not a two-way pager module and a cellular telephone is coupled in some manner to microprocessor **26**, microprocessor **26** may cause the cellular telephone to call the transmitting station **19** to inform it when the paging receiver has entered and been awaken from a sleeping mode.

The above description is considered that of the preferred embodiments only. Modifications of the invention will occur to those skilled in the art and to those who make or use the invention. Therefore, it is understood that the embodiments shown in the drawings and described above are merely for illustrative purposes and not intended to limit the scope of the invention, which is defined by the following claims as interpreted according to the principles of patent law, including the doctrine of equivalents.

APPENDIX A

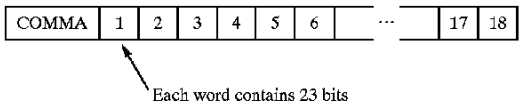
GSC Paging Format

The GSC code format consists of a preamble, a start code, an address and one or more blocks of data. The blocks of data are transmitted at twice the bit rate as the start code and address.



Preamble

The preamble begins with a comma which is 14 bits of a reversal pattern, alternating zeroes and ones. The comma is followed by 18 repetitions of the same 23-bit pattern. There exist 10 different bit patterns in use today. This divides the population of GSC receiving pagers into ten groups. If a pager detects the bit pattern of its group, it will continue to receive the address otherwise it will return to its low current mode. This way, the receiver need only sample often enough to assume that the preamble is detected and pages won't be missed.



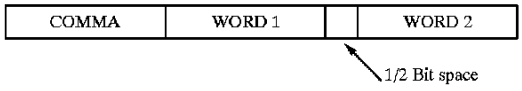
Start Code:

The start code marks the end of the preamble and signals that an address is to follow. It also provides timing information when pages are being sent in batches.

Address:

The start code and address begin with a comma followed by two 23-bit words. These bits are transmitted at 300 bits per second. The two words provide enough data to uniquely define 100,000 different addresses and correct errors in transmission.

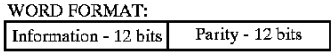
START CODE & ADDRESS:



Word Format:

Each 23-bit word begins with 12 information bits followed by 11 parity bits. The parity bits are included to provide a way of detecting bit errors and correcting them. Eleven parity bits are sufficient to correct at most 3-bit errors per word.

WORD FORMAT:

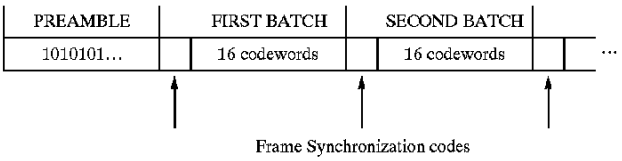


Data Block Format:

Each block of data begins with a half bit space followed by 8 words of 15 bits each. These bits are transmitted at 600 bits per second which is twice as fast as start code and address bits. The information in each word contains error detection and correction bits but only allows for upper case characters when sending alpha-numeric data.

POCSAG Paging Format:

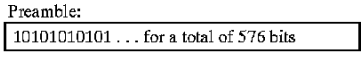
The POCSAG code format consists of a preamble and one or more batches of data codewords. The batches are separated by a frame synchronization code.



Preamble:

The preamble is 576 bits of a reversal pattern, alternating zeros and ones. It is included to alert the receiver that data is to follow. This way, the receiver need only sample often enough to assure that the preamble is detected and pages won't be missed.

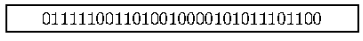
Preamble:



Frame Synchronization Code:

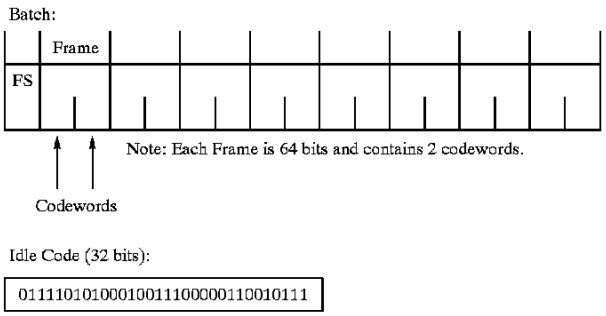
The frame synchronization (FS) code is a unique combination of 32 bits. The FS is used to identify the beginning of each batch of and to provide a starting point by which the frames of data within each batch can be counted.

Frame Synchronization Code (32 bits):



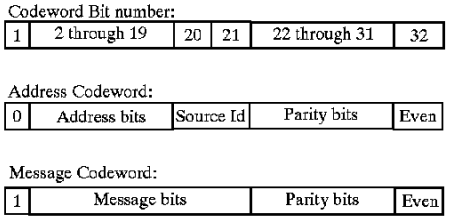
Batch:

Each batch of data begins with a FS and is followed by 8 frames of data. Each frame of data must contain 2 codewords. Each codeword is 32 bits long. If a page requires an odd number of codewords, an extra idle codeword is used to complete the frame. The idle codeword is a unique pattern like the FS.



Codeword Structure:

Each codeword is 32 bits in length. The first bit indicates the type of data that the codeword contains. A zero in the first bit indicates that the codeword contains address data. A one in the first bit indicates that the codeword contains message data. In each type of codeword, the data is in bits **2** through **21**. Bits **22** through **32** are used as parity bits for error detection and correction algorithms.



Address Codeword:

This codeword contains an address in bits **2** through **19** which makes this page specific to one pager within the population of pagers. Included in the 18-bit address are three bits which define the frame (0 through 7) in which the next codeword will be found. The next 2 bits **20** and **21**, identify the source as being from one of four groups of sources within an area. The next 10 bits **(22** through **31)** are included for error detection and correction and the last bit **(32)** provides even parity.

Message Codeword:

This codeword contains a 20-bit message of any information in bits **2** through **21**. The integrity of these information bits is protected by the error detection and correction routines as the address codewords above. The information bits contain alpha-numeric data encoded as 7-bit ASCII characters.

The invention claimed is:

1. A vehicle communication and control system comprising:

a transceiver for sending and receiving RF signals including messages, location data, information requests, and control codes;

a processor coupled to said transceiver for supplying messages, location data, information requests, and control codes to said transceiver for transmission from the vehicle, and for receiving and processing messages, location data, information requests, and control codes intended for the vehicle;

a location identifying sensor coupled to said processor for supplying vehicle location data representing a current detected location of the vehicle;

a user interface coupled to said processor for providing information to a user, and for enabling a user to input commands to be executed by said processor; and

vehicle bus interface for coupling said processor to a vehicle bus to enable said processor to issue and receive commands and other information from vehicle accessories and components coupled to the vehicle bus,

wherein said processor is adapted to:

transmit an emergency message in response to a received command through said transceiver, the emergency message including the vehicle location data received from said location identifying sensor,

transmit vehicle location data through said transceiver in response to a tracking request signal received by said transceiver,

request and receive diagnostic data from a diagnostic database connected to the vehicle bus through said vehicle bus interface and transmit the received diagnostic data through said transceiver in response to a request for such diagnostic data,

transmit a request for roadside assistance through said transceiver in response to a roadside assistance command, the request including the vehicle location data received from said location identifying sensor,

transmit an accessory control signal through said vehicle bus interface to control a designated accessory connected to the vehicle bus in response to a command received from a remote source through said transceiver.

2. The system as defined in claim **1**, wherein said transceiver includes a cellular transceiver for enabling two-way voice and data communication over a cellular network.

3. The system as defined in claim **2**, wherein said user interface includes a speaker coupled to said cellular transceiver for enabling audio messages to be heard by a user.

4. The system as defined in claim **2**, wherein said user interface includes a microphone coupled to said cellular transceiver to allow a user to communicate with a remote location.

5. The system as defined in claim **2** and further including audio recording means coupled to said processor and said cellular transceiver for digitizing, storing, and playing back audio messages received through said cellular transceiver.

6. The system as defined in claim **5**, wherein said user interface includes a microphone for receiving audio messages from a user and recording received audio messages in said audio recording means.

7. The system as defined in claim **2** and fixer including a cellular modem coupled between said processor and said cellular transceiver.

8. The system as defined in claim 1 and further including audio recording means coupled to said processor for digitizing, storing, and playing back audio messages.

9. The system as defined in claim 8, wherein said user interface includes a microphone for receiving audio messages from a user and recording received audio messages in said audio recording means.

10. The system as defined in claim 9, wherein said user interface includes a dedicated user-actuated switch for commanding said audio recording means to begin recording an audio message received through said microphone.

11. The system as defined in claim 8, wherein said user interface includes a dedicated user-actuated switch for commanding said audio recording means to play back stored audio messages.

12. The system as defined in claim 1, wherein said user interface includes a speaker for enabling audio messages to be heard by a user.

13. The system as defined in claim 1 and further including a handset coupling port for coupling a telephone handset to said transceiver for making and receiving telephone calls through said transceiver.

14. The system as defined in claim 1, wherein said processor is further adapted to transmit a request for navigational routing instructions through said transceiver in response to a command received from said user interface, said request including a destination and the vehicle location data received from said location identifying sensor, and to generate and supply navigational routing instructions to said user interface for review by a user in response to the receipt of such navigational routing instructions through said transceiver.

15. The system as defined in claim 1 and further including an electronic compass coupled to said processor for generating vehicle heading data, wherein said processor supplies vehicle heading information to said user interface for output to a user.

16. A vehicle communication and control system comprising:

a transceiver for sending and receiving RF signals including messages, location data, vehicle-identification data, information requests, and control codes;

a processor coupled to said transceiver for supplying messages, location data, vehicle-identification data, information requests, and control codes to said transceiver for transmission from the vehicle, and for receiving and processing messages, location data, vehicle-identification data, information requests, and control codes intended for the vehicle;

a location identifying sensor coupled to said processor for supplying vehicle location data representing a current detected location of the vehicle;

memory means coupled to said processor for storing and supplying vehicle-identification data to said processor for transmission;

a user interface coupled to said processor for providing information to a user, and for enabling a user to input commands to be executed by said processor, said user interface including a display coupled to said processor for displaying information to a user;

an electronic compass system coupled to said processor for generating vehicle heading data, wherein said processor supplies vehicle heading information to said user interface for output to a user; and

vehicle bus interface for coupling said processor to a vehicle bus to enable said processor to issue and receive commands and other information from vehicle accessories and components coupled to the vehicle bus,

wherein said processor is adapted to:

transmit an emergency message in response to a received command through said transceiver, the emergency message including the vehicle location data received from said location identifying sensor,

transmit vehicle location data through said transceiver in response to a tracking request signal received by said transceiver,

request and receive diagnostic data from a diagnostic database connected to the vehicle bus through said vehicle bus interface and transmit the received diagnostic data through said transceiver in response to a request for such diagnostic data,

supply text messages that are received through said transceiver to said user interface for retrieval by a user,

transmit text messages through said transceiver in response to commands received from said user interface,

transmit a request for roadside assistance through said transceiver in response to a roadside assistance command, the request including the vehicle location data received from said location identifying sensor,

transmit an accessory control signal through said vehicle bus interface to control a designated accessory connected to the vehicle bus in response to a command received from a remote source through said transceiver, and

transmit vehicle-identification data stored in said memory means through said transceiver in response to a received command.

17. The system as defined in claim 16, wherein said transceiver includes a cellular transceiver for enabling two-way voice and data communication over a cellular network.

18. The system as defined in claim 17, wherein said user interface includes a speaker coupled to said cellular transceiver for enabling audio messages to be heard by a user.

19. The system as defined in claim 17, wherein said user interface includes a microphone coupled to said cellular transceiver to allow a user to communicate with a remote location.

20. The system as defined in claim 17 and further including audio recording means coupled to said processor and said cellular transceiver for digitizing, storing, and playing back audio messages received through said cellular transceiver.

21. The system as defined in claim 20, wherein said user interface includes a microphone for receiving audio messages from a user and recording received audio messages in said audio recording means.

22. The system as defined in claim 16 and further including audio recording means coupled to said processor for digitizing, storing, and playing back audio messages.

23. The system as defined in claim 22, wherein said user interface includes a microphone for receiving audio messages from a user and recording received audio messages in said audio recording means.

24. The system as defined in claim 23, wherein said user interface includes a dedicated user-actuated switch for commanding said audio recording means to begin recording an audio message received through said microphone.

25. The system as defined in claim 22, wherein said user interface includes a dedicated user-actuated switch for commanding said audio recording means to play back stored audio messages.

26. The system as defined in claim 16, wherein said user interface includes a speaker for enabling audio messages to be heard by a user.

27. The system as defined in claim 16 and further including a handset coupling port for coupling a telephone handset to said transceiver for making and receiving telephone calls through said transceiver.

28. The system as defined in claim 16, wherein said processor is further adatped to transmit a request for navigational routing instructions through said transceiver in response to a command received from said user interface, said request including a destination and the vehicle location data received from said location identifying sensor, and to generate and supply navigational routing instructions to said user interface for review by a user in response to the receipt of such navigational routing instructions through said transceiver.

* * * * *

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Chou et al.

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(45) **Date of Patent: Dec. 11, 2001**

(54) **SYSTEM AND METHOD FOR VEHICLE DIAGNOSTICS AND HEALTH MONITORING**

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(52) **U.S. Cl.** **701/33**; 701/32

(58) **Field of Search** 701/29, 33, 32, 701/207; 342/357.09; 709/203; 340/539

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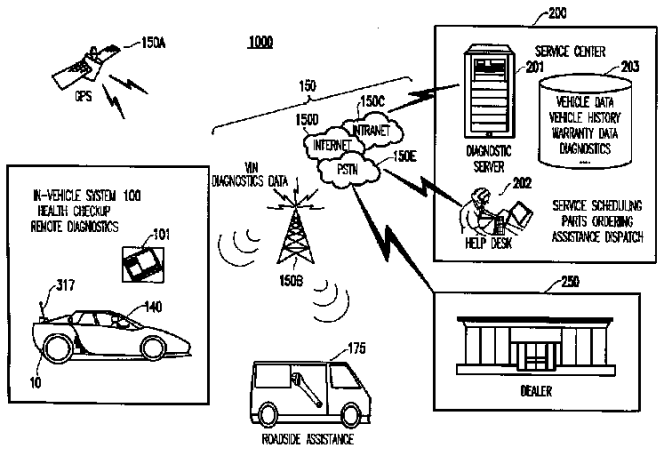
(74) *Attorney, Agent, or Firm*—Stephen C. Kaufman, Esq.; McGinn & Gibb, PLLC

(57) **ABSTRACT**

A system and method for vehicle diagnostic and health monitoring includes a client computer device within the vehicle, coupled to the vehicle's monitoring systems, for data management, remote session management and user interaction, a communication system, coupled to the client computer device, for providing remote communication of data including data derived from internal monitoring systems of the vehicle, and a remote service center including a vehicle data store, a server computer, a diagnostic engine, and a communicator for communicating the results of analysis of vehicle information to the client computer device via the communication system.

24 Claims, 5 Drawing Sheets



OMEGA EXHIBIT 2036

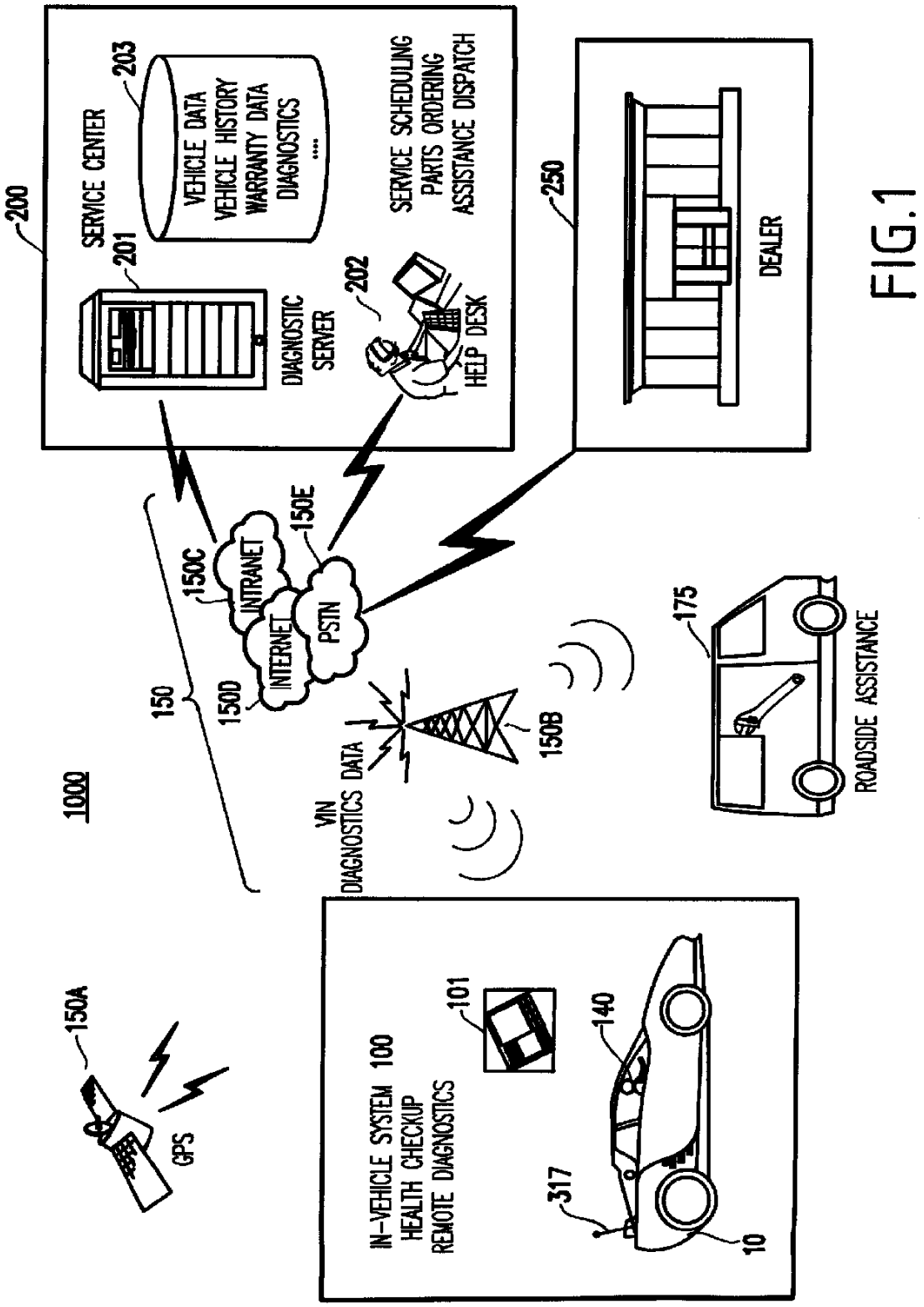

1000
200
SERVICE CENTER
201
DIAGNOSTIC SERVER
202
HELP DESK
203
VEHICLE DATA
VEHICLE HISTORY
WARRANTY DATA
DIAGNOSTICS
....
SERVICE SCHEDULING
PARTS ORDERING
ASSISTANCE DISPATCH
250
DEALER
150
150C
INTRANET
150E
PSTN
150D
INTERNET
150B
VIN
DIAGNOSTICS DATA
175
ROADSIDE ASSISTANCE
150A
GPS
IN-VEHICLE SYSTEM 100
HEALTH CHECKUP
REMOTE DIAGNOSTICS
101
140
317
10

FIG.1

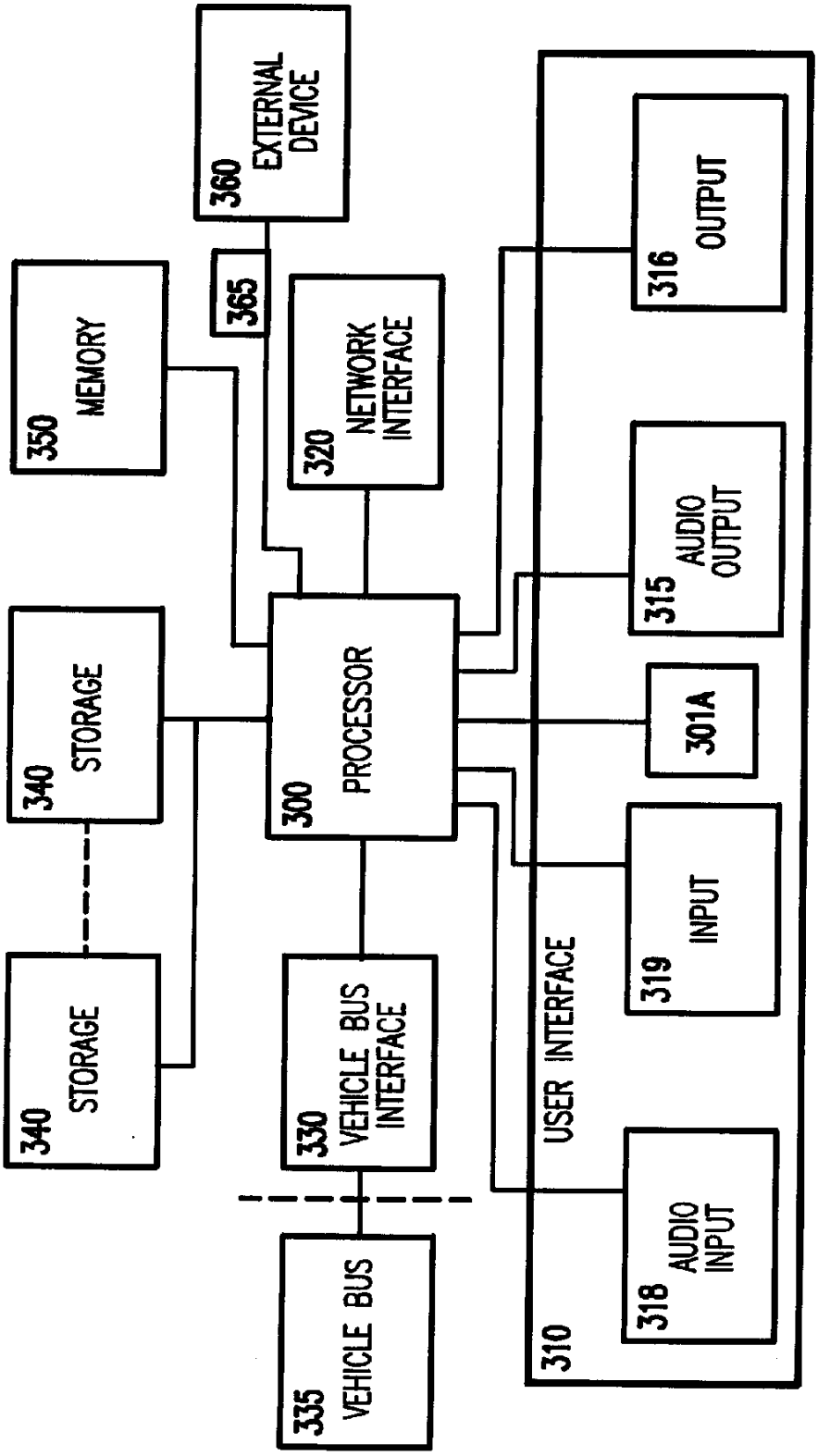

360 EXTERNAL DEVICE
365
350 MEMORY
320 NETWORK INTERFACE
316 OUTPUT
315 AUDIO OUTPUT
340 STORAGE
300 PROCESSOR
301A
340 STORAGE
330 VEHICLE BUS INTERFACE
319 INPUT
USER INTERFACE
335 VEHICLE BUS
318 AUDIO INPUT
310

FIG. 2

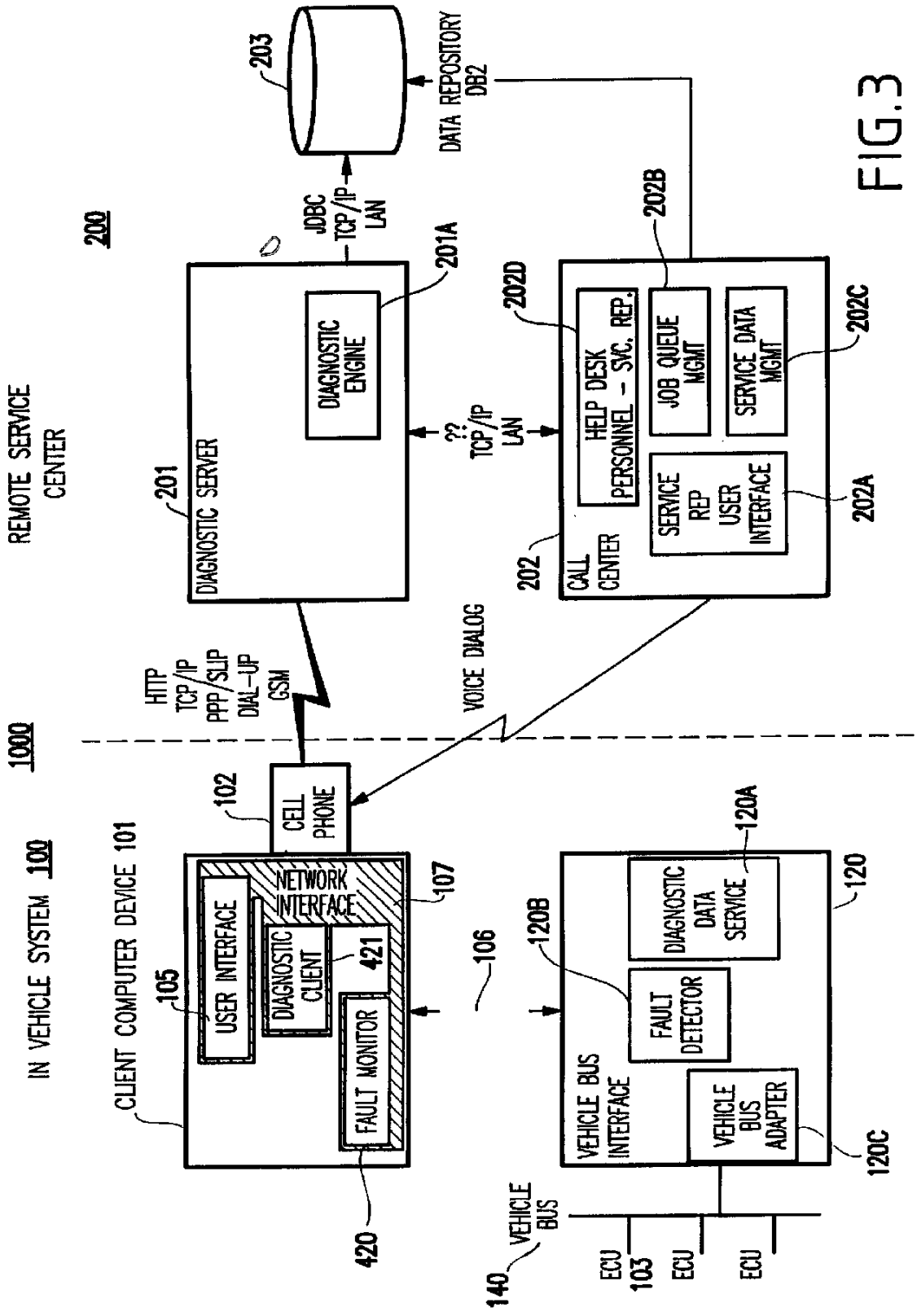

203
DATA REPOSITORY DB2
JDBC TCP/IP LAN
200
201A
DIAGNOSTIC ENGINE
202B
202D
HELP DESK PERSONNEL – SVC. REP.
JOB QUEUE MGMT
SERVICE DATA MGMT
202C
REMOTE SERVICE CENTER
201
DIAGNOSTIC SERVER
?? TCP/IP LAN
SERVICE REP USER INTERFACE
202A
202
CALL CENTER
HTTP TCP/IP PPP/SLIP DIAL-UP GSM
VOICE DIALOG
1000
102
CELL PHONE
IN VEHICLE SYSTEM 100
CLIENT COMPUTER DEVICE 101
NETWORK INTERFACE
107
USER INTERFACE
105
DIAGNOSTIC CLIENT
421
FAULT MONITOR
106
120A
120B
DIAGNOSTIC DATA SERVICE
120
FAULT DETECTOR
VEHICLE BUS INTERFACE
VEHICLE BUS ADAPTER
120C
420
VEHICLE BUS
140
ECU
103
ECU
ECU

FIG.3

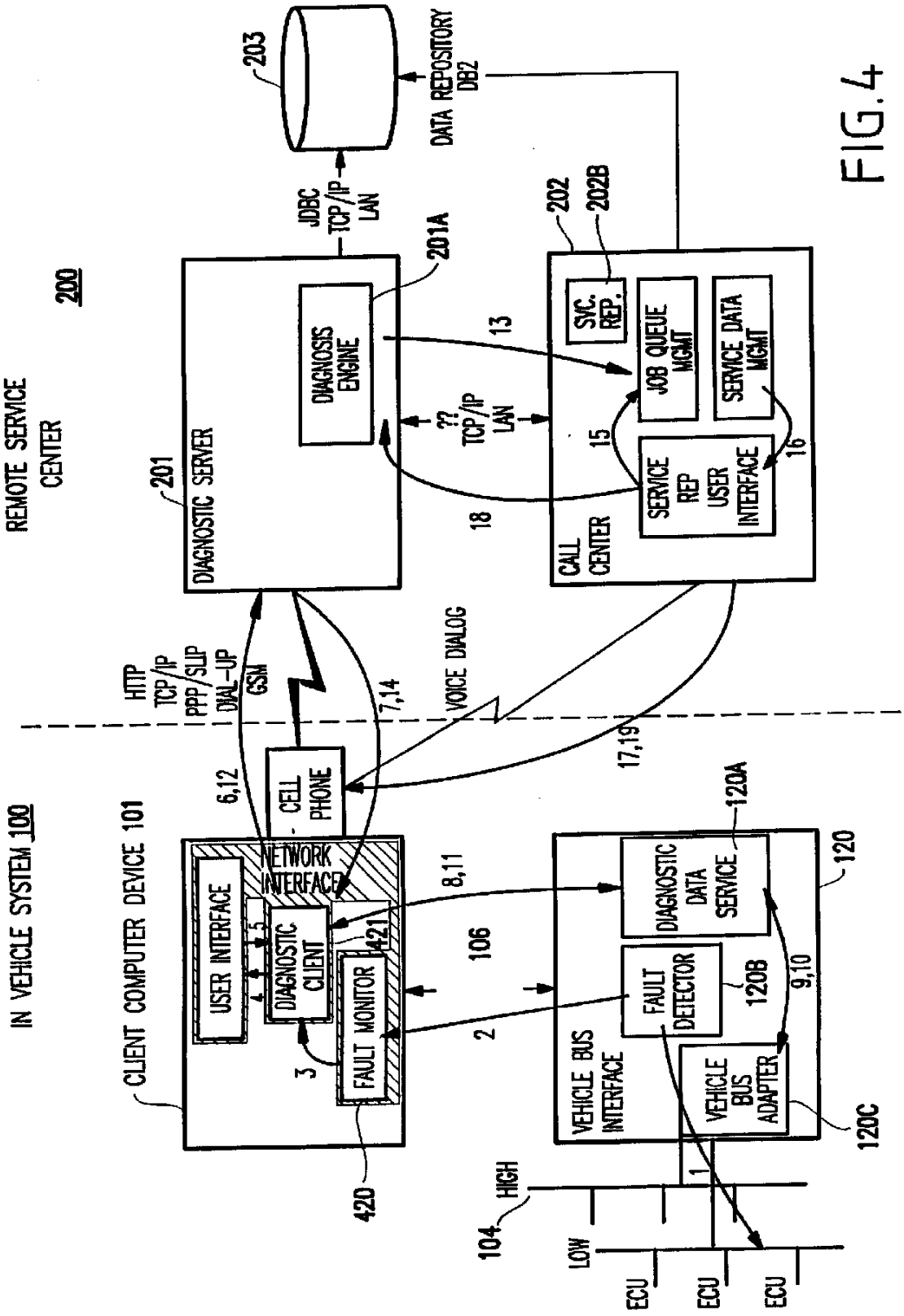

REMOTE SERVICE CENTER
200
203
DATA REPOSITORY DB2
JDBC TCP/IP LAN
201A
DIAGNOSIS ENGINE
201
DIAGNOSTIC SERVER
202
202B
SVC. REP.
JOB QUEUE MGMT
SERVICE DATA MGMT
SERVICE REP USER INTERFACE
CALL CENTER
13
15
16
18
?? TCP/IP LAN
HTTP
TCP/IP
PPP/SLIP
DIAL-UP
GSM
7,14
VOICE DIALOG
17,19
6,12
CELL PHONE
IN VEHICLE SYSTEM 100
CLIENT COMPUTER DEVICE 101
NETWORK INTERFACE
USER INTERFACE
DIAGNOSTIC CLIENT
FAULT MONITOR
421
420
3
4
5
106
2
8,11
120A
DIAGNOSTIC DATA SERVICE
120
FAULT DETECTOR
120B
9,10
VEHICLE BUS INTERFACE
VEHICLE BUS ADAPTER
120C
1
104
HIGH
LOW
ECU
ECU
ECU

FIG. 4

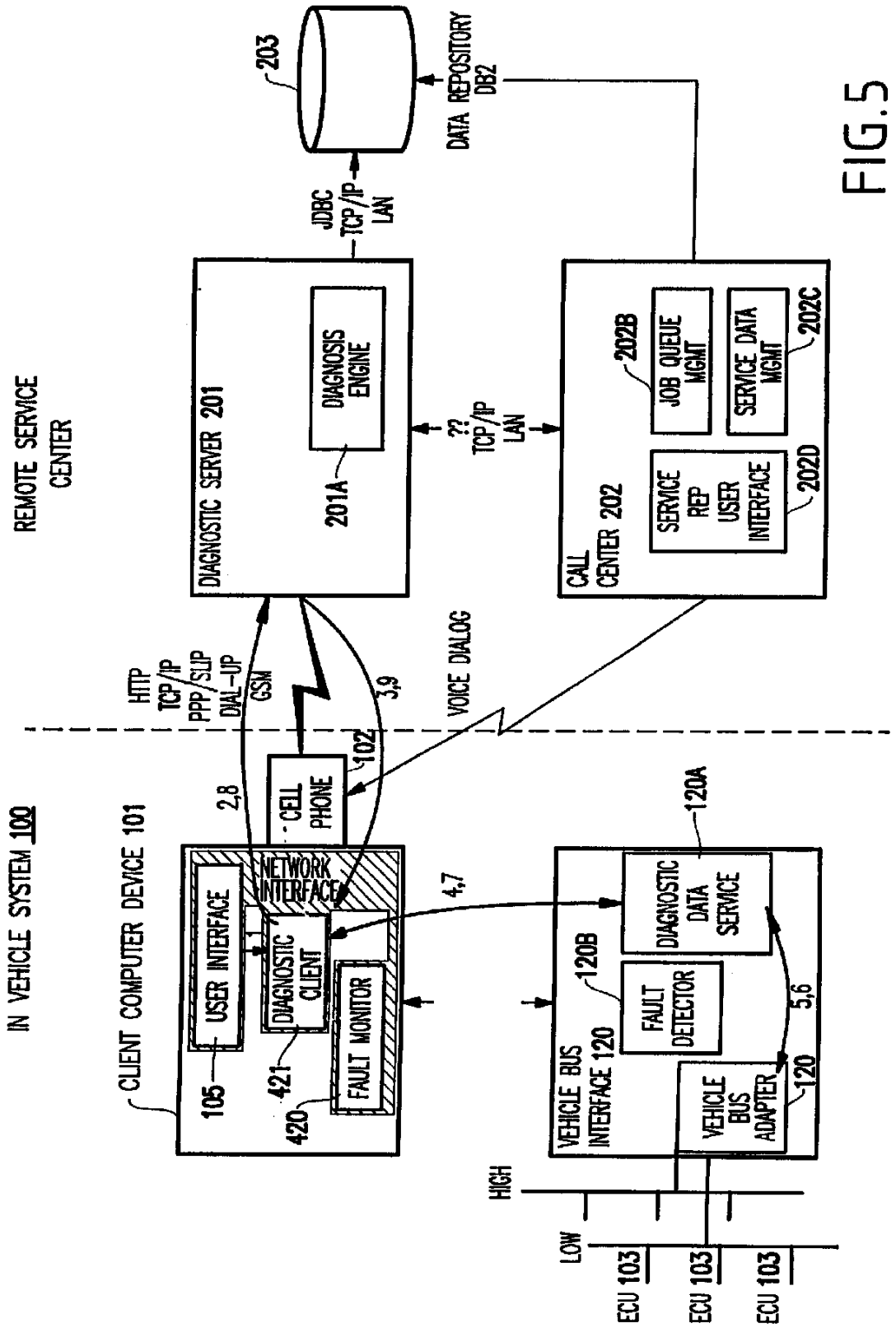

REMOTE SERVICE CENTER
IN VEHICLE SYSTEM 100
CLIENT COMPUTER DEVICE 101
DIAGNOSTIC SERVER 201
DIAGNOSIS ENGINE
201A
203
DATA REPOSITORY DB2
JDBC TCP/IP LAN
?? TCP/IP LAN
CALL CENTER 202
JOB QUEUE MGMT
202B
SERVICE DATA MGMT
202C
SERVICE REP USER INTERFACE
202D
HTTP TCP/IP PPP/SLIP DIAL-UP
GSM
2,8
3,9
VOICE DIALOG
CELL PHONE
102
NETWORK INTERFACE
USER INTERFACE
DIAGNOSTIC CLIENT
FAULT MONITOR
105
421
420
4,7
120A
DIAGNOSTIC DATA SERVICE
120B
FAULT DETECTOR
VEHICLE BUS INTERFACE 120
VEHICLE BUS ADAPTER
120
5,6
HIGH
LOW
ECU 103
ECU 103
ECU 103

FIG.5

SYSTEM AND METHOD FOR VEHICLE DIAGNOSTICS AND HEALTH MONITORING

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention generally relates to a vehicle monitoring system and method, and more particularly to a method and system for vehicle diagnostics and health monitoring.

2. Description of the Related Art

Motor vehicles contain complex mechanical systems that are monitored and regulated by computer systems such as electronic control units (ECUs) and the like.

Such ECUs monitor various components of the vehicle including engine performance, carburation, speed/acceleration control, transmission, exhaust gas recirculation (EGR), braking systems, etc.

However, vehicles perform such monitoring typically only for the vehicle driver and without communication of any impending results, problems and/or vehicle malfunction to a remote site for trouble-shooting, diagnosis or tracking for data mining.

Systems that provide for remote monitoring do not have a means for automated analysis and communication of problems or potential problems and recommendations to the driver.

As a result, the vehicle driver or user is often left stranded, or irreparable damage occurs to the vehicle as a result of neglect or driving the vehicle without the user knowing the vehicle is malfunctioning until it is too late.

SUMMARY OF THE INVENTION

In view of the foregoing and other problems of the conventional methods and structures, an object of the present invention is to provide a method and structure to extract information provided by the vehicle's internal monitoring systems, to transfer that information to a remote service center, to provide a means and method for comparison and analysis of the information, and to provide timely information to the driver of the vehicle.

In a first aspect of the present invention, an information system for a vehicle includes an electronic data collector (e.g., preferably for obtaining electronic data from the vehicle's internal monitoring systems), a client computer device within the vehicle (e.g., preferably for data management, remote session management and user interaction), a communication unit (e.g., preferably coupled to the client computer device, for providing remote communication for the client computer device), a remote service center (e.g., including a vehicle data store, a server computer, and a call center for communicating with the client computer device via the communication unit).

With the unique and unobvious structure and method of the invention, information can be reliably extracted from a vehicle's internal monitoring systems, and the information can be transferred to a remote service center. Further, the information can be compared and analyzed, to provide timely information for the driver of the vehicle to avoid the vehicle driver being stranded or the vehicle being irreparably damaged. Additionally, the ability of a driver to initiate health checkups brings the driver assurance of the proper functioning of his vehicle as well as reminders for preventive maintenance which will prevent the development of problems.

This system and method benefits the vehicle manufacturer and service provider by enhancing customer loyalty and providing timely feedback to solve engineering and manufacturing problems.

BRIEF DESCRIPTION OF THE DRAWINGS

The foregoing and other purposes, aspects and advantages will be better understood from the following detailed description of a preferred embodiment of the invention with reference to the drawings, in which:

FIG. **1** illustrates an upper level environment in which the present invention is utilized;

FIG. **2** illustrates exemplary in-vehicle hardware components for the system shown in FIG. **3**;

FIG. **3** illustrates an exemplary architecture of a fault monitoring and diagnosis system according to the present invention;

FIG. **4** illustrates a fault monitoring and diagnosis event operation flow; and

FIG. **5** illustrates a health checkup event operation flow according to the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Referring now to the drawings, and more particularly to FIGS. **1–5**, there are shown preferred embodiments of the method and structures according to the present invention.

FIG. **1** illustrates an upper level environment of a system according to the present invention.

As shown in FIG. **1**, the system **1000** includes a vehicle **10** with a vehicle driver or user **140**, having an in-vehicle computing system **100**, a client computer device **101** installed to enable vehicle health checkup and remote diagnostics, a communication link **150** (e.g., via wireless base stations **150**B, or the like) for communicating vehicle information (e.g., vehicle identification number, (VIN), diagnostic data, and the like). Such a link may be interfaced with an intranet **150**C, the Internet **150**D, or a public (or private) switch telephone network (PSTN) **150**E. Further shown, the vehicle location is established, for example by a device **317** (e.g., antenna or the like) for receiving positioning information from orbiting Global Positioning System (GPS) satellites **150**A.

Further shown is a roadside assistance unit **175** for assisting the vehicle based on a signal received over the communication link **150**.

A remote service center **200** is also provided having a diagnostic server **201**, a help desk **202** and a data repository **203**. The help desk **202** schedules services, orders parts, and dispatches assistance through the roadside assistance unit **175**.

Further, a dealer **250** is shown communicating with the remote service center **200** and optionally with the vehicle **10**.

FIG. **2** is a block diagram providing an exemplary component overview for the in-vehicle hardware. The in-vehicle hardware provides a platform for the client computer device **101** and for the system functions shown in the architectural design in FIG. **3**. As shown in FIG. **2**, the in-vehicle hardware includes a processor **300** coupled with memory **350**, a user interface **310**, a network interface **320**, a vehicle interface **330**, at least one persistent storage device **340**, and optional external devices **360**.

The processor **300** may be of a conventional type or it may be an embedded system depending upon the designer's requirements. Examples include an Intel Pentium®, or the Hitachi SH-4 for an embedded system.

The user interface includes one or more input means such as an audio input **318** capability for speech recognition, speaker identification, or voice recording. For this a microphone such as those manufactured by AKG or Sony can be used. Other input means **319** may include a touch screen for, as an example, entering menu selections by pressing a particular area of the screen, and actuator buttons **301A** such as a push-to-talk (PTT) button to initiate audio input to the processor or a "911" button for triggering a call for emergency help. The user interface also includes a plurality of output means such as an audio output capability **315** for generating auditory signals, text-to-speech, and prerecorded voice playback. The audio output may be coupled to the vehicle's speakers. The output means **316** may also include a display screen and indicator lights.

The processor is integrated with a network interface **320** to provide communication capability with the remote service center **200**. Preferably, the network interface comprises a removable wireless telephone such as the Motorola i1000+ and a docking facility for the wireless phone integrated with the client computer device. Both voice and data connections can be supported by interfacing the processor **300** and the wireless phone. The telephone integration provides basic communication functions. It establishes a data (e.g. TCP/IP) connection with a remote service center (e.g., remote service center **200**). Wireless technologies such as GSM (Global System for Mobile Communications), CDMA (Code Division Multiple Access), TDMA (Time Division Multiple Access), iDEN™ (a TDMA-based Motorola technology), and AMPS (Advanced Mobile Phone System) can all be supported. The phone may also be used for wireless voice communications.

The processor **300** is coupled to a vehicle bus **335** through a vehicle bus interface **330**. The coupling between the client computer device and the vehicle bus interface **106** of FIG. **3**, may be one of RS-232, USB (Universal Serial Bus), IDB (ITS Data Bus), Ethernet, and the like. The vehicle bus interface may support one of vehicle bus standards such as CAN (Controller Area Network) and the Society of Automotive Engineers' SAE J1850 - Class B Data Communication Network Interface. Alternatively, the processor supports some or all of the functions of the vehicle bus interface and connects directly to the vehicle bus **335**. The vehicle bus shown in FIG. **2** is an inherent part of all new automobiles. The dotted line is used as an indication that the vehicle bus is built into the vehicle.

The in-vehicle hardware includes at least one persistent storage device **340** such a hard disk, CD-ROM, flash memory, and the like coupled to the processor. The processor may also be coupled by additional interface means **365** such as infrared, RF, serial and parallel ports and the like, to communicate with external devices **360** such as printer, fax, personal digital assistant (PDA), notebook computer, etc. Optionally, the processor **300** may be coupled to a location sensing device such as a GPS receiver **317** (FIG. **1**) to provide vehicle location information. The system may or may not assume the availability of the automatic vehicle position information. Location-related scenarios, such as emergency help dispatch may use automatic vehicle positioning or may depend on the driver to provide position information.

In an exemplary system, such capabilities have been provided. Further, other computing devices such as a laptop computer or personal data assistant (PDA) may be used to perform the function of the processor **300** and some or all of the additional hardware components and to provide the hardware platform for the client computer device **101**.

In-Vehicle Computing System

FIG. **3** depicts a more detailed system architectural view of a preferred embodiment of the system **1000** according to the present invention for fault monitoring and diagnosis. The system includes the in-vehicle system **100** (including client computer device **101**) and the remote service center **200**.

The application software that makes up the in-vehicle computing system **100** includes an in-vehicle client computer device **101** and a vehicle bus interface **120**. The vehicle bus interface may run on a hardware component separate from that of the client computer device **101**, such as those manufactured by Vetronix Inc. or DigiTech Inc., or may have some or all of its functions contained within the client computer device **101**.

The vehicle bus interface **120** is responsible for replying to requests for parametric data. It is also responsible for continuously monitoring the vehicle bus **104** for any fault reported by the ECUs **103**, in terms of diagnostic trouble codes (DTCs).

The vehicle bus interface **120** includes the following modules: vehicle bus adapter **120C**, fault detector **120B**, and diagnostic data service **120A**. The fault detector **120B** polls the vehicle bus **104** through the vehicle bus adapter **120C** checking for fault codes reported by the vehicle ECUs **103**. The vehicle bus adapter **120C** translates the messages received from the vehicle bus into the language of the fault detector. It also translates messages from the fault detector into the language of the vehicle bus. The fault code specifications and protocols of the vehicle may be Original Equipment Manufacturer (OEM) and model dependent. The term "vehicle fault codes" is meant to be synonymous with the term "trouble code" or "diagnostic trouble code". A listing of such codes may be found in the publication of the Society of Automotive Engineers, "SAE On-Board Diagnostics for Light and Medium Duty Vehicles Standards Manual". The diagnostic data service **120A** accepts request for vehicle parametric data and retrieves the data using the vehicle bus adapter.

The client computer device **101** performs several functions including communicating to the remote service center **200** by means of the network interface **107** using the cell phone **102**. It sends requests for diagnostic services such as health checkup and fault diagnosis to the service center.

In support of this function, it sends diagnostic trouble codes (DTCs) and vehicle information to the service center. It handles incoming requests for data from the service center. It communicates through the user interface **105** to the driver using a combination of audio, indicator lights, and text. The severity, and optionally the description, of the reported trouble codes may be so communicated. Proper recommended actions such as "stop now", "go to a service station immediately", or "contact the service center for further help by . . . " are spoken to the driver using text-to-speech (ITS).

The client computer device **101** handles DTCs by listening for vehicle faults through the fault monitor **420**, classifies the severity of the faults (e.g. alarm or warning), provides a description of the DTCs and a recommended course of action. The client computer device also manages the state of active requests, vehicle status, and other relevant information handling functions, e.g. including bootup and stored information or data.

Further, the client computer device may initiate a remote health checkup upon a user request. The driver or user may request a comprehensive, remote health checkup if the driver or user feels that the vehicle is behaving abnormally, is alerted by the application of potential trouble, or simply wants to get a checkup before a long trip.

The in-vehicle system establishes a data connection, using a cellular phone **102**, with a diagnostic server **201** at the service center **200**, collects diagnostic data using the diagnostic data service **120**A, and uploads a snapshot of the vehicle data (e.g. VIN, test data with time-stamp) to the diagnostic server **201**. The in-vehicle system may need to interact with the server **201** throughout a diagnosis or health checkup session, collecting and providing additional vehicle information as requested by the server **201**. The result from the server **201** indicates either that the vehicle is in good health with no urgent action required, or that one or more problems requiring immediate attention are detected.

When the vehicle is deemed to be in good health, a report enumerating the items checked and the conditions of those items is provided to the client computer device and reported to the driver or user using TTS and the display.

When the vehicle is deemed to have a problem, the client computer device informs the driver or user to expect a callback from service center help desk personnel—customer service representative (CSR) **202**D for further information. The in-vehicle system may also provide the capability to allow the driver or user to talk to a customer service representative (CSR) at the call center **202**. Through the user interface **105**, the driver or user may initiate a request that will result in a call back by a CSR at a later time.

Similar to the health checkup request, the in-vehicle system collects and uploads a snapshot of the vehicle data, including any trouble codes reported by the ECUs, to the diagnostic server **201**. The system may also provide additional diagnostic data at the request of the diagnostic server. The driver or user may be notified that he or she will be receiving a call from the service center. The driver is also given an estimate of the time to expect the call.

Remote Service Center and Server

The remote service center **200** of FIG. **3** comprises a diagnostic server **201** that has access to data related to the vehicle such as as-built, history, diagnostics, warranty, service information and failure mode data. The diagnosis server **201** is linked to the data repository **203** via a TCP/IP link, LAN, or the like.

Further, the service center may be operatively coupled to a call center system **202** via a local area network (LAN), TCP/IP, or the like. The call center system **202** includes a service representative user interface **202**A, a job queue management unit **202**B, and a service data management unit **202**C. The call center system **202** is linked to the data repository **203**. It may be staffed with help-desk personnel (e.g. customer service representatives). Alternatively, the remote service center **200** may be completely automated.

The center **200** is optionally connected to the dealer's network (as shown in FIG. **1**) to provide additional services such as dispatching service vehicles, service scheduling, parts ordering, dealer references and the like.

Within the diagnostic server **201** at the service center **200** is a diagnosis engine **201**A. The main function of the diagnosis engine **201**A is to provide a health checkup or a diagnosis using the data obtained from the vehicle, the vehicle's past history, and the diagnostics information about the particular model of the vehicle. It is also possible to incorporate qualitative symptom descriptions from the driver as part of the diagnostic input.

The diagnosis engine **201**A may deploy a combination of technologies, ranging from model-based monitoring to case-based reasoning, to determine the health of the vehicle, identify potential troubles, and diagnose existing problems. The diagnostic server **201** also includes components that interact with the vehicle client **101**, the vehicle data repositories **203**, and the call-center **202** system.

An exemplary operation of the server center is described below. Upon receiving a request from the client, the server **201** establishes a diagnosis session, and collects data from the in-vehicle system **100** and the data repository **203**, as guided by the diagnosis engine **201**A.

The diagnosis engine **201**A first determines if a fault or a potential of a fault is present by checking if any trouble code is reported by the client, and checking a predetermined list of vehicle attribute values against their normal operating characteristics. If no fault is found and the vehicle data appears normal, the diagnosis engine **201** A returns a health report to the server **201**. The server **201** in turn returns the report to the client computer device **101** via the data connection, and terminates the session.

If a fault or potential of a fault is identified, the diagnostic server **201** informs the vehicle client computer device about the presence of trouble, and then terminates the data connection. Server **201** then compiles the relevant data and creates a case for the call center system **202** to handle.

An available customer service representative **202**D picks up the case from the to-be-responded job queue and initiates a voice call to the vehicle. Assisted by diagnosis tools (e.g., on-line manuals, rule-based diagnosis or case-based reasoning), the customer service representative (CSR) **202**D analyzes the problem and may identify the cause of the fault. The driver or user also may describe certain symptoms not captured by the diagnostic data (e.g. noise, vibration, etc.) to the CSR. The CSR in turn feeds the symptom descriptions to the diagnostic server **201** to conduct further analysis. Through voice dialogs with the driver or user, the CSR can explain the diagnosis and provide advice on what to do with the problem. Finally, the case is logged by the system with case resolution input from the CSR.

In a preferred embodiment, no voice communication call is made to the driver unless such a request has been made by the driver through use of the user interface buttons or speech recognition. Information may otherwise be returned to the driver through the use of data communications.

In an exemplary implementation, only a subset of data, such as vehicle information and diagnostics for the vehicle model (e.g., 1999 Mercedes ML 320), and functions, such as fault determination and health checkup, necessary for supporting various scenarios, as described below, are made available at the service center. Of course, the designer can include any or all of the above data in combination with different data, as determined by the designer's constraints and requirements.

Exemplary Implementations

The invention may be employed with great utility in a large variety of situations. Several exemplary scenarios are discussed in detail below.

Fault Monitoring and Diagnostics

Referring to FIG. **3**, the system can be employed for fault monitoring and diagnostics.

In such a case, for example, one or more diagnostic trouble codes, generated by the vehicles' ECUs **103**, are detected in the vehicle bus interface **120** by the fault detector **120**B. These trouble codes are sent to the fault monitor **420** component of the vehicle client computer device **101**. The fault monitor may further process these trouble codes and finally sends them to the diagnostic client **421**.

Thereafter, the diagnostic client **421** classifies the severity of trouble codes into a predetermined severity class (e.g. a warning of a pending problem or an alarm indicating immediate attention needed because of a severe malfunction) and also determines an associated set of recommended actions for the driver (or other user, e.g. passenger or navigator) of

the vehicle **140** (shown in FIG. 1). It is to be understood that the terms "driver" or "user" indicate any vehicle user who employs the invention.

The driver is informed by the user interface **105**, by audio (e.g., TTS, prerecorded, or synthesized sounds) and/or visual display output using the output devices **315** and **316** of the user interface **310** shown in FIG. **2**, that a vehicle fault, characterized by the reported trouble codes, has been detected and whether the fault is a warning or an alarm. The driver is also advised to take appropriate action based on the severity of the fault (e.g. "pull over" to a safe area). At the same time, a "Call Me" button and an "Acknowledge" button appear on the touch screen display. These buttons may also be physically installed buttons **301**A., as shown in FIG. **2**.

The driver or user may acknowledge this fault message by pressing the "Acknowledge" button. In this case, the diagnostic client can assume that the driver has been informed and take appropriate action (e.g. stop playing audio alert message, alter visual display, etc.). If the driver does not acknowledge the fault message, the diagnostic client may take some action on behalf of the driver, based on the prior classification of the received vehicle fault(s). For example, if the vehicle fault indicates that the air bags have been deployed, the diagnostic client **421** may automatically initiate requests to the service center **200** to notify police, dispatch emergency medical assistance and roadside service.

The driver may initiate a vehicle diagnostics request by pressing the "Call Me" button (from the driver point of view, pressing the "Call Me" button will result in a call to the driver by a service representative from the service center), or by pressing the PTT button **301**A shown in FIG. **2** and issuing a equivalent spoken command. In this case, a data communication link is established through the network interface **320** to the service center **200**, and data containing fault codes, DTCs, vehicle parameter values, and vehicle ID information, is sent to the diagnostic server **201**. The size of the data stream is estimated to be on the order of 1 kilobyte. Optional information includes a callback number, GPS coordinates, etc. The exchange of information may be repeated more than once before the data link is closed.

The call center server **202** receives this information, in addition to the analytical results of the diagnostic server (e.g., diagnosis of vehicle problem and recommended actions for repair), displays the information for the help desk personnel (including service representatives) **202**D, and fetches stored vehicle information from the data repository **203** for the service representative. A voice call is simultaneously placed to the vehicle, connecting the service representative **202**D to the vehicle driver or user **140**.

The service representative at the help desk **202** greets the driver and suggests a course of action. For severe vehicle-disabling malfunctions, the service representative may take various assisting actions (e.g., telephone a garage, alert roadside assistance, dispatch help immediately). For less severe vehicle faults, the service representative may arrange for vehicle service by consulting the driver and dealer service center, schedule and parts availability. Out-of-stock parts may be ordered and repair scheduled based on part lead-times. All or some of these options may be incorporated into the inventive system.

Turning to FIG. **4**, a process flow will be described with reference to step numbers shown in FIG. **4**.

In FIG. **4**, the fault detector **120**B periodically polls the vehicle bus **104**, checking for fault codes reported by the vehicle ECUs (step 1).

Then, in step 2, the fault detector **120**B reports newly detected fault codes along with associated information (e.g. time stamp, etc.) to the fault monitor **420** on the vehicle client computer device. (An alternative implementation is that the fault detector **120**B is a part of the fault monitor **420** which periodically polls the ECUs through the vehicle bus adapter **120**C.) In step 3, the fault monitor notifies the diagnostic client about the occurrence of the faults detected along with the fault codes.

Thereafter, the diagnostic client determines the severity of the faults by looking in the predefined fault code/severity/recommendation table (step 4). It communicates with the driver through the user interface **100** about the detected faults, their severity and recommended driver actions. There are a plurality of severity levels such as a warning and/or an alarm.

In step 5, the driver triggers a request for further information about the faults and guidance. For example, the driver may press the "Call Me" button (or the like on the touch screen). Then, the diagnostic client **421** initiates a diagnosis session with the diagnostic server **201** (step 6). The diagnostic client **421** passes the fault codes, vehicle identification and other relevant information to the server **201**.

In step 7, the diagnostic server requests additional information (e.g. vehicle parametric data) from the diagnostic client **421**. Then, in step 8, the diagnostic client requests the data from the diagnostic data service **120**A.

In step 9, the diagnostic data service interrogates the ECUs **103** via the vehicle bus adapter **120**C for the requested data.

Then, in step 10, the ECUs **103** provides the requested data. In step 11, the data is returned to the diagnostic client **421**, and thereafter, in step 12, the data is in turn transmitted to the diagnostic server **201**. Steps 7 through 12 may be repeated to obtain all of the relevant vehicle data.

In step 13, the diagnostic server places the request on a job queue for the call center **202** to process and simultaneously initiates the diagnosis engine **201**A analysis. The diagnostic analysis may consist of comparing the diagnostic data with a standard data set containing a list of known faults and recommended actions or may include a more complex fault classification analysis using techniques such as a neural network, classification trees, expert systems, case-based reasoning, and pattern recognition.

Then, in step 14 the diagnostic server **201** provides the diagnostic client **421** with an estimate of when to expect a call back from the customer service representative, and terminates the data connection. The diagnostic client **421** then conveys this information to the driver through the user interface **105**. After the diagnosis engine **201**A has completed its analysis and posted the results, a service representative can pick up the job from the queue using the service representative user interface **202**A. (In step 15)

In step 16, all information relevant to this diagnosis transaction is gathered and presented to the representative, and then, in step 17, the service representative places a call to the driver, through, for example a phone network to a cellular telephone located in the vehicle. If the cause of the faults cannot be identified based on the available data, the service representative may ask the driver for qualitative descriptions of the symptoms.

In step 18, the service representative may use this newly provided information and reinvoke the diagnostic server **201** to investigate the problem further. Finally, in step 19, the service representative communicates with the driver, and provides guidance.

Vehicle Health Checkup

The inventive system also may be employed to advise of the health of the vehicle.

In this scenario, the driver initiates an automated health checkup by using the touch-screen or speech recognition user interface **310** of the vehicle client **101**.

Then, vehicle information, estimated to be on the order of 1 kilobyte in size, including, for example, vehicle identification number (VIN), any trouble codes, and/or a snapshot of the vehicle data, are retrieved by the vehicle client **101** through the vehicle bus interface **120**.

The vehicle client **101** combines vehicle ID information with the information from the vehicle bus interface **120** and sends the data to the Diagnostic Server **201** over a data link. The data link is kept open.

The diagnostics server **201** retrieves vehicle information from the data repository **203** and compares the data from the vehicle with the repository data. Then, the diagnostic server **201** prepares a report listing any out-of-range parameters and actions required (e.g., "coolant level is low"). Trend analysis on the parameters may also be performed, based on the present and historical data collected from the vehicle, to detect any drifting of the performance characteristics and to provide early guidance for preventive maintenance (e.g., "change oil in 1500 miles").

The report is sent to the client computer device **101** over the data link. The client computer device stores the results in memory **350**, displays them on the touch screen, and reads them to the driver via TTS. The driver is given the option of placing a call to speak to a service representative **202**D at the call center **202**.

Referring now to FIG. **5**, a health checkup event flow is presented. The numbers of the steps refer to the numbers found in the flow, as shown in FIG. **5**.

First, in step 1, the driver triggers a request (e.g., presses the "Checkup" button) for an automated vehicle health checkup by using the touch-screen or speech recognition user interface **105** of the vehicle client.

Then in step 2, the diagnostic client **421** initiates a health checkup session with the diagnostic server **201**, and in step 3, the diagnostic server instructs the diagnostic client to gather vehicle data, such as VIN, malfunction codes, and/or a snapshot of the vehicle data.

Then in step 4, the diagnostic client **421** requests the data from the diagnostic data service **120**A at the vehicle bus interface **120**. Then, in step 5, the diagnostic data service interrogates the ECUs **103** via the vehicle bus adapter **120**C for the requested data.

In step 6, the ECUs **103** provide the requested data, and in step 7, the data is returned to the diagnostic client **421**. Then, in step 8, the data is in turn transmitted to the diagnostic server **201**. The diagnostic client may use a visual interface, such as a progress bar to inform the driver that processing is in progress.

In step 9, the diagnostic server **201** compares the vehicle data with the stored nominal values. The diagnostic server **201** prepares a report and transmits it to the client computer **101**. The report may be displayed on the client's display using indicator icons that are easily understandable by the driver at a glance while operating the vehicle. For example, a "thumbs up", a "thumbs down", or a flat hand or the like, and a summary of the report, may be displayed on the output device **316**. Thereafter, the data connection is terminated.

The above-described health checkup process may be completely automated without intervention or involvement by a person at the remote service center.

The present invention is not limited to the scenarios and embodiments listed above, but instead may be practiced with a plurality of modifications and extensions.

For example, remote health monitoring and diagnostics shares many features with other automotive applications and services. It may be desirable to bundle the remote health monitoring and diagnostics with other services or to extend it with related application functions. For example, the remote diagnostics service could certainly be offered on top of an Emergency/Mayday service (e.g., "OnStar"). Other applications and services that can be developed or bundled as extensions of the diagnostics services include: breakdown service, network diary, vehicle user manual update, OEM Callback Services, fleet management, theft prevention, vehicle parameter update/change, remote vehicle access, concierge services, etc.

While the invention has been described in terms of several preferred embodiments, those skilled in the art will recognize that the invention can be practiced with modification within the spirit and scope of the appended claims.

What is claimed is:

1. An information system for a vehicle, comprising:

a client computer device within the vehicle, coupled to the vehicle's monitoring systems, for data management, remote session management and user interaction;

a communication system, coupled to said client computer device, for providing remote communication of data including data derived from said monitoring systems of the vehicle; and

a remote service center including a vehicle data store, a server computer, a diagnostic engine, and a communicator for communicating the results of analysis of vehicle information to said client computer device via said communication system,

wherein said data communicated comprises vehicle identification information, and

wherein said communication system provides for voice communications.

2. The system according to claim **1**, wherein said data further comprises at least one of vehicle location data and diagnostic data.

3. The system according to claim **1**, wherein said client computer device comprises a processor system including a processor, a memory coupled to said processor, input/output (I/O) ports, a user interface, and a communication device.

4. The system according to claim **3**, wherein said user interface includes an input device comprising at least one of speech recognition, speaker identification, voice recording, touch screen display, and actuator buttons.

5. The system according to claim **3**, wherein said user interface includes an output device comprising at least one of text-to-speech, voice playback, auditory signals, display screen, and indicator lights.

6. The system according to claim **1**, wherein said client computer device comprises at least one of an embedded computer, a laptop computer and a personal data assistant (PDA).

7. The system according to claim **1**, wherein the client computer device is coupled to a vehicle bus through a vehicle bus interface.

8. The system according to claim **7**, wherein said vehicle bus interface uses one of an RS-232 interface, a universal serial bus (USB), an ITS Data Bus (IDB), and Ethernet.

9. The system according to claim **7**, wherein said vehicle bus comprises one of a controller area network (CAN) and Society of Automotive Engineers' SAE J1850 data communication network interface.

10. The system according to claim **1**, wherein said client computer device is integrated with a telephone to provide establishment of at least one of a data connection and a voice connection with said remote service center.

11. The system according to claim **1**, wherein said remote service center includes a call center which is automated.

12. An information system for a vehicle, comprising:

a client computer device within the vehicle, coupled to the vehicle's monitoring systems, for data management, remote session management and user interaction;

a communication system, coupled to said client computer device, for providing remote communication of data including data derived from said monitoring systems of the vehicle; and

a remote service center including a vehicle data store, a server computer, a diagnostic engine, and a communicator for communicating the results of analysis of vehicle information to said client computer device via said communication system,

wherein said remote service center includes a call center including help-desk personnel.

13. The system according to claim 12, wherein the call center performs at least one of diagnostic analysis, provides recommendations, schedules services, orders parts, and dispatches assistance.

14. The system according to claim 12, wherein said client computer device is integrated with a telephone to provide establishment of at least one of a data connection and a voice connection with said remote service center.

15. The system according to claim 12, wherein said call center help-desk personnel access data related to the vehicle.

16. The system according to claim 12, wherein said call center includes a service representative user interface, a job queue management unit, and a service data management unit linked to a data repository of the service center.

17. The system of claim 12, wherein said communication system provides for voice communications.

18. The system of claim 12, wherein said remote service center includes a call center including help-desk personnel.

19. A method of remote diagnostics of a vehicle, comprising:

detecting, by a fault monitor, one or more fault codes generated by an electronic control unit of said vehicle;

notifying a diagnostic client of said fault codes;

checking, by said diagnostic client, the codes against a stored list to distinguish warning codes from a severe malfunction;

based on said checking, advising a user whether a warning code or a severe malfunction is present;

based on said advising, initiating a call to a remote service center using a data link;

forwarding data containing malfunction codes, vehicle parameter values, and vehicle identification information to a diagnostic server of said remote service center; and

receiving, by the diagnostic server, said data, and fetching stored vehicle information from a data repository, and displaying said data and the stored vehicle information for a service representative, while simultaneously placing a call to the vehicle.

20. The method according to claim 19, wherein for a predetermined malfunction, said service representative communicates with a service facility to dispatch assistance.

21. The method according to claim 19, wherein said detecting, notifying, and checking is performed more than one time.

22. The method according to claim 19, wherein said call to said remote service center is initiated by the user.

23. The method according to claim 19, wherein said call from said remote service center to said vehicle connects said service representative to the vehicle user.

24. The method according to claim 19, wherein said call to said vehicle connects said diagnostic server to said diagnostic client within the vehicle.

* * * * *

Exhibit F

IN THE UNITED STATES DISTRICT COURT
FOR THE MIDDLE DISTRICT OF FLORIDA
ORLANDO DIVISION

OMEGA PATENTS, LLC,
a Georgia limited liability company,

Plaintiff,

vs. **Case No. 6:13-cv-1950-Orl-31DAB**

CALAMP CORP.,
a Delaware corporation,

Defendant.
_____/

PLAINTIFF'S DISCLOSURE OF INITIAL INFRINGEMENT CONTENTIONS

Pursuant to the Case Management and Scheduling Order (Doc. 29), Plaintiff Omega Patents, LLC ("Omega") hereby serves it initial infringement contentions regarding U.S. Patent Nos. 6,346,876 B1 ("the '876 Patent"); 6,737,989 B2 ("the '989 Patent"); 6,756,885 B1 ("the '885 Patent"); 7,671,727 B2 ("the '727 Patent"); and 8,032,278 B2 ("the '278 Patent"), (collectively "patents-in-suit") on Defendant Calamp Corp. ("Calamp").

Because discovery has just begun, Omega makes these infringement contentions based on information presently known. Omega reserves the right to supplement and/or amend these contentions as a result of any ruling from the Court, including but not limited to the issuance of a *Markman* ruling.

Subject to these objections, Omega states as follows:

I. INFRINGEMENT

Omega contends that the following claims of the asserted patents are infringed by Calamp's LMU-3000 and LMU-3030 products: 1, 3-5, 12, 14, 16, 28, 34-36, and 41 of the '876

Patent; 23, 31, 32, 34 and 35 of the '989 Patent; 1-3, 12, 14 and 24 of the '885 Patent; 1, 10, 11, 19 and 25 of the '727 Patent; and 1-6, 8, 11-14, 16, 18, 19 and 21 of the '278 Patent.

Claim charts illustrating Omega's contentions are attached hereto and correspond to the following Exhibits:

Exhibit A-1	Infringement of the '876 Patent
Exhibit A-2	Infringement of the '989 Patent
Exhibit A-3	Infringement of the '885 Patent
Exhibit A-4	Infringement of the '727 Patent
Exhibit A-5	Infringement of the '278 Patent

Dated: May 30, 2014

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CERTIFICATE OF SERVICE

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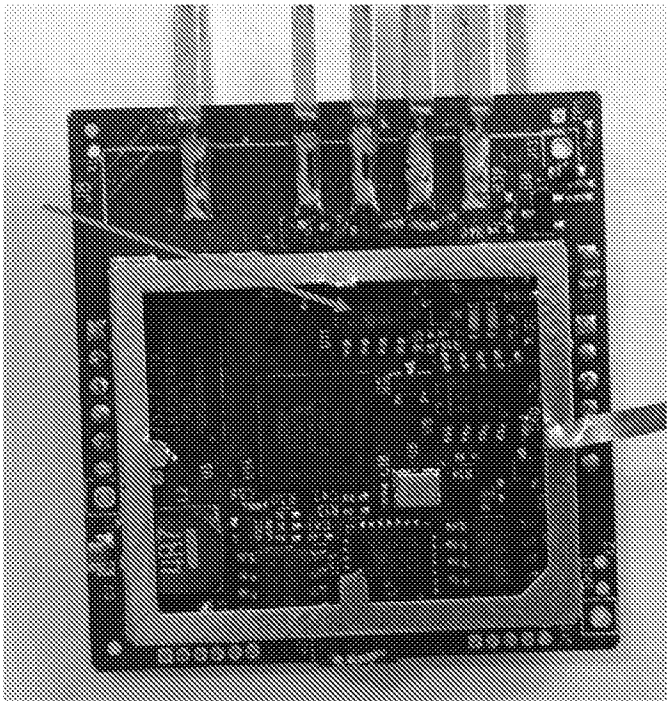
EXHIBIT A-1

U.S. PATENT 6,346,876	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[1]
1. A control system for a vehicle comprising a data communications bus and at least one vehicle device connected to the data communications bus, the control system comprising:	The LMU-3000 is part of a control system for a vehicle comprising a data communications bus and at least one vehicle device connected to the data communications bus.
a transmitter and a receiver for receiving signals from said transmitter; and	The LMU-3000 uses a transmitter and a receiver for receiving signals from said transmitter. The LMU-3000 includes a cellular module that allows transmission to and reception from a central station:

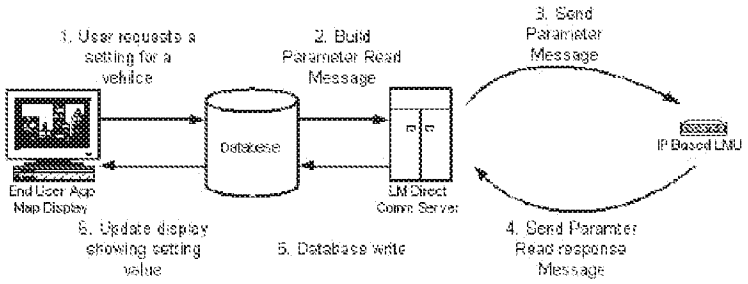
[1] The LMU-3000 and LMU-3030 are advertised as having the same functionality and features described herein. Thus, references throughout these claim charts to the LMU-3000 are intended to apply equally to the LMU-3030.

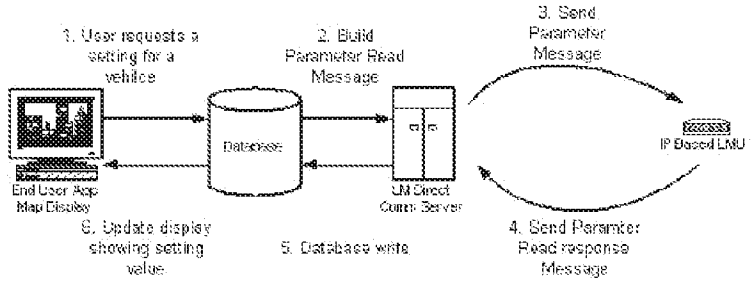
U.S. PATENT 6,346,876	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[1]
a multi-vehicle compatible controller at the vehicle and cooperating with said transmitter and receiver, said multi-vehicle compatible controller generating at least one set of command signals on the data	The LMU-3000 includes a multi-vehicle compatible controller at the vehicle and cooperating with said transmitter and receiver, said multi-vehicle compatible controller generating at least one set of command signals on the data communications bus for the at least one vehicle device, the at least one set of

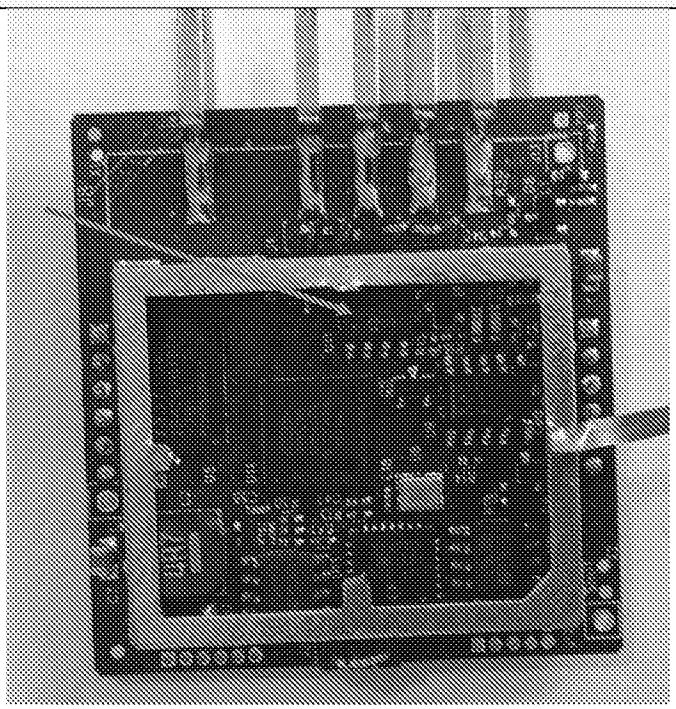
U.S. PATENT 6,346,876	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[1]
communications bus for the at least one vehicle device, the at least one set of command signals comprising at least one working command signal and at least one non-working command signal for a given vehicle to thereby provide command compatibility with a plurality of different vehicles.	command signals comprising at least one working command signal and at least one non-working command signal for a given vehicle to thereby provide command compatibility with a plurality of different vehicles. The vehicle device is the vehicle's engine control module (ECM). The LMU-3000 includes a multivehicle compatible controller that cooperates with the cellular module.

U.S. PATENT 6,346,876	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[1]
	The LMU-3000 includes a CAN bus transceiver, product MCP2551I:  On initial installation, the multi-vehicle compatible controller generates a

U.S. PATENT 6,346,876	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[1]
	sequence of working and non-working command signals to determine command compatibility of different vehicles, including CAN 11 Bit 7DF message, CAN 29 Bit 18DB33F1 message, J1850 VPW 68 6A F1 message, J1850 PWM message, K-Line messages and J1850 VPW 6C 10 F1 message.
3. A control system according to claim 1 wherein said multi-vehicle compatible controller generates command signals sequentially.	The LMU-3000 includes a multi-vehicle compatible controller generates command signals sequentially, using the following sequence: CAN 11 Bit 7DF message, CAN 29 Bit 18DB33F1 message, J1850 VPW 68 6A F1 message, J1850 PWM message, K-Line messages and J1850 VPW 6C 10 F1 message.
4. A control system according to claim 1 wherein said multi-vehicle compatible controller generates command signals each representing digitally coded information.	The LMU-3000 includes a multi-vehicle compatible controller generates command signals each representing digitally coded information, using the following messages: CAN 11 Bit 7DF message, CAN 29 Bit 18DB33F1 message, J1850 VPW 68 6A F1 message, J1850 PWM message, K-Line messages and J1850 VPW 6C 10 F1 message.
5. A control system according to claim 1 wherein said multi-vehicle compatible controller comprises a memory for storing data relating to the at least one set of command signals.	The LMU-3000 includes a multi-vehicle compatible controller comprising a memory for storing data relating to the at least one set of command signals, including the following messages: CAN 11 Bit 7DF message, CAN 29 Bit 18DB33F1 message, J1850 VPW 68 6A F1 message, J1850 PWM message, K-Line messages and J1850 VPW 6C 10 F1 message. After configuration, the memory also stores data relating to the learned vehicle.
12. A control system according to claim 1 wherein said multi-vehicle compatible controller is further for storing a set of device codes for a given vehicle	The LMU-3000 includes a multi-vehicle compatible controller is further for storing a set of device codes for a given vehicle device for a plurality of different vehicles, for reading a device code from the data communications bus,

U.S. PATENT 6,346,876	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[1]
device for a plurality of different vehicles, for reading a device code from the data communications bus, and for determining a match between a read device code and the stored device codes to thereby provide reading compatibility with a plurality of different vehicles.	and for determining a match between a read device code and the stored device codes to thereby provide reading compatibility with a plurality of different vehicles. The LMU-3000 stores messages for CAN, J1850 and K Line buses, reads the messages transmitted from a vehicle device on the bus, and matches the read message to the stored message to provide compatibility with different vehicles.
14. A control system according to claim 1 wherein said transmitter comprises at least a central station transmitter; and wherein said receiver is at the vehicle.	The LMU-3000 includes a cellular module that allows communication between the device and a central station.  LM Direct Reference Manual v.8.6.c.2 p. 53.
16. A control system according to claim 1 wherein said receiver comprises at least a central station transmitter; and wherein said transmitter is at the vehicle.	The LMU-3000 includes a cellular module that allows communication between the device and a central station.

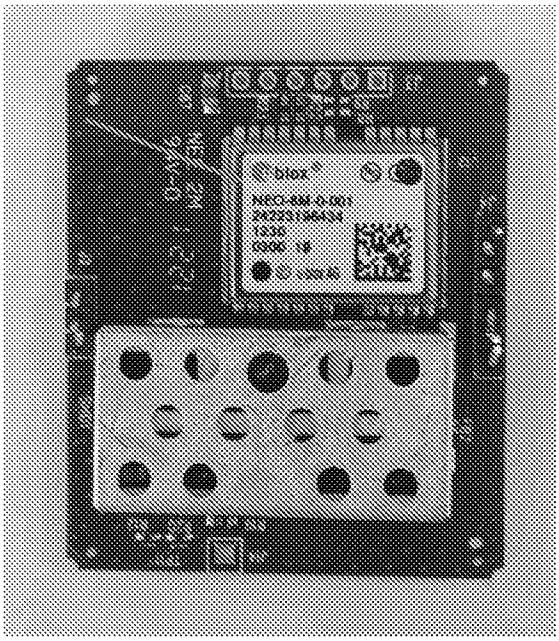
U.S. PATENT 6,346,876	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[1]
	 LM Direct Reference Manual v.8.6.c.2 p. 53.
28. A control method for a vehicle comprising a data communications bus and at least one vehicle device connected to the data communications bus, the method comprising:	The LMU-3000 allows one to practice a control method for a vehicle comprising a data communications bus and at least one vehicle device connected to the data communications bus.
generating at least one set of command signals on the data communications bus for the at least one vehicle device, the at least one set of command signals comprising at least one working command signal and at least one non-working command signal for a given vehicle to thereby provide command compatibility with a plurality of different vehicles.	The LMU-3000 generates at least one set of command signals on the data communications bus for the at least one vehicle device, the at least one set of command signals comprising at least one working command signal and at least one non-working command signal for a given vehicle to thereby provide command compatibility with a plurality of different vehicles. The at least one vehicle device is the vehicle's ECM. The LMU-3000 includes a CAN bus transceiver, product MCP2551I:

U.S. PATENT 6,346,876	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[1]
	 On initial installation, the multi-vehicle compatible controller generates a sequence of working and non-working command signals to determine command compatibility of different vehicles, including CAN 11 Bit 7DF message, CAN 29 Bit 18DB33F1 message, J1850 VPW 68 6A F1 message, J1850 PWM

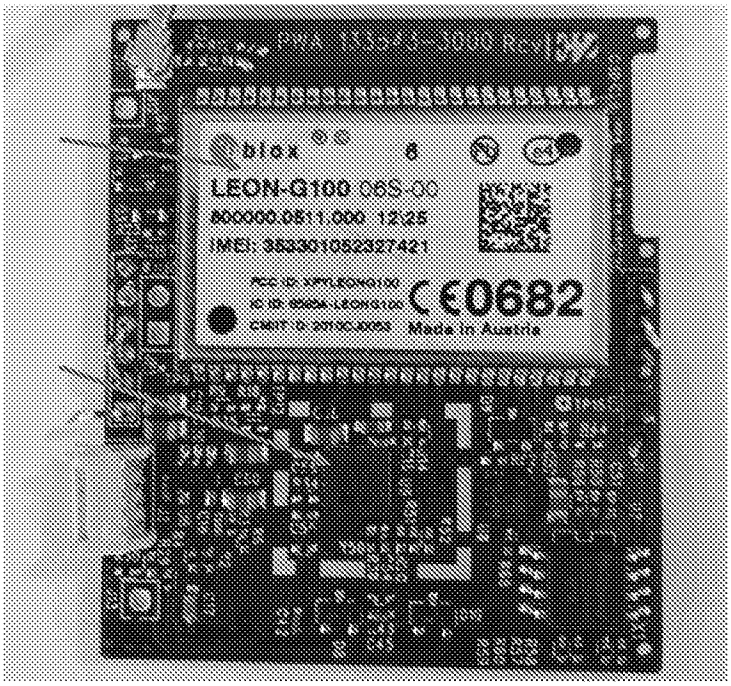
U.S. PATENT 6,346,876	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[1]
	message, K-Line messages and J1850 VPW 6C 10 F1 message.
34. A method according to claim 28 wherein the command signals are generated sequentially.	The LMU-3000 includes a multi-vehicle compatible controller generates command signals sequentially, using the following sequence: CAN 11 Bit 7DF message, CAN 29 Bit 18DB33F1 message, J1850 VPW 68 6A F1 message, J1850 PWM message, K-Line messages and J1850 VPW 6C 10 F1 message.
35. A method according to claim 28 the command signals each represent digitally coded information.	The LMU-3000 includes a multi-vehicle compatible controller generates command signals each representing digitally coded information, using the following messages: CAN 11 Bit 7DF message, CAN 29 Bit 18DB33F1 message, J1850 VPW 68 6A F1 message, J1850 PWM message, K-Line messages and J1850 VPW 6C 10 F1 message.
36. A method according to claim 28 further comprising storing in a memory data relating to the at least one set of command signals.	The LMU-3000 includes a multi-vehicle compatible controller comprises a memory for storing data relating to the at least one set of command signals, including the following messages: CAN 11 Bit 7DF message, CAN 29 Bit 18DB33F1 message, J1850 VPW 68 6A F1 message, J1850 PWM message, K-Line messages and J1850 VPW 6C 10 F1 message. After configuration, the memory also stores data relating to the learned vehicle.
41. A method according to claim 28 further comprising:	
storing a set of device codes for a given vehicle device for a plurality of different vehicles;	The LMU-3000 stores a set of device codes for a given vehicle device for a plurality of different vehicles.

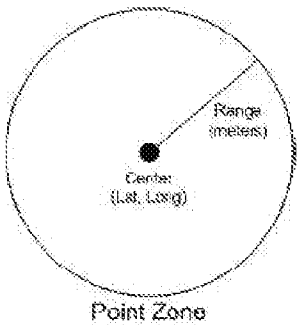
U.S. PATENT 6,346,876	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[1]
reading a device code from the data communications bus; and	The LMU-3000 reads a device code from the data communications bus.
determining a match between a read device code and the stored device codes to thereby provide reading compatibility with a plurality of different vehicles.	The LMU-3000 determines a match between a read device code and the stored device codes to thereby provide reading compatibility with a plurality of different vehicles.

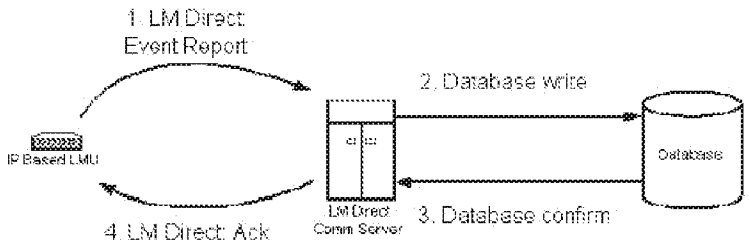
EXHIBIT A-2

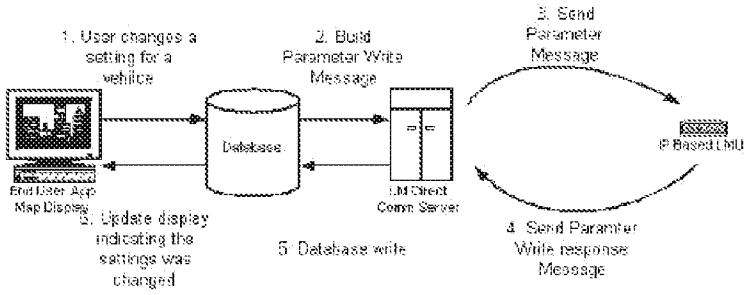
U.S. PATENT 6,737,989	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[2]
23. A tracking unit for a vehicle comprising:	The LMU-3000 is a tracking unit for a vehicle.
a vehicle position determining device, a wireless communication device, and a controller cooperating with said wireless communications device and said vehicle position determining device to determine and send vehicle position information to a monitoring station;	The LMU-3000 is a vehicle position determining device: 

[2] The LMU-3000 and LMU-3030 are advertised as having the same functionality and features described herein. Thus, references throughout these claim charts to the LMU-3000 are intended to apply equally to the LMU-3030.

U.S. PATENT 6,737,989	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[2]
	a wireless communication device, and a controller cooperating with said wireless communications device and said vehicle position determining device to determine and send vehicle position information to a monitoring station. Depicted below is the wireless communication device and controller. 

U.S. PATENT 6,737,989	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[2]
said controller storing a user selected reference location;	The LMU-3000 includes a controller storing a user selected reference location.
said controller also sending the vehicle position information based upon the vehicle moving beyond a radial threshold distance from the user selected reference location.	The LMU-3000 includes a controller also sending the vehicle position information based upon the vehicle moving beyond a radial threshold distance from the user selected reference location. PEG Programming Guide (v1.0.0), p. 26(section 3.8.2.1) sets forth the Parameter IDs and how geofences are set:  3-4 Point Zone Definition Calamp's LMU Manager guides customers through setting up geofencing by allowing customers to set a geofence zone using the "Zones" tab in LMU Manager, then setting up an input trigger for zone entry/zone exit, and programming the LMU-3000 to send report.

U.S. PATENT 6,737,989	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[2]
	 LM Direct Reference Guide v.8.6.c.2 p. 45.
31. The vehicle tracking unit according to claim 23 wherein said controller comprises at least one memory for storing the user selected reference location and vehicle position information therein.	The LMU-3000 includes at least one memory for storing the user selected reference location and vehicle position information therein.
32. The vehicle tracking unit according to claim 23 wherein said controller sets the user selected reference location based upon at least one signal provided by the monitoring station.	The LMU-3000 includes a controller that sets the user selected reference location based upon at least one signal provided by the monitoring station. The user can use LMU Manager to set the user selected reference location and send it to the LMU-3000 via a monitoring station.

U.S. PATENT 6,737,989	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[2]
	 LM Direct Reference Guide v.8.6.c.2 p. 55.
34. The vehicle tracking unit according to claim 32 wherein the at least one signal includes the user selected reference location.	The LMU-3000 according to claim 32 that includes at least the user selected reference location.
35. The vehicle tracking unit according to claim 23 wherein said vehicle position determining device comprises a Global Positioning System (GPS) device.	The LMU-3000 includes a Global Positioning System (GPS) device.

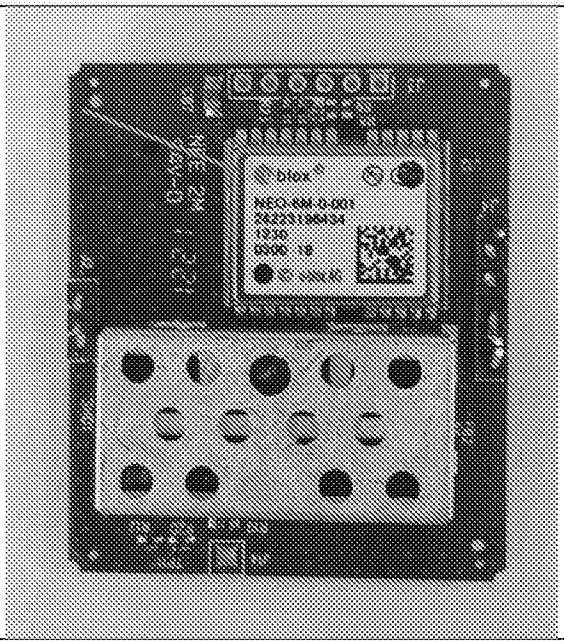
U.S. PATENT 6,737,989	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[2]
	

EXHIBIT A-3

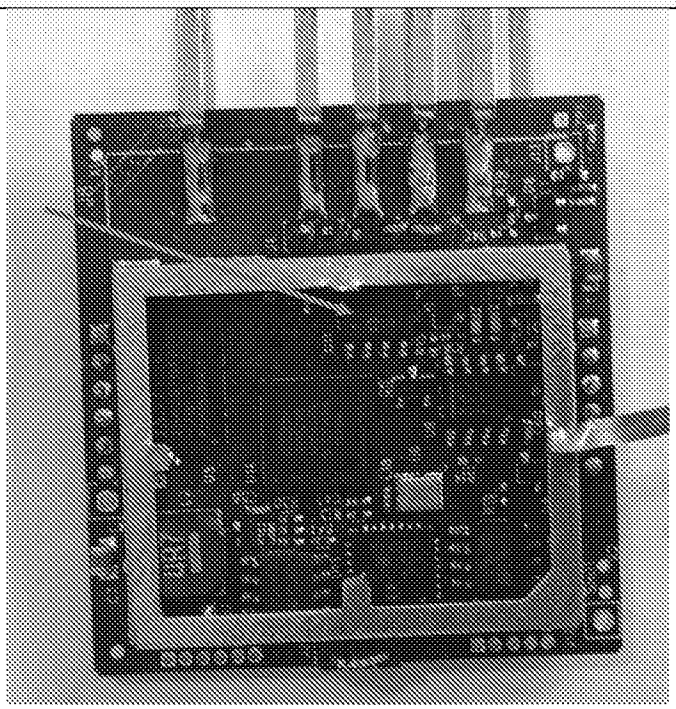
U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
1. A control system for a vehicle comprising a data communications bus and at least one vehicle device connected thereto, the control system comprising:	The LMU-3000 is a control system for a vehicle comprising a data communications bus and at least one vehicle device connected thereto.
a transmitter and a receiver for receiving signals from said transmitter; and	The LMU-3000 has a transmitter and a receiver for receiving signals from said transmitter. The LMU-3000 includes a cellular module that allows transmission to and reception from a central station. Below is the cellular module that comprises a transmitter and receiver.

[3] The LMU-3000 and LMU-3030 are advertised as having the same functionality and features described herein. Thus, references throughout these claim charts to the LMU-3000 are intended to apply equally to the LMU-3030.

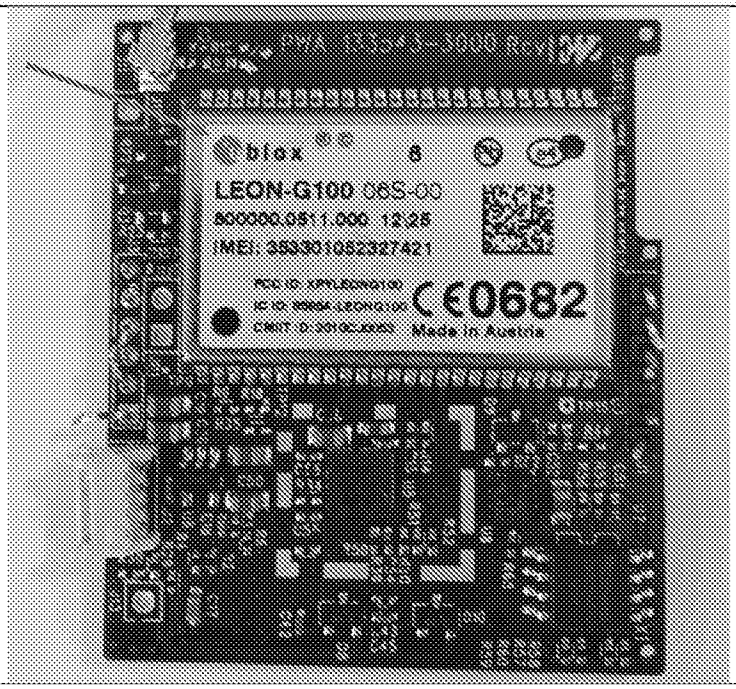
U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
a multi-vehicle compatible controller cooperating with said transmitter and said receiver and for storing a set of device codes for a given vehicle device for a plurality of different vehicles, for reading a device code from the data communications	The LMU-3000 includes a multi-vehicle compatible controller cooperating with said transmitter and said receiver and for storing a set of device codes for a given vehicle device for a plurality of different vehicles, for reading a device code from the data communications bus, and for determining a match between a read device code and the stored device codes to thereby provide compatibility

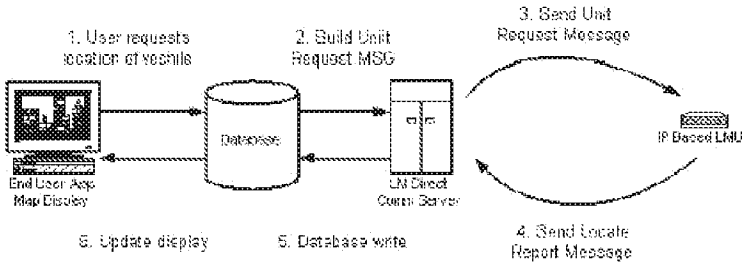
U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
bus, and for determining a match between a read device code and the stored device codes to thereby provide compatibility with a plurality of different vehicles.	with a plurality of different vehicles. The given vehicle device is the ECM. The LMU-3000 stores messages for CAN, J1850 and K Line buses, reads the messages transmitted from a vehicle device on the bus, and matches the read

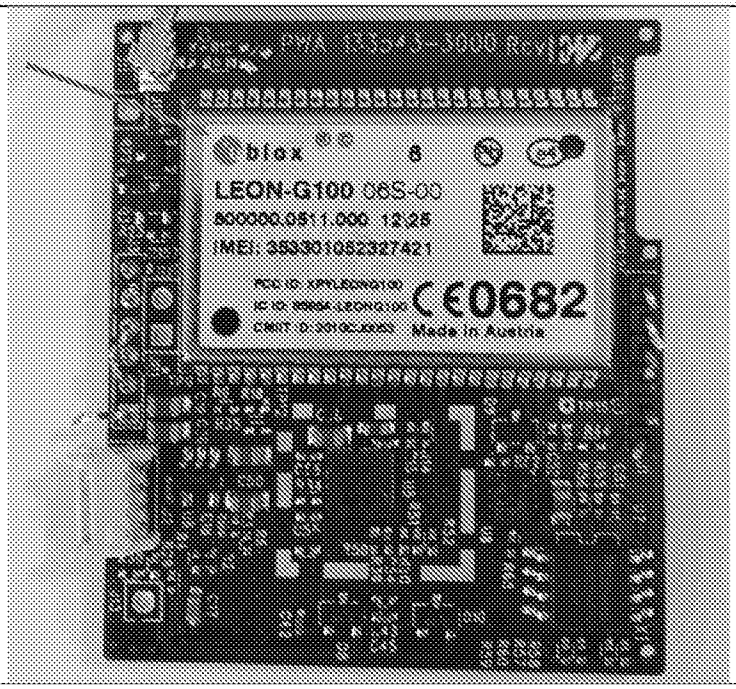
U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
	message to the stored message to provide compatibility with a plurality of different vehicles. The LMU-3000 includes a CAN bus transceiver, product MCP25511:

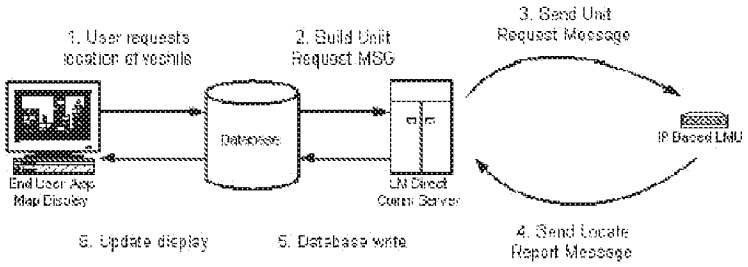
U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
	
2. A control system according to claim 1 wherein said multi-vehicle compatible controller comprises a memory for the stored device codes.	The LMU-3000 includes a multi-vehicle compatible controller comprises a memory for the stored device codes. The LMU-3000 includes a memory for storing device codes, including the following messages: CAN 11 Bit 7DF

U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
	message, CAN 29 Bit 18DB33F1 message, J1850 VPW 68 6A F1 message, J1850 PWM message, K-Line messages and J1850 VPW 6C 10 F1 message. After configuration, the memory also stores data relating to the learned vehicle.
3. A control system according to claim 2 wherein said multi-vehicle compatible controller comprises a processor cooperating with said memory for determining the match between the read device code and the stored device codes.	The LMU-3000 includes a multi-vehicle compatible controller comprises a processor cooperating with said memory for determining the match between the read device code and the stored device codes.
12. A control system according to claim 1 wherein said transmitter comprises at least a central station transmitter; and wherein said receiver is at the vehicle.	The LMU-3000 includes a cellular module that allows communication between the device and a central station.

U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
	

U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
	 LM Direct Reference Guide v.8.6.c.2 p. 47.
14. A control system according to claim 1 wherein said receiver comprises at least a central station transmitter; and wherein said transmitter is at the vehicle.	The LMU-3000 includes a cellular module that allows communication between the device and a central station.

U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
	

U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
	 LM Direct Reference Guide v.8.6.c.2 p. 47.
24. A control method for a vehicle comprising a data communications bus and at least one vehicle device connected thereto, the method comprising:	The LMU-3000 allows one to practice a control method for a vehicle comprising a data communications bus and at least one vehicle device connected thereto.
storing a set of device codes for a given vehicle device for a plurality of different vehicles;	The LMU-3000 stores a set of device codes for a given vehicle device for a plurality of different vehicles. The LMU-3000 stores messages for CAN, J1850 and K Line buses for a plurality of different vehicles.
reading a device code from the data communications bus; and	The LMU-3000 reads a device code from the data communications bus. The LMU-3000 reads the messages transmitted from a vehicle device on the bus.
determining a match between a read device code and the stored device codes and performing a function based thereon to thereby provide compatibility with a plurality of different vehicles.	The LMU-3000 determines a match between a read device code and the stored device codes and performing a function based thereon to thereby provide compatibility with a plurality of different vehicles. The LMU-3000 matches the read message to the stored message to provide compatibility with a plurality of different vehicles.

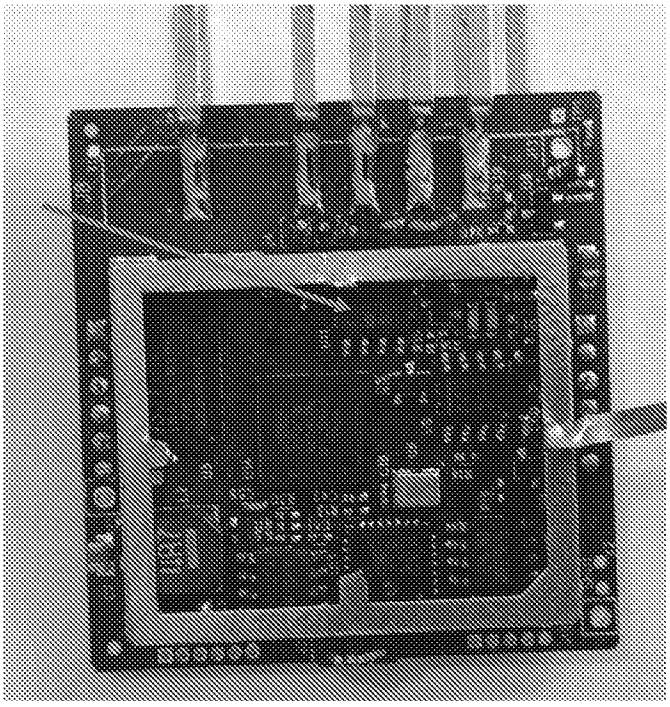
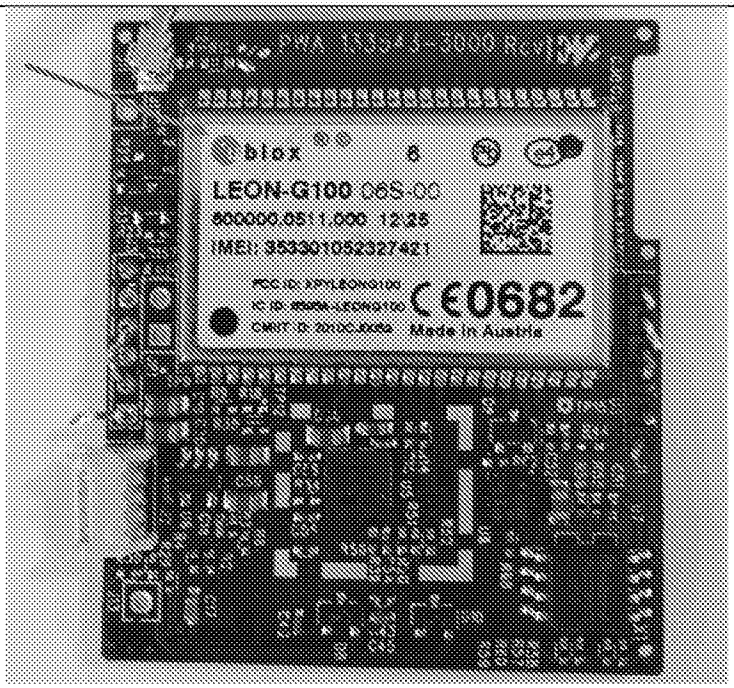
U.S. PATENT 6,756,885	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[3]
	The LMU-3000 includes a CAN bus transceiver, product MCP2551I: 

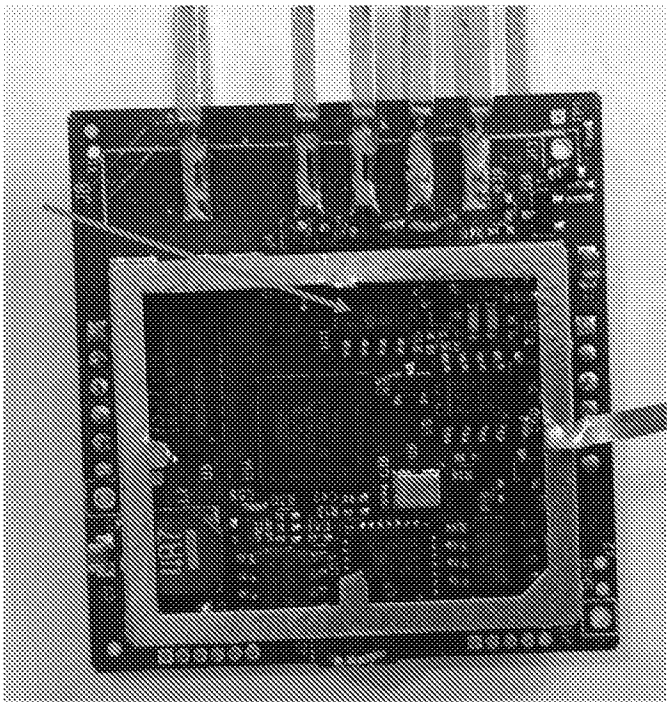
EXHIBIT A-4

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
1. A speed exceeded notification device for a vehicle of a type comprising a vehicle data communications bus extending throughout the vehicle, and at least one vehicle device generating data related to vehicle speed on the vehicle data communications bus, the speed exceeded notification device comprising:	The LMU-3000 is a speed exceeded notification device for a vehicle of a type comprising a vehicle data communications bus extending throughout the vehicle, and at least one vehicle device generating data related to vehicle speed on the vehicle data communications bus.
a wireless communications device; and	The LMU-3000 includes a wireless communications device. The LMU-3000 includes a cellular module.

[4] The LMU-3000 and LMU-3030 are advertised as having the same functionality and features described herein. Thus, references throughout these claim charts to the LMU-3000 are intended to apply equally to the LMU-3030.

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
	
a controller to be coupled to the vehicle data communications bus for reading the data related to vehicle speed from the vehicle data communications bus, and determining when a vehicle speed exceeds a speed threshold for a	The LMU-3000 includes a controller to be coupled to the vehicle data communications bus for reading the data related to vehicle speed from the vehicle data communications bus, and determining when a vehicle speed exceeds a speed threshold for a first time period and based thereon cooperating with said wireless communications device to send a remote vehicle speed exceeded notification.

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
first time period and based thereon cooperating with said wireless communications device to send a remote vehicle speed exceeded notification.	The controller is depicted below:

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
	The LMU-3000 includes a CAN bus transceiver, product MCP2551I:  Using the PEG Programming Guide (v1.0.0), p. 17 (section 3.5), the user sets the

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
	correct Parameter IDs for how the features work and sets the Speed above delay (time it has to be over speed before report) 3.5 **Speed Thresholds and Movement** The LMU has five Speed Thresholds to use within PEG, four of which are tied to generic Speed Thresholds (Parameter 257, indexes 0-3) and the last to the Moving Speed Threshold (Parameter 1035). Each Threshold is measured in cm/s, though many of the tools used with the LMU (eg PULS and LMU Manager) convert this into MPH or km/h. The Calamp LMU Manager Users Guide explains how to configure features for speed notification. The Speed Threshold is set in LMU Manager, and an input trigger defines the speed above, no conditions, and to send report. Calamp includes canned event message sent (LM Direct Reference Guide v. 8.6.c.2 (p. 4)) that include position and speed.

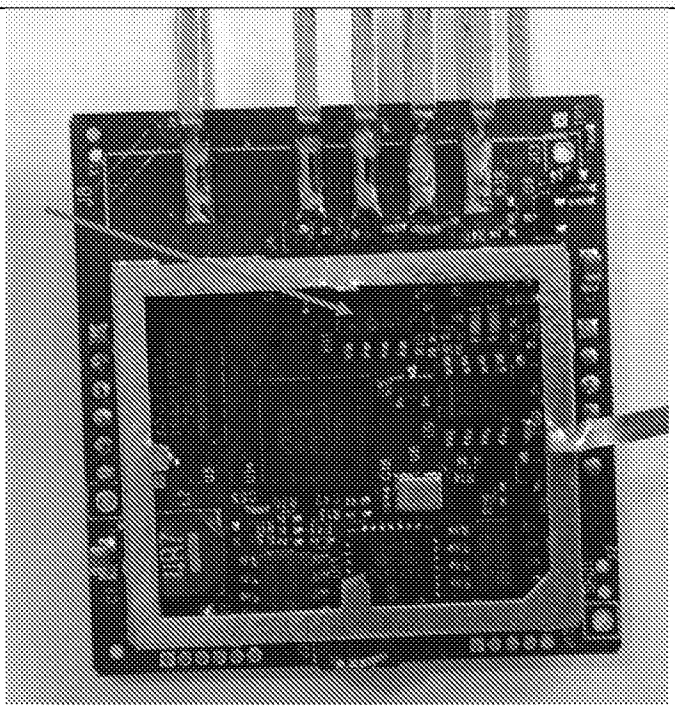
U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
	Event Report Message (Message Type 2)

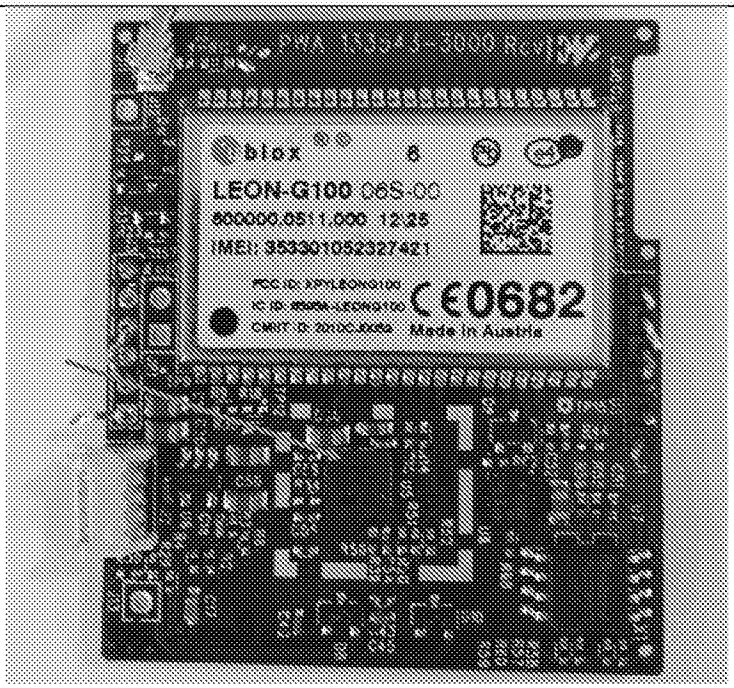
Event Report messages are initiated by the LMU and are generated by the LMU's Programmable Event Generator (PEG). They can be either Acknowledged or Unacknowledged Requests. The Server should respond to an Acknowledged Event Report Request with an Acknowledge message. Event reports have the following structure:

15	0
Options Header (optional)	..
..	..
Message Header	..
..	..
Update Time (msByte)	Update Time
Update Time	Update Time (lsByte)
Time of Fix (msByte)	Time of Fix
Time of Fix	Time of Fix (lsByte)
Latitude (msByte)	Latitude
Latitude	Latitude(lsByte)
Longitude (msByte)	Longitude
Longitude	Longitude (lsByte)
Altitude (msByte)	Altitude
Altitude	Altitude(lsByte)
Speed (msByte)	Speed
Speed	Speed (lsByte)
Heading (msByte)	Heading (lsByte)
Satellites	Fix Status
Carrier (msByte)	Carrier (lsByte)
RSSI (msByte)	RSSI (lsByte)
Comm State	HDOP
Inputs	Unit Status
Event Index	Event Code
Accums	spare
AccumList(msByte)	AccumList
AccumList	AccumList (lsByte)
..	..

Event Report Message Format

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
10. The speed exceeded notification device according to claim 1 wherein the remote vehicle speed exceeded notification further comprises a speed of the vehicle.	The LMU-3000 is a speed exceeded notification device according to claim 1 wherein the remote vehicle speed exceeded notification further comprises a speed of the vehicle. Calamp includes canned event message (LM Direct Reference Guide v. 8.6.c.2 (p. 4)) that include position and speed.
11. The speed exceeded notification device according to claim 1 wherein the remote vehicle speed exceeded notification further comprises a vehicle position.	The LMU-3000 is a speed exceeded notification device according to claim 1 wherein the remote vehicle speed exceeded notification further comprises a vehicle position. Calamp includes canned event message (LM Direct Reference Guide v. 8.6.c.2 (p. 4)) that include position and speed.
19. A method for speed exceeded notification in a vehicle of a type comprising a vehicle data communications bus extending throughout the vehicle, and at least one vehicle device generating data related to vehicle speed on the vehicle data communications bus, the method comprising:	The LMU-3000 provides a method for speed exceeded notification in a vehicle of a type comprising a vehicle data communications bus extending throughout the vehicle, and at least one vehicle device generating data related to vehicle speed on the vehicle data communications bus.
using a controller coupled to the vehicle data communications bus for reading the data related to vehicle speed from the vehicle data communications bus, and	The LMU-3000 provides using a controller coupled to the vehicle data communications bus for reading the data related to vehicle speed from the vehicle data communications bus. The LMU-3000 includes a CAN bus transceiver, product MCP2551I:

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
	 The controller is depicted below:

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
	 Using the PEG Programming Guide (v1.0.0), p. 17 (section 3.5), the user sets the correct Parameter IDs for how the features work and sets the Speed above delay (time it has to be over speed before report).

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
	3.5 **Speed Thresholds and Movement** The LMU has five Speed Thresholds to use within PEG, four of which are tied to generic Speed Thresholds (Parameter 257, indexes 0-3) and the last to the Moving Speed Threshold (Parameter 1035). Each Threshold is measured in cm/s, though many of the tools used with the LMU (eg PULS and LMU Manager) convert this into MPH or km/h. The Calamp LMU Manager Users Guide explains how to configure features for speed notification. The Speed Threshold is set in LMU Manager, and an input trigger defines the speed above, no conditions, and to send report. Calamp includes canned event message sent (LM Direct Reference Guide v. 8.6.c.2 (p. 4)) that include position and speed.

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
	Event Report Message (Message Type 2)

Event Report messages are initiated by the LMU and are generated by the LMU's Programmable Event Generator (PEG). They can be either Acknowledged or Unacknowledged Requests. The Server should respond to an Acknowledged Event Report Request with an Acknowledge message. Event reports have the following structure:

15	0
Options Header (optional)	..
..	..
Message Header	..
..	..
Update Time (msByte)	Update Time
Update Time	Update Time (lsByte)
Time of Fix (msByte)	Time of Fix
Time of Fix	Time of Fix (lsByte)
Latitude (msByte)	Latitude
Latitude	Latitude(lsByte)
Longitude (msByte)	Longitude
Longitude	Longitude (lsByte)
Altitude (msByte)	Altitude
Altitude	Altitude(lsByte)
Speed (msByte)	Speed
Speed	Speed (lsByte)
Heading (msByte)	Heading (lsByte)
Satellites	Fix Status
Carrier (msByte)	Carrier (lsByte)
RSSI (msByte)	RSSI (lsByte)
Comm State	HDOP
Inputs	Unit Status
Event Index	Event Code
Accums	spare
AccumList(msByte)	AccumList
AccumList	AccumList (lsByte)
..	..

Event Report Message Format

U.S. PATENT 7,671,727	
OMEGA PATENT CLAIMS	LMU-3000/LMU-3030[4]
determining when a vehicle speed exceeds a speed threshold for a first time period and based thereon cooperating with a wireless communications device to send a remote vehicle speed exceeded notification.	The LMU-3000 provides for determining when a vehicle speed exceeds a speed threshold for a first time period and based thereon cooperating with a wireless communications device to send a remote vehicle speed exceeded notification, as shown above.
25. The method according to claim 19 wherein the remote vehicle speed exceeded notification further comprises at least one of an identity of the vehicle, a speed of the vehicle, a vehicle position, and a time the vehicle exceeded the speed threshold.	The LMU-3000 provides the remote vehicle speed exceeded notification further comprises at least one of an identity of the vehicle, a speed of the vehicle, a vehicle position, and a time the vehicle exceeded the speed threshold. Calamp includes canned event message (LM Direct Reference Guide v. 8.6.c.2 (p. 4)) that include position and speed.