

ADVANCE COMPUTER COMMUNICATION SYSTEMS IN HYBRID VEHICLES

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Abstract - This paper presents an overview of advance signal processors and computer systems in present day hybrid vehicles. The increase in processing speeds of the present day digital signal processors has helped in development of hybrid cars at commercial level. Hybrid vehicles make use of computer control systems that are extremely complicated. The recent advances in processing speed and power, the invention of graphical software environments, and real-time operating systems, have contributed towards the development of these complex hybrid vehicles. The use of a high-speed 'communication bus' on the vehicle, known as CAN (Controller Area Network), play an important role. These communication buses allow the embedded controller to communicate with each another.

I. INTRODUCTION

In recent years, the amount of computerization used in vehicles has increased significantly. This trend is expected to continue as manufacturers initiate further advances in safety, reliability, and comfort.

Electric Vehicle (EV) is a high-tech electro-mechanical gadget controlled by computer and powered by combination of fuel. EVs make use of mechanical motion, microelectronics, power electronics, material, control, electric motor, electrochemistry, vehicle technology and many other allied technologies. Electric vehicle is not a simple substitution of a fuel-operated drive because of intrinsically different approach between an electrical machine and a typical fuel machine, and problems engendered from the battery system. It is an organic combination of allied fields and matching of various technologies. For an electric vehicle, its body, under pan, and relative auxiliary parts are the foundation. The battery, motor and driver technology are key. Vehicle Control Unit (VCU) is the main center of an electric vehicle. It realizes the desired response characteristic of electric vehicle. VCU is the media between the man and the machine. The aim of VCU is to realize the optimal performance of the vehicle as a single unit. According to the performance requirement and actual work condition, VCU collects and analyzes the information from the system, and synthetically manages and controls the vehicle. It also provides safe diagnostic service of the whole system.

The main parts in the EV research include VCU, electric vehicle Battery Management Unit (BMU), Power Management Unit (PMU), and electric vehicle auxiliary system. Each part is relatively independent at the same time they work harmoniously. So, communication is requested between each part while they work

independently. The block diagram of a typical electric vehicle is shown in Fig. 1. VCU needs to coordinate with BMU and PMU while electric vehicle is on work. The dynamic parameters of motor, such as rotary speed, current, and driving voltage are read from PMU. The parameters of battery including voltage, temperature and power are read from BMU. The vehicle body parameters can be read from the electric vehicle auxiliary system. VCU deals with these parameters and returns the related information to PMU, BMU, relays, and liquid crystal display system.

The paper presents an overview of available and future scope for advancement in computer communication system in electric and hybrid vehicles.

II. VEHICLE CONTROL UNIT

The control system of the electric vehicle uses module management mode. It is useful for circuit design and integration of the system, and convenient to manufacture and maintain. The main functions of VCU are that it can contact the driver and vehicle, explain the driver's commands to accelerate, decelerate, brake, turning, back, etc, and provide information about the state of the vehicle. VCU provides excellent drive performance. It takes optimum control strategy to establish accurate working conditions, precisely calculate torque of electric vehicle, and implement efficiency optimization control and torque control. VCU controls power flow. In order to reasonably utilize energy, it manages the energy of battery, and the energy of auxiliary battery. An energy flow control block realizes this function and provides safe charging and driving. It examines and controls the temperature of motor, cooling system, drive system, and work condition.

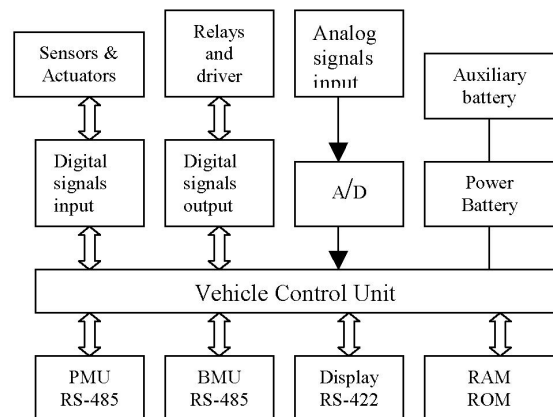


Fig. 1 Schematic block diagram of a typical electric vehicle

III. COMMUNICATION PROTOCL

Command center of the vehicle control system is the VCU. All information is collected and analyzed here. According to the actual working condition, VCU manages and controls the vehicle. The schematic of hardware system of a typical HEV is shown in Fig. 2. It consists of motor control, power management unit, battery management unit, battery charger, display panel and auxiliary control system. During any communication, if the subordinate system does not respond after 40 ms, it sends request information again or stops request and displays the error message. Information is exchanged between PMU and BMU, and is displayed in the display system; whereas information is also stored in RAM. Digital Signal Processing (DSP) realizes the control orders of electric motor drive system. Control circuit of vehicle performs the control of relays, energy flow, and protective functions. The auxiliary battery provides power to the VCU. The information of power battery state is exchanged between the VCU and BMU. The primary duty of VCU is to carry out communication amongst different units of the electric vehicle.

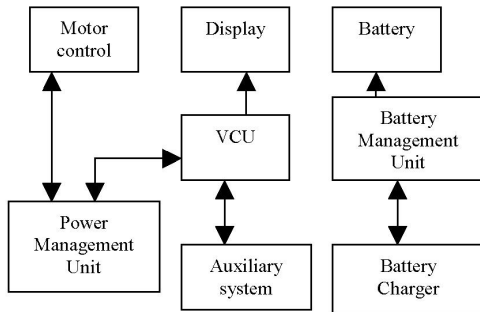


Fig. 2 Schematic of hardware configuration of electric vehicle

In the communication system of electric vehicle, RS-485 is selected as communication mode with baud rate of 19,200 bits/sec. It uses ASCII code to exchange data. The system utilizes twisted pair wire system, half duplex, principal, and subordinate communication mode. The BMU, VCU and PMU interface is shown in Fig. 3.

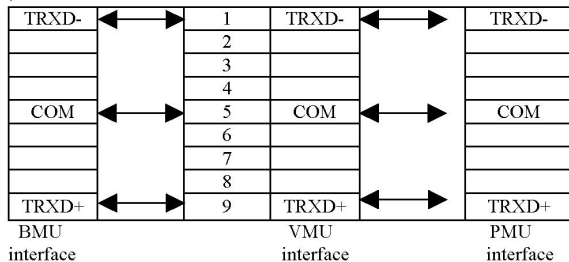


Fig. 3 Communication interface between sub-systems

The communication protocols of the VCU, PMU and BMU is shown in Table I. The process of communication is as follows. The serial port is on receiving mode. VCU is

in communication with BMU and PMU every 200 msec. The interval between BMU and PMU is 100 msec. BMU and PMU send data to VMU every 20 msec, after receiving information. If the subordinate system has no response after 40 msec, the system defines the instance as communication error.

TABLE I
COMMUNICATION PROTOCOL

Communication protocol between VCU and BMU		
Number	Content	Meaning
1	STX	Start symbol
2	0	Number of Host
3	1/0	Number of slave station
4	ETX	Stop symbol
Communication protocol between VCU and PMU		
Number	Content	Meaning
1	STX	Start Symbol
2	1	Number of BMU
3	BMURec	Receive accurately Y/N
4	Chang	Charge Yes or No
5	SorError	Battery Breakdown
6	Warning	Battery Temperature
7-10	BatTem	Battery Temperature
11-14	BatRes	Residual battery charge
15-18	BatVol	Battery voltage
19-22	BMUSUM	BMUSUM
23	ETX	Stop Symbol
Communication protocol between VCU and BMU		
Number	Content	Meaning
1	STX	Start symbol
2	0	Number of Host
3	2	Number of slave
4	Bat	Forbid
5	SorError	Power Alarm Y/N
6-9	BatRes	Residual battery charge
10-13	Sum2	Checksum
14	ETX	Stop
Communication protocol between PMU and VCU		
Number	Content	Meaning
1	STX	Start Symbol
2	2	Number of slave
3	Receive	Receive accurately Y/N
4	MotError	Motor Breakdown Y/N
5-8	MotCur	Motor Current
9-12	MotVol	Motor Voltage
13-16	MotSpe	Motor Speed
17-20	OilGate	Accelerometer signal
21-24	PMUSum	Battery Voltage
25	ETX	Stop Symbol

IV. COMPUTER COMMUNICATION SYSTEM

Introduction of advanced control systems, which combine multiple sensors, actuators, and Electronic Control Units (ECU), has begun to place boundary demands on the existing Controller Area Network (CAN)

communications bus found in most electric vehicles. As a result, initiatives by scientists, engineers, automobile manufacturers and suppliers have led to the creation of open standards for new deterministic, fault-tolerant, and high-speed bus system.

Today, CAN is used in the automotive industry as the primary in-vehicle network for enabling any device to communicate and work with any other device on the network without creating a great strain on the bus. This communication is ideal for powertrain and body electronic applications, such as acceleration skid control (ASC), which requires communications between multiple devices including engine timing and carburetor control units to reduce torque when drive-wheel slippage occurs.

Another use for the CAN network is on a vehicle's instrument panel, which typically consists of a speedometer, a tachometer, and fuel and temperature gauges and is updated with data that travels from the actual sensors to the dashboard through the CAN network. In addition, the CAN network can increase passenger comfort in vehicles. Examples of this include air-conditioning, lighting, and side-mirror control.

In addition to CAN networks, many electric vehicles use additional buses for smaller sub-networks within the vehicle. J1850 and Local Interconnect Network (LIN) connect several devices present within a single device, such as a passenger seat. Media-Oriented Systems Transport (MOST) is a common bus used for multimedia networking of devices such as DVD players with different speakers in the vehicle. These sub-networks are all connected to each other by gateways that allow them to connect to the main CAN network as a single device.

As electronics continue to spread into virtually every aspect of cars and driving, in-vehicle networks will need to expand their functionality. Future in-car control applications, such as drive-by-wire and brake-by-wire, will replace direct mechanical control of a vehicle with ECU-generated bus commands. These new application areas require features that existing communications buses simply address.

For example, safety-relevant applications have real-time requirements such as a high-priority message must be transmitted in a predefined amount of time. When braking, it is absolutely essential that the correct data be sent from the brake pedal to the actual brakes without any unpredictable latency in the communication.

These safety-relevant applications also require increased levels of tolerance against faulty components within the entire system. Using the same example, if one of the wires of the communications bus were to break or loosen, it would be essential for the data to have another route to reach its target. Large increase in the number of electrical devices in vehicles also will require a higher bandwidth to handle the increased volume of data being sent across the communications bus.

The data transfer rate is another area where communications buses are insufficient for future hybrid electric vehicle applications. In the future, powertrain applications will require data to be sent between devices at

rates far exceeding the 1-Mb/s limit available on present day networks.

The transmission protocol used in EV is based on pre-allocated time slots, so no arbitration is required. This and characteristics such as wide variety of supported topologies, fast error detection, flexible bandwidth allocation among nodes, and the bus monitor lead to efficient operation.

V. COMMUNICATION APPLICATION

The communication within the hybrid vehicles through computer based digital signal processor has many roles to play. Anti-lock brake systems (ABS) is an example of this process. A brake controller for ABS communicates information about wheel rotation and speed to the engine controller and transmission controller. The engine controller determines the amount of acceleration and torque the driver is asking for from the engine. The torque then can be communicated to the transmission to select the proper gear. If the brake controller indicates that there is a wheel spinning or slipping, this information is then communicated back to the engine via the CAN bus to reduce torque and thus control the spinning or slipping wheel. This is termed as traction control and is obtained through advanced digital signal processing.

The hybrid vehicles have a much more complicated control system than ABS. The hybrid power train has essentially two power trains — a fuel engine power train and an electric motor power train. The hybrid controller coordinates the two and the driver has to control both.

In the hybrid vehicle controller, the communications occur between multiple layers of control and communications systems: electric motor controller, engine controller, battery management system, brake system controller, transmission controller, and electrical grid controller. The computer control system integrates many of the functions that used to be only one controller's responsibility. An example of this complex coordination is regenerative braking. Part of the braking is shared between the standard foundation brake system—traditional friction pads, rotors, and drums—and the braking recovery system that sends electrical energy to the rechargeable batteries. Each component system knows what the other is doing and is adjusting its own status based on information provided by the other. In terms of regenerative braking, the net result is the car's ability to stop in a normal controlled manner while recharging its batteries without having to plug in. All this is made possible through high-speed digital computer processing.

VI. DSP BASED ENERGY MANAGEMENT SYSTEM

Electric vehicle has a DSP based Motor Controller, which regulates the flow of energy from battery power pack to the motor in direct relation to pressure applied on the accelerator. It ensures perfect speed control and optimum use of energy in both forward and reverse directions.

The heart of EV is the Energy Management System (EMS) that monitors and controls all its vital functions as shown in Fig. 4. The EMS is a computerized system that optimizes charging and energy output of batteries to maximize operating range and improve performance.

The system also predicts available range for a given state of battery charge, and is a standard EV feature. The EMS also maintains an electronic database of the vehicle performance that enables service personnel to run diagnostic checks on the vehicle to give service information.

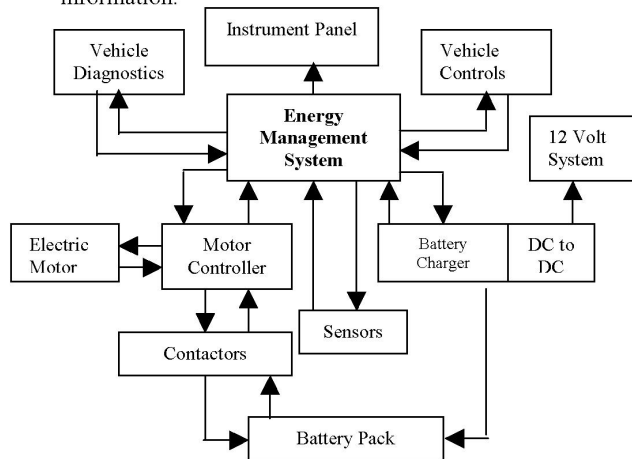


Fig. 4 DSP Based Energy Management System in Electric Vehicle

VII. COMMUNICATION COMPONENTS IN VEHICLE NETWORK

A typical central controller is composed of a NI PXI-8170RT controller and a NI compact FieldPoint (cFP) cFP-2020 unit. The PXI controller is in a PXI-1000B chassis, with the other peripheral components in a real-time processing mode to accomplish all the data acquisition, signal processing, communication and control for the whole vehicle. The cFP unit is responsible for relatively low level, non-time critical control such as fuel storage and delivery management, battery health, and hydrogen safety. The PXI has a higher operating speed and is used to process high level signals (e.g. speed and power) and complex operations such as the power train control algorithm implementation.

An in-vehicle communication network and distribution management system reduces the number of connection points and thereby increases the reliability of execution. The communication architecture for the controllers consists of different types of communication buses, providing different functionality and availability. The information between the central controller, engine and motor controller is through serial port protocol. The communication among the NI products (PXI and cFP units) is built with a high speed TCP/IP protocol in a client /server mode, because of its high efficiency and the ability to communicate with out-of-vehicle devices. Besides the TCP/IP protocol, series RS-232 protocol is also used to communicate programmatically between the central control system and components such as motor controller

and electronic-meter (E-meter). Fig.5 shows typical in-vehicle network.

A typical electric vehicle employing communication networking has router, bridge, switch, electronic-meter, motor controller, electronic control unit, and ancillary systems as shown in Fig. 5.

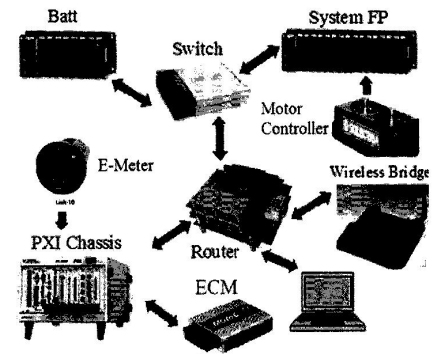


Fig. 5 Communication components in-vehicle network

VIII. CONTROL NETWORK

The control system of a hybrid vehicle is designed so that the driver gets a traditional vehicle control interface comprising of a steering wheel, an accelerator pedal, a brake pedal, a gearshift, a clutch pedal and the instrument panel. Hybrid Vehicle Control Unit (HVCU) normally implements the control strategy through real-time controller. There are four high-speed CAN buses one for each major component as shown in Fig. 6. Four buses are required to prevent collisions between CAN message ids that may be common between the components. Torque demand is read from the driver via the accelerator pedal position sensor. The demand is analyzed by the HVCU and converted into torque requests for the diesel and electric motor. These requests are sent to the diesel Electronic Control Unit (ECU) as analog voltages and to the Integrated Power Train (IPT) as CAN messages. The driver selects a gear using a conventional gearshift and clutch pedal. The HVCU recommends an optimum gear to the driver and monitors the driver's choice to protect the drive train from damaging gear selections and clutch usage.

IX. CONCLUSION

The paper presents an overview of computer communication systems in electric and hybrid vehicles. It gives certain details of vehicle control unit, protocol used in communication through controller area network. Some applications of computer communication have been addressed. DSP based energy management system communicating through different components such as router, bridge, switch, is described. A typical control network for hybrid vehicle is presented. The paper

highlights the relevance and importance of fast emerging communication complexities in automotive vehicles as demanded by increasing consumer comfort.

REFERENCES

- [1] Hong -xing Wu, Shu-kang Cheng, Shu-mei Cui, "Communication of vehicle management unit in the electric vehicle," IEEE Trans on Magnetics, Vol. 41, No. 1, January 2005, pp. 514-517.
- [2] H. Oman, "Electric car progress," IEEE Aerospace Electronic System Magazine, Vol.17, No.6, pp. 30-35, June 2002.
- [3] M. Barth and M.Todd, "Intelligent transportation system architecture for a multi-station shared vehicle system," in Proc. IEEE Intelligent Transportation Systems Conf., 2000, pp. 240-245.
- [4] H. Schopp and D.Teichner, "Video and audio applications in vehicles enabled by networked systems," in ICCE Int. Conf. Consumer Electronics, 1999, pp. 218-219.
- [5] A Ward, "The electric car: Development and future of battery, hybrid and fuel cell cars," IEE Review, vol.48, p. 14 2002.
- [6] K. K. Lee, Y.T.Lee, and M.Xie, "Designing a human vehicle interface for an intelligent community vehicle." In Proc. IEEE/ IEEE/JSAI Int. Conf. Intelligent Transportation Systems Conf., 1999, pp. 740-745.
- [7] J. P. Comu, "High energy batteries for EV -A whole solution to clean up the environment," in Proc. IEE Colloq. Electric Vehicles – A Technology Roadmap for the Future, 1998, pp. 5/1-5/515.
- [8] N.J. Schouten, M.A. Salman, and N.A.Kheir, "Fuzzy logic control for parallel hybrid vehicles, control systems technology," IEEE Trans. Control System Technology., vol.10, no.3, pp. 460-468, May 2002.
- [9] Xiaolai He, "Development and validation of a hybrid electric vehicle with hydrogen internal combustion engine", Doctoral Thesis, Texas Technical University, May 2006, pp. 41-59.
- [10] Computer Communication in Reva Electric Car, <http://www.revaindia.com>

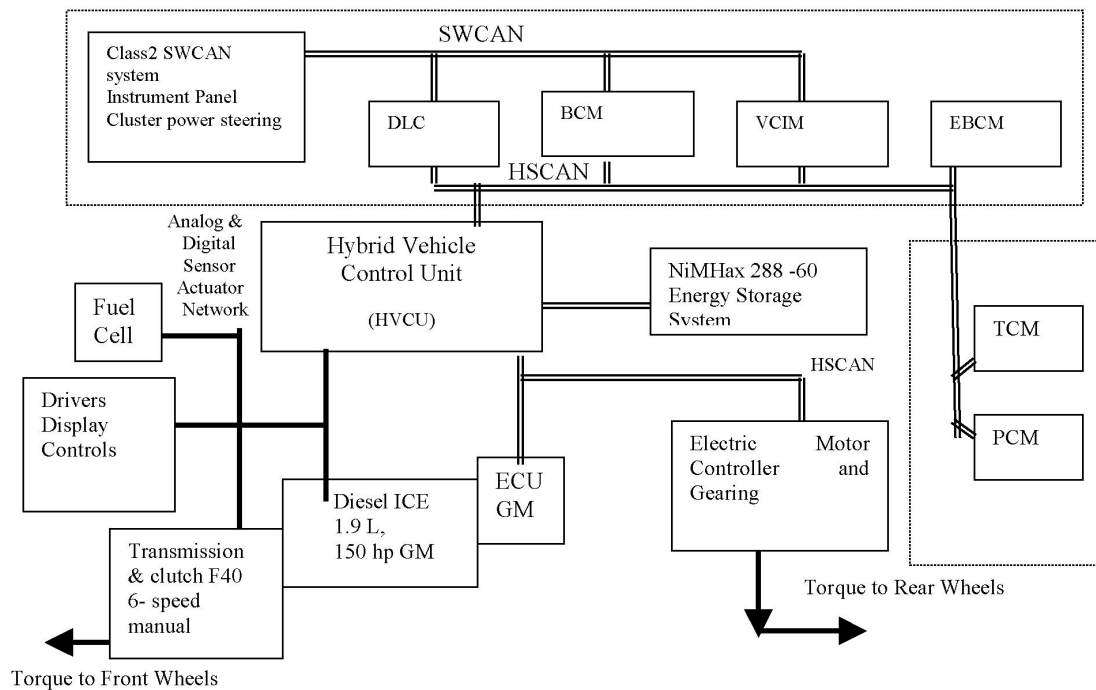


Fig. 6 Control Network Block Diagram

BCM: Battery Control Module/ Battery Condition Monitor
ICE: Internal Combustion Engine
HSCAN: High Speed Control Area Network
TCM: Torque Control Module
DLC: Data Link Control

VCIM: Vector Controlled Induction Motor
ECU: Electronic Control Unit
SWCAN: Single Wire Control Area Network
PCM: Power Control Module