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PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

FILE HISTORY

US 6,581,565

PATENT:	6,581,565
INVENTORS:	HESLOP GARON NIGEL
	DIXON JON
	BLACHFORD RICHARD STEPHEN
TITLE:	Engine torque controller
APPLICATION NO:	US2002191641A
FILED:	09 JUL 2002
ISSUED:	24 JUN 2003
COMPILED:	19 SEP 2022

WDC

JUN 2 4 2003

PATENT NUMBER and DATE
6581565

U.S. UTILITY Patent Application

APPL NUM	FILING DATE	CLASS	SUBCLASS	GAU	EXAMINER
10191641	07/09/2002	123	295	3747	ARGENBRIGHT

**APPLICANTS: Heslop Garon; Dixon Jon; Blachford Richard;

BEST COPY

**CONTINUING DATA VERIFIED: TWS
None

** FOREIGN APPLICATIONS VERIFIED: TWS
EUROPEAN PATENT OFFICE (EPO) 01306301.1 07/23/2001

PG-PUB DO NOT PUBLISH ☐ | RESCIND ☐

Foreign priority claimed	☑ yes ☐ no	ATTORNEY DOCKET NO
35 USC 119 conditions met	☑ yes ☐ no	10541-1524
Verified and Acknowledged Examiner's initials	TWS	

TITLE : Engine torque controller

U.S.DEPT. OF COMM./PAT.& TM-PTO-436L(Rev. 12-94)

5-23-03 Formal Drawings (3 shts) set 1 7-9-02

NOTICE OF ALLOWANCE MAILED		CLAIMS ALLOWED	
3/21/03	Assistant Examiner	Total Claims: 7	Print Claim for O.G: 1
ISSUE FEE	Tony M. Argenbright Primary Examiner Art Unit 3747 3-19-03	DRAWING	
Amount Due: #1600.00	Date Paid: 5-12-03	Sheets Drwg.: 3	Figs.Drwg.: 3
☐ TERMINAL DISCLAIMER	Primary Examiner	Print Fig.: 3	
	PREPARED FOR ISSUE	Application Examiner	

ISSUE ELIGIBLE

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FILED WITH: ☐ DISK (CRF) ☐ CD-ROM
(Attached in pocket on right inside flap)

6,581,565

Engine torque controller

Transaction History

Date	Transaction Description
07-09-2002	Workflow - Drawings Finished
07-09-2002	Workflow - Drawings Matched with File at Contractor
07-09-2002	Information Disclosure Statement (IDS) Filed
07-09-2002	Information Disclosure Statement (IDS) Filed
07-09-2002	Request for Foreign Priority (Priority Papers May Be Included)
07-09-2002	Initial Exam Team nn
08-12-2002	Application Is Now Complete
08-13-2002	Application Dispatched from OIPE
08-16-2002	Case Docketed to Examiner in GAU
03-21-2003	Dispatch to Publications
03-21-2003	Mail Notice of Allowance
03-21-2003	Notice of Allowance Data Verification Completed
03-24-2003	Receipt into Pubs
03-26-2003	Workflow - File Sent to Contractor
04-29-2003	Receipt into Pubs
05-12-2003	Issue Fee Payment Verified
05-12-2003	Issue Fee Payment Received
05-23-2003	Application Is Considered Ready for Issue
05-28-2003	Receipt into Pubs
06-05-2003	Issue Notification Mailed
06-24-2003	Recordation of Patent Grant Mailed
06-24-2003	Patent Issue Date Used in PTA Calculation
09-08-2003	Correspondence Address Change
02-02-2006	Post Issue Communication - Certificate of Correction
09-06-2017	File Marked Found
09-20-2017	File Marked Found
01-31-2020	Petition Requesting Trial
01-31-2020	Petition Requesting Trial
02-11-2020	Correspondence Address Change
02-12-2020	Change in Power of Attorney (May Include Associate POA)
08-05-2020	Request for Trial Granted
08-05-2020	Request for Trial Granted
04-20-2021	Termination or Final Written Decision
04-20-2021	Termination or Final Written Decision

10191641

10/191641
07/09/02

INITIALS

CONTENTS

		Date Received (Incl. C. of M.) or Date Mailed			Date Received (Incl. C. of M.) or Date Mailed
1.	Application papers.		31.		
2.	Priority	7.9.02	32.		
3.	IDS	7.9.02	33.		
4.	Exr's Amdt. / A	3/21/03	34.		
5.	Reg for cofc	09/02/03	35.		
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CLASSIFICATION NOTES

Examiner/ Classifier	Class	Date	Initials

POSITION	NAME	ID NO.	DATE
FEE DETERMINATION	WA		07-15-02
FILE ASSEMBLY			
QUALITY CHECK			07-17-02
SCANNING			7/9
CLASSIFIER			7/24
FORMALITY REVIEW	M.D.	625	08-08-02
RESPONSE			

ISSUE SLIP STAPLE AREA (for additional cross-references)

ISSUING CLASSIFICATION

ORIGINAL		CROSS REFERENCE(S)								
CLASS	SUBCLASS	CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)							
123	295	123	406.23	406.47	478					
INTERNATIONAL CLASSIFICATION										
F02D	41/14									
F02B	17/00									
	1									
	1									
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∧ Continued on Issue Slip Inside File Jacket

INDEX OF CLAIMS

✓ ..... Rejected – (Through numeral) ... Canceled N ..... Non-elected A ..... Appeal
= ..... Allowed + ... Restricted I ..... Interference O ..... Objected

Claim Final	Claim Original	Date 3/19/03
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If more than 150 claims or 9 actions staple additional sheet here

08-09-02

SEARCH

Class	Sub.	Date	Exmr.
123	295 350 352 399 406.23 406.47 406.55 478 480 488	3-19-03	TMA

INTERFERENCE SEARCHED

Class	Sub.	Date	Exmr.
123	295 350 352 399 406.23 406.47 406.55 478 480 488	3-19-03	TMA

SEARCH NOTES

(List databases searched. Attach search strategy inside.)

	Date	Exmr.

US006581565B2

(12) **United States Patent**
Heslop et al.

(10) **Patent No.: US 6,581,565 B2**
(45) **Date of Patent: Jun. 24, 2003**

(54) **ENGINE TORQUE CONTROLLER**

(75) Inventors: **Garon Nigel Heslop**, Billericay (GB); **Jon Dixon**, Maldon (GB); **Richard Stephen Blachford**, Cambridge (GB)

(73) Assignee: **Visteon Global Technologies, Inc.**, Dearborn, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/191,641**

(22) Filed: **Jul. 9, 2002**

(65) **Prior Publication Data**

US 2003/0015169 A1 Jan. 23, 2003

(30) **Foreign Application Priority Data**

Jul. 23, 2001 (EP) 01306301

(51) **Int. Cl.**[7] **F02D 41/14**; F02B 17/00

(52) **U.S. Cl.** **123/295**; 123/406.23; 123/406.47; 123/478

(58) **Field of Search** 123/295, 350, 123/352, 399, 406.23, 406.47, 406.55, 478, 480, 488

(56) **References Cited**

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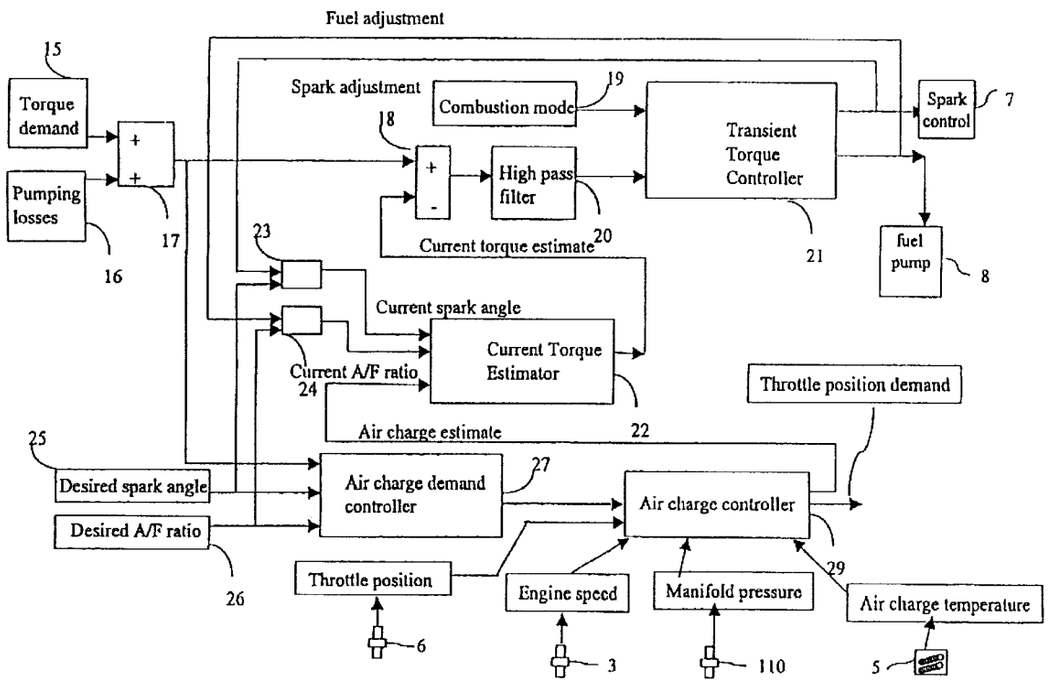
* cited by examiner

Primary Examiner—Tony M. Argenbright
(74) *Attorney, Agent, or Firm*—Brinks Hofer Gilson & Lione

(57) **ABSTRACT**

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines. The invention provides a torque controller and a method of controlling torque for an engine in which torque is controlled in dependence upon a filtered difference signal where the filtered difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque.

7 Claims, 3 Drawing Sheets



PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

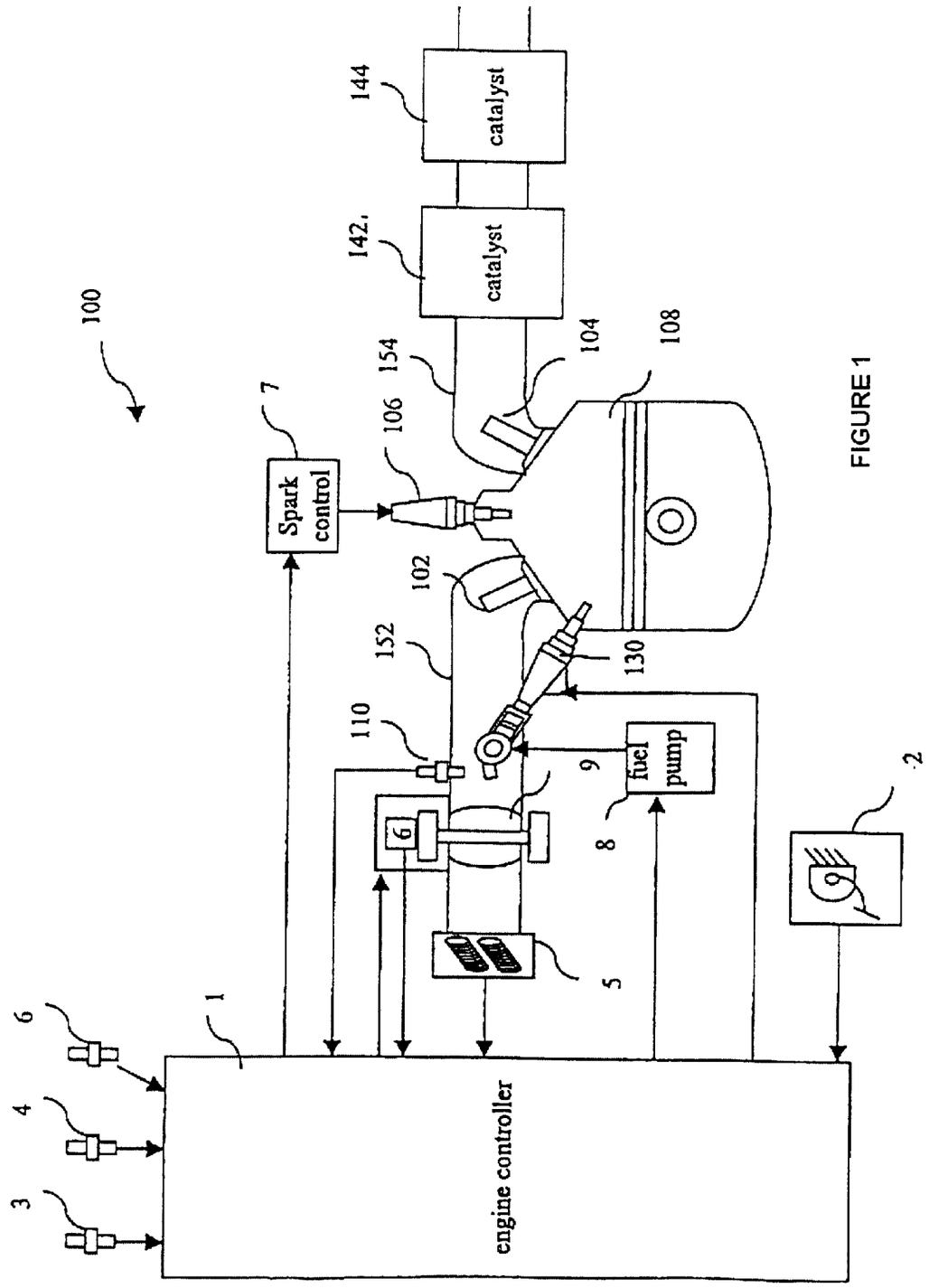

100
144
catalyst
142
catalyst
154
104
108
7
Spark control
106
102
152
130
110
9
fuel pump
8
2
6
5
1
6
4
3
engine controller

FIGURE 1

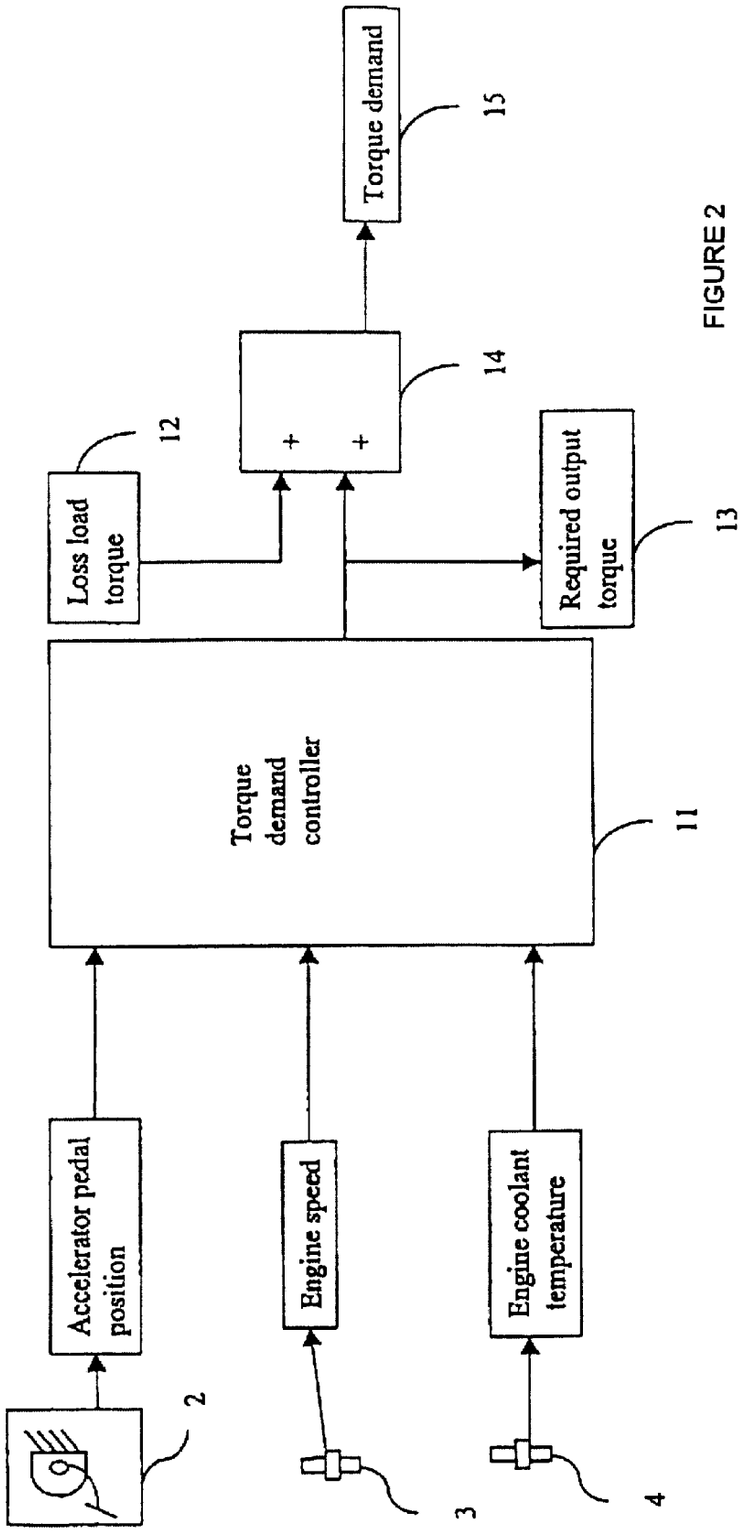

Torque demand
15
14
+
+
12
Loss load torque
Required output torque
13
Torque demand controller
11
Accelerator pedal position
Engine speed
Engine coolant temperature
2
3
4

FIGURE 2

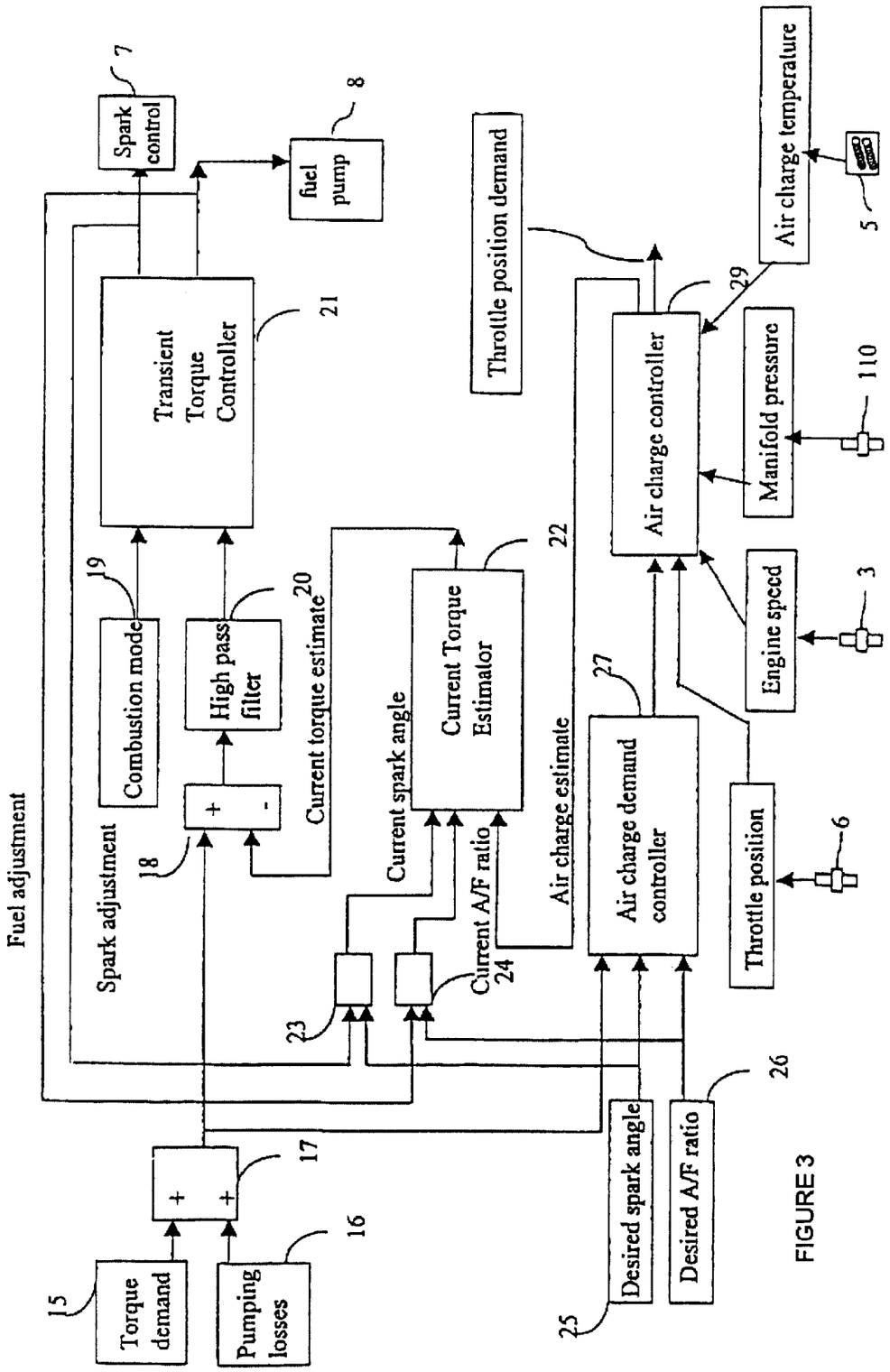

Spark control
7
fuel pump
8
Transient Torque Controller
21
Throttle position demand
Air charge temperature
5
29
Air charge controller
Manifold pressure
110
Combustion mode
19
High pass filter
20
Current torque estimate
22
Current Torque Estimator
Fuel adjustment
Spark adjustment
18
+
-
Current spark angle
Air charge estimate
27
Air charge demand controller
Engine speed
3
23
Current A/F ratio
24
Throttle position
6
Torque demand
15
Pumping losses
16
17
+
+
Desired spark angle
25
Desired A/F ratio
26

FIGURE 3

ENGINE TORQUE CONTROLLER

TECHNICAL FIELD

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines.

BACKGROUND

An engine torque controller is comprised of a torque demand controller and a torque producer. The torque demand controller determines a required target torque, in accordance with an accelerator pedal position, current engine speed, external loads and other factors. This determined torque is then used by the torque producer to produce the desired torque by controlling the spark angle and the air/fuel ratio.

Direct Injection Spark Ignition (DISI) engines inject fuel directly into cylinders where it is ignited by a spark from a spark plug. DISI engines operate in a stratified mode or a homogenous mode. When a DISI engine is in the stratified mode, the combustion chambers contain stratified layers having different air/fuel mixtures. The strata closest to the spark plug contains a stoichiometric mixture, which is a mixture in which the exact amount of air to combust the amount of fuel is present, i.e. when the combustion leaves no excess oxygen or unburned fuel. Subsequent strata contain progressively leaner mixtures. Operation in a stratified mode occurs at lower speeds and lower load conditions.

When the engine is in a homogenous mode, a homogenous mixture of air and fuel is introduced into the combustion chamber. Homogenous operation may be either lean of stoichiometry (i.e. higher air/fuel ratio), at stoichiometry, or rich of stoichiometry (i.e. lower air fuel ratio).

In engine torque controllers for DISI engines, when the engine is operating in stratified mode, spark angle has little influence on the torque produced. The torque producer modifies the air/fuel in order to control the torque produced. Conversely, when the engine is operating in homogenous mode, the air/fuel ratio is controlled tightly in order to maintain correct operation of the catalytic converter to reduce noxious emission. The torque producer modifies the timing of the spark ignition in order to control the torque produced.

A problem occurs in either of these modes of operation when there is a steady state error between the torque demanded and the estimate of the torque produced. In the stratified mode if a fuel adjustment occurs due to such a steady state error then the air/fuel ratio will not be ideal and fuel economy will suffer and performance of the catalytic converter will deteriorate. In the homogenous mode, if the timing of the spark ignition is altered due to such a steady state torque error then the fuel economy will once again suffer and the engine is more likely to stall when a load is imposed. Therefore, there is a need for a method of correction for a steady state error between the torque demanded and an estimate of the torque produced.

SUMMARY

In a preferred embodiment, the engine is a direct injection spark ignition engine and the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode. If the signal indicates that the engine is operating in the stratified mode then the fuel and spark controller is arranged to control the fuel adjustment signal. If the signal indicates that the engine is operating in the homogeneous mode then the fuel and spark controller is arranged to control the spark adjustment signal.

Preferably, the controller also has an air charge controller arranged to receive an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal. Preferably, there is also an air charge demand controller arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

According to another aspect of the invention, there is provided a method of controlling torque for an engine. The method includes estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal, comparing the estimated current torque signal with a desired torque signal to provide a difference signal, and filtering low frequency components from the difference signal. Finally, controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

These and other aspects and advantages of the present invention will become apparent upon reading the following detailed description of the invention in combination with the accompanying figures.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a block diagram illustrating part of an engine and an engine controller, in accordance with the present invention;

FIG. **2** is a block diagram of a torque demand controller, in accordance with the present invention; and

FIG. **3** is a block diagram of a torque producer, in accordance with the present invention.

DETAILED DESCRIPTION

FIG. **1** illustrates an embodiment of a direct injection spark ignition engine **100** which has an engine controller **1**. The engine controller **1** receives signals from an accelerator pedal and sensor assembly **2**, an engine speed sensor **3**, an engine temperature sensor **4**, an air charge temperature sensor **5**, a manifold absolute pressure sensor **110** and a throttle position indicator **6**.

A fuel injector **130** injects fuel directly into a combustion chamber **108**. The injected fuel mixes with an air charge which enters through an air intake valve **102** via an air intake manifold **152**. The air charge is controlled by a throttle **9** and the fuel injected is controlled by a fuel pump **8**. A spark control unit **7** controls a spark plug **106**, to generate a spark for ignition of the air/fuel mixture. Exhaust gases from the resulting combustion exit via an exhaust valve **104** into an exhaust manifold **154**. The exhaust manifold **154** has a three way catalytic converter **142** and a Nox trap/catalyst **144**.

FIG. **2** illustrates an embodiment of a torque demand controller **11** that is part of the engine controller **1**. The torque demand controller **11** calculates a required output torque signal **13**, based on an accelerator pedal position signal received from the accelerator pedal and sensor assembly **2**, an engine speed signal received from the engine speed sensor **3** and an engine temperature signal received from the engine temperature sensor **4**. A loss load torque signal **12**, which represents losses due to losses in the engine and powertrain system, is added to the required output torque signal **13** by an adder **14** to generate a torque demand signal **15**.

Referring now to FIG. **3**, an adder **17** receives as inputs the torque demand signal **15** and a pumping losses signal **16**, which represents losses due to the inherent losses in the engine cycle (i.e. due to the energy required to draw air in and to push out exhaust gases). The adder **17** outputs a desired torque signal.

An air charge demand controller **27** receives as inputs the desired torque signal, a desired spark angle signal **25** and a desired air fuel ratio signal **26**. The desired spark angle signal **25** and the desired air fuel ratio signal **26** are calculated elsewhere in the engine controller **1** and depend upon signals such as engine speed, engine load and engine temperature.

The air charge demand controller **27** generates an air charge demand signal that is received by an air charge controller **29**. The air charge controller **29** also receives as inputs a signal indicating throttle position that is received from the throttle position indicator **6** (FIG. **1**), the engine speed sensor **3**, the manifold absolute pressure sensor **110** and the air charge temperature meter **5**. The air charge controller **29** generates a signal indicating desired throttle position that is sent to throttle **9** (FIG. **1**) and a signal representing an estimate of the air charge.

The estimated air charge may be different from the air charge demanded by the air charge demand controller **27** due to delays in the engine **100**, such as the time taken for the throttle **9** to move, the time taken for the pressure in the air intake manifold **152** to rise or fall, or any errors in position of the throttle. The air charge estimate signal is sent to a current torque estimator **22**.

The current torque estimator **22** uses the air charge estimate signal, together with a signal representing the current spark angle and a signal representing the current air/fuel ratio to generate a signal representing an estimate of the current torque.

The estimate of the current torque is compared to the desired torque signal by a comparator **18** to generate an error signal which is then filtered by a high pass filter **20**. The resulting filtered error signal is used by a transient torque controller **21** to generate signals for temporarily adjusting the torque produced by the engine **100**.

A combustion mode signal **19**, which is produced elsewhere in the engine controller **1**, indicates whether the engine **100** is operating in a stratified mode or in a homogenous mode. If the engine **100** is operating in the stratified mode then a fuel adjustment signal is generated and sent to the fuel pump **8** in order to adjust the amount of fuel which is injected into the combustion chamber **108** by the fuel injector **130**. If the engine **100** is operating in the homogenous mode then a spark adjustment signal is generated and sent to the spark control unit **7** to adjust the timing of the ignition spark generated by the spark plug **106**.

The signal representing the current spark angle is calculated by a calculator **23** using the desired spark angle and any spark adjustment signal received from the transient torque controller **21**. The signal representing the current air fuel ratio is calculated by a calculator **24** using the desired air fuel ratio and any fuel adjustment signal received from the transient torque controller **21**. When the engine **100** is operating in stratified mode the current spark angle will be equal to the desired spark angle **25**. When the engine **100** is operating in homogenous mode the current air/fuel ratio will be equal to the desired air fuel ratio **26**.

As any person skilled in the art of systems and methods of controlling the torque output of an engine will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the invention without departing from the scope of this invention defined in the following claims.

What is claimed is:

1. A device for controlling a torque output of an engine, the device comprising:

a torque demand controller for generating a torque demand signal; and

a torque producer which receives the torque demand signal, the torque producer includes:

an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal;

a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal;

a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent; and

a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal.

2. The device in claim **1**, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

3. The device in claim **2**, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel.

4. The device of claim **1**, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode, and

wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode, and

wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode.

5. The device in claim **4**, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

6. The device in claim **5**, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel.

7. A method for controlling a torque output of an engine, the method comprising:

estimating a current torque signal from a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;

comparing the estimated current torque signal with a desired torque signal to output a difference signal;

filtering out a plurality of low frequency components from the difference signal; and

controlling a fuel adjustment signal and a spark adjustment signal in dependence upon a filtered difference signal.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4,
Lines 30 and 53, after "air/fuel" insert -- ratio -- before "." (period).

Signed and Sealed this

Twenty-eighth Day of October, 2003



JAMES E. ROGAN
Director of the United States Patent and Trademark Office

PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
PATENT AND TRADEMARK OFFICE
FEE RECORD SHEET

07/16/2002 WASFAW1 00000025 061500 10191641

01 FC:101 740.00 CH

PTO-1556
(5/87)

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07-10-02 EV 916641 02 0902

#2/Priority 8/16/02

"Express Mail" mailing label number EV 107432431 US
Date of Deposit July 9, 2002

Case No. 10541-1524

PATENT APPLICATION TRANSMITTAL LETTER

To the Commissioner for Patents:

Transmitted herewith for filing is the patent application of: Garon Nigel Heslop; Jon Dixon; and Richard Stephen Blachford for : ENGINE TORQUE CONTROLLER. Enclosed are:

- ☒ 3 sheet(s) of drawings, 12 pages of application (including title page), and the following Appendices : _____.
- ☒ Declaration.
- ☒ Power of Attorney.
- ☐ Verified statement to establish small entity status under 37 CFR §§ 1.9 and 1.27.
- ☒ Assignment transmittal letter and Assignment of the invention to : Visteon Global Technologies, Inc..
- ☒ Certified Copy of European Priority Document; Information Disclosure Statement, Form PTO 1449 with references; Two Return Postcards.

Claims as Filed	Col. 1	Col. 2	Small Entity			Other Than Small Entity	
For	No. Filed	No. Extra	Rate	Fee	or	Rate	Fee
Basic Fee				$ 370	or		$ 740
Total Claims	7-20		x$9=	$	or	x$18=	$0
Indep. Claims	2-3		x$42=	$	or	x$84=	$0
Multiple Dependent Claims Present			+$140=	$	or	+$280=	$0
*If the difference in col. 1 is less than zero, enter "0" in col. 2.			Total	$	or	Total	$740.00

- ☒ Please charge my Deposit Account No. 06-1500 in the amount of $: 740.00. A duplicate copy of this sheet is enclosed.
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  - ☐ Any patent application processing fees under 37 CFR § 1.17.
  - ☐ The issue fee set in 37 CFR § 1.18 at or before mailing of the Notice of Allowance, pursuant to 37 CFR § 1.311(b).

July 9, 2002
Date

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US PATENT NO. 6,581,565

PRINT OF DRAWINGS
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123/296

1715161.070902

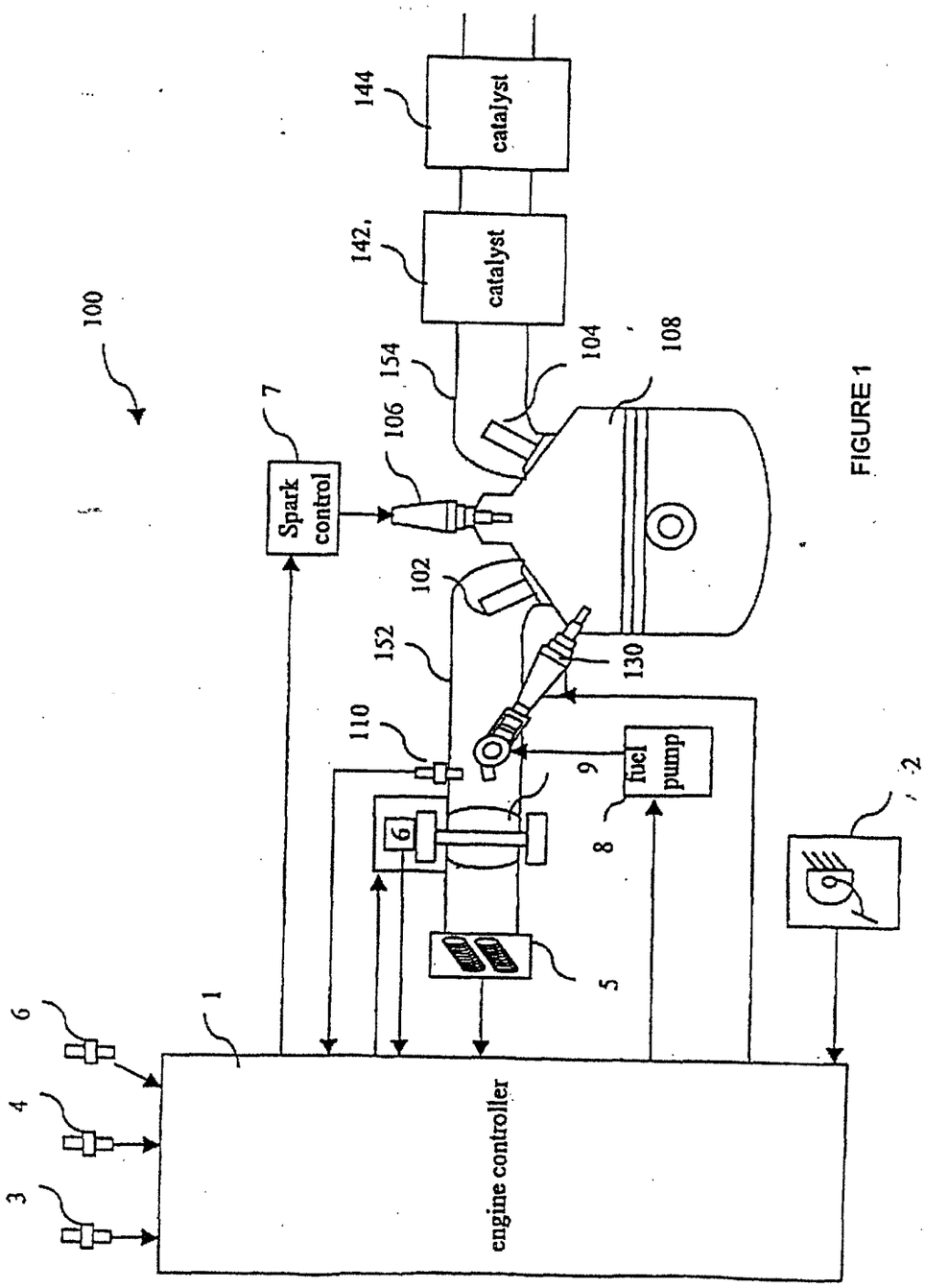


FIGURE 1

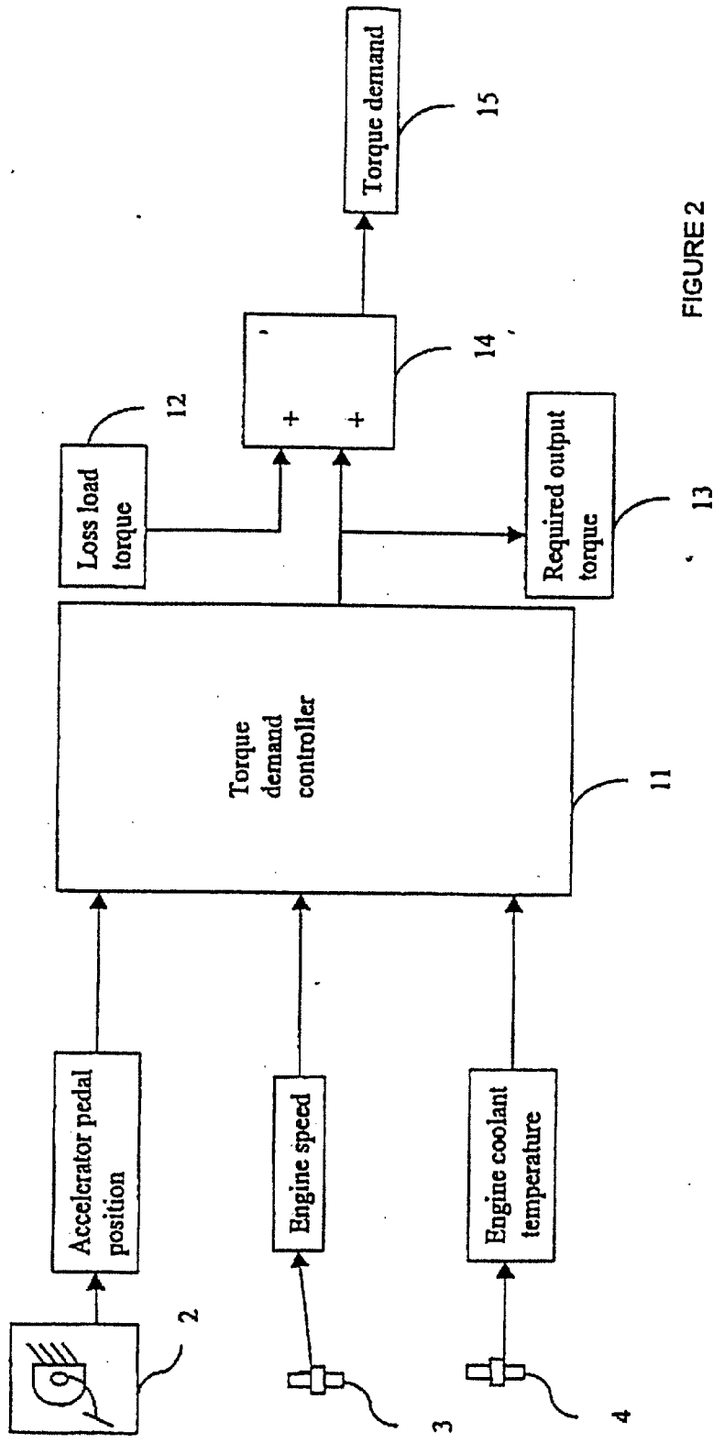

Torque demand
15
14
+
+
12
Loss load torque
Required output torque
13
Torque demand controller
11
Accelerator pedal position
Engine speed
Engine coolant temperature
2
3
4

FIGURE 2

PRINT OF DRAWINGS
AS ORIGINALLY FILED

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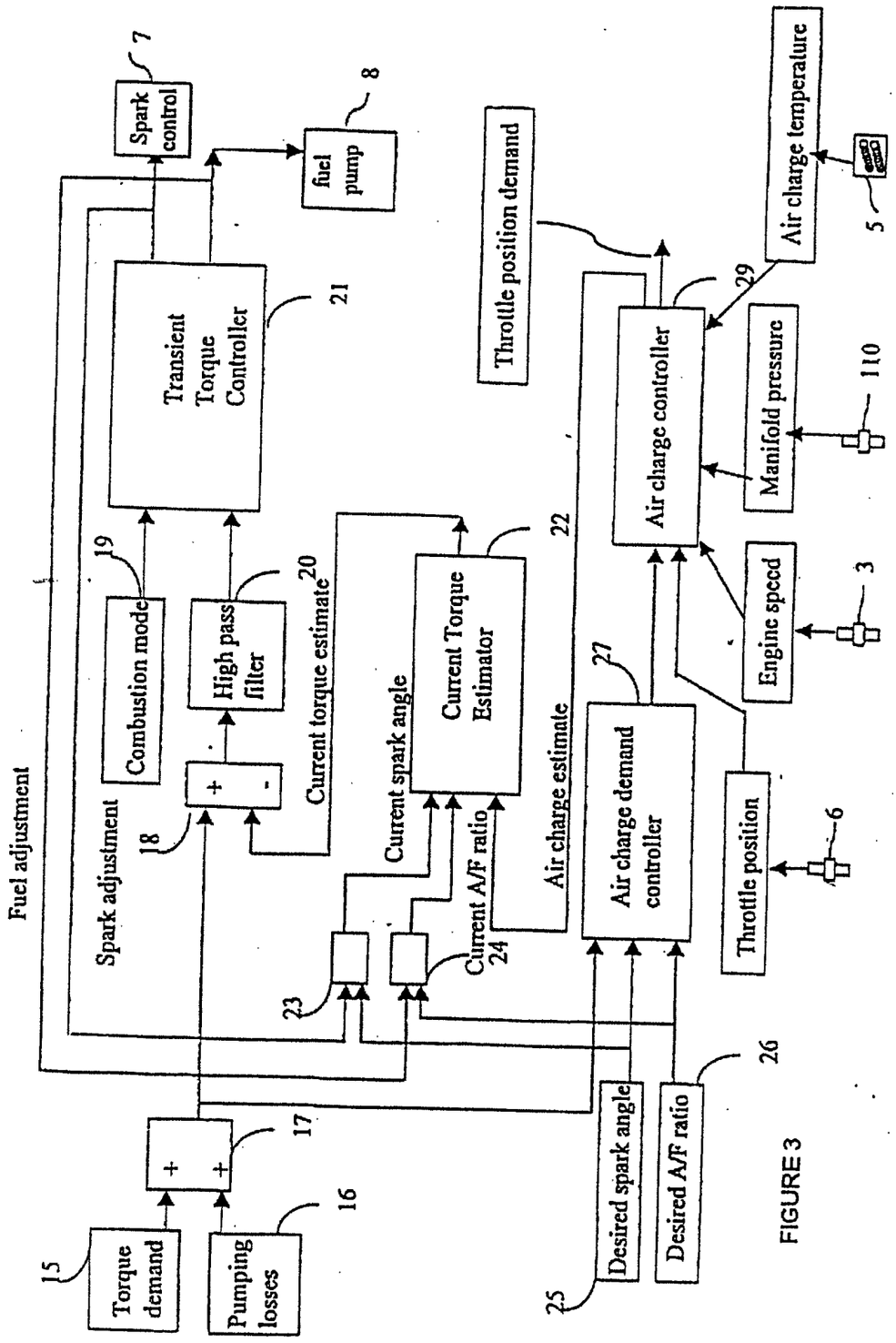


FIGURE 3

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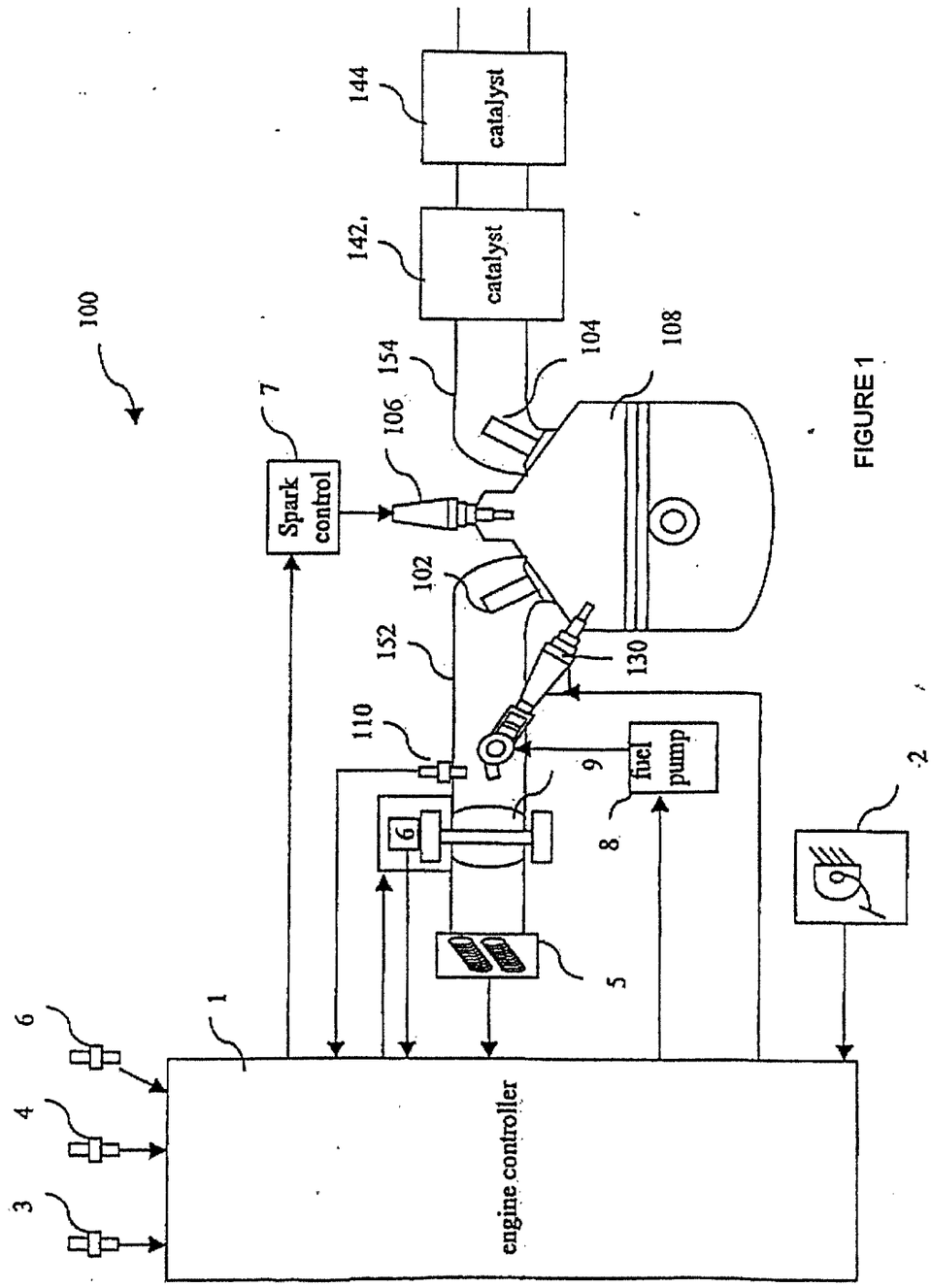


FIGURE 1

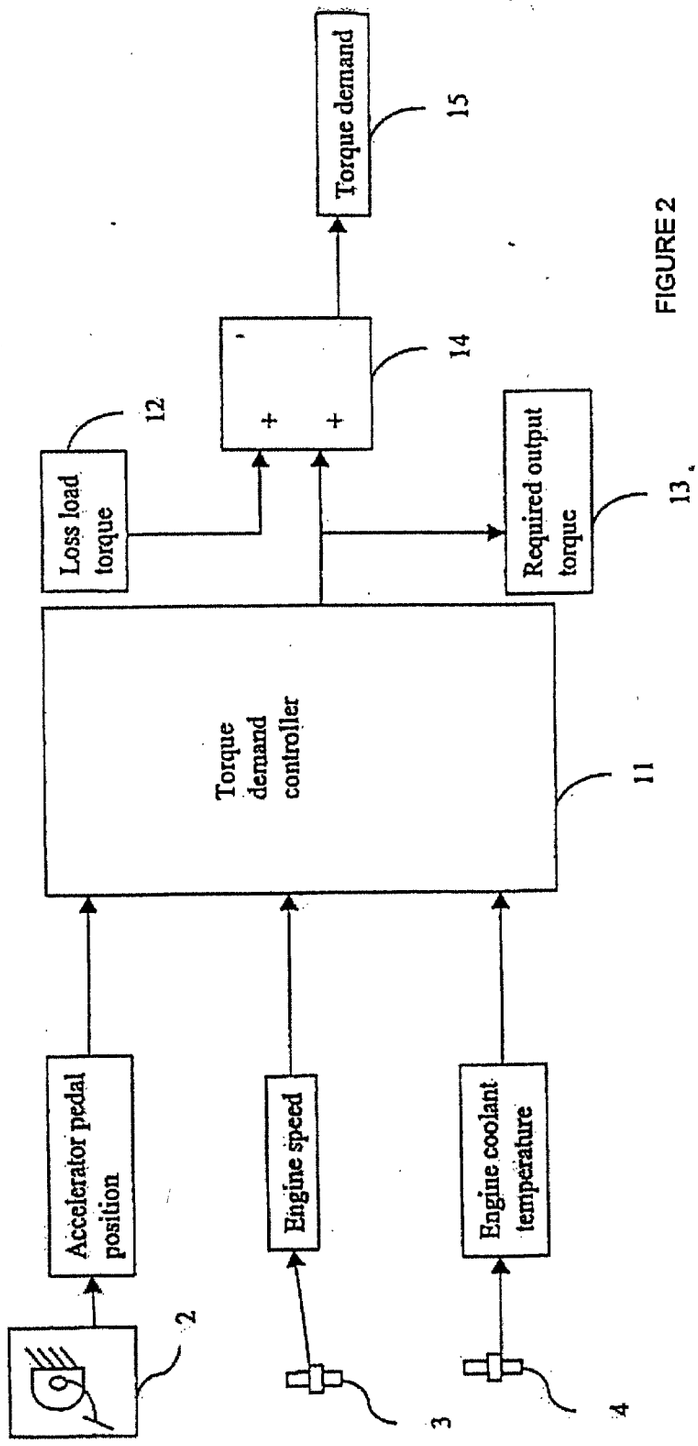

Torque demand
15
14
+
+
12
Loss load torque
Required output torque
13
Torque demand controller
11
Accelerator pedal position
Engine speed
Engine coolant temperature
2
3
4

FIGURE 2

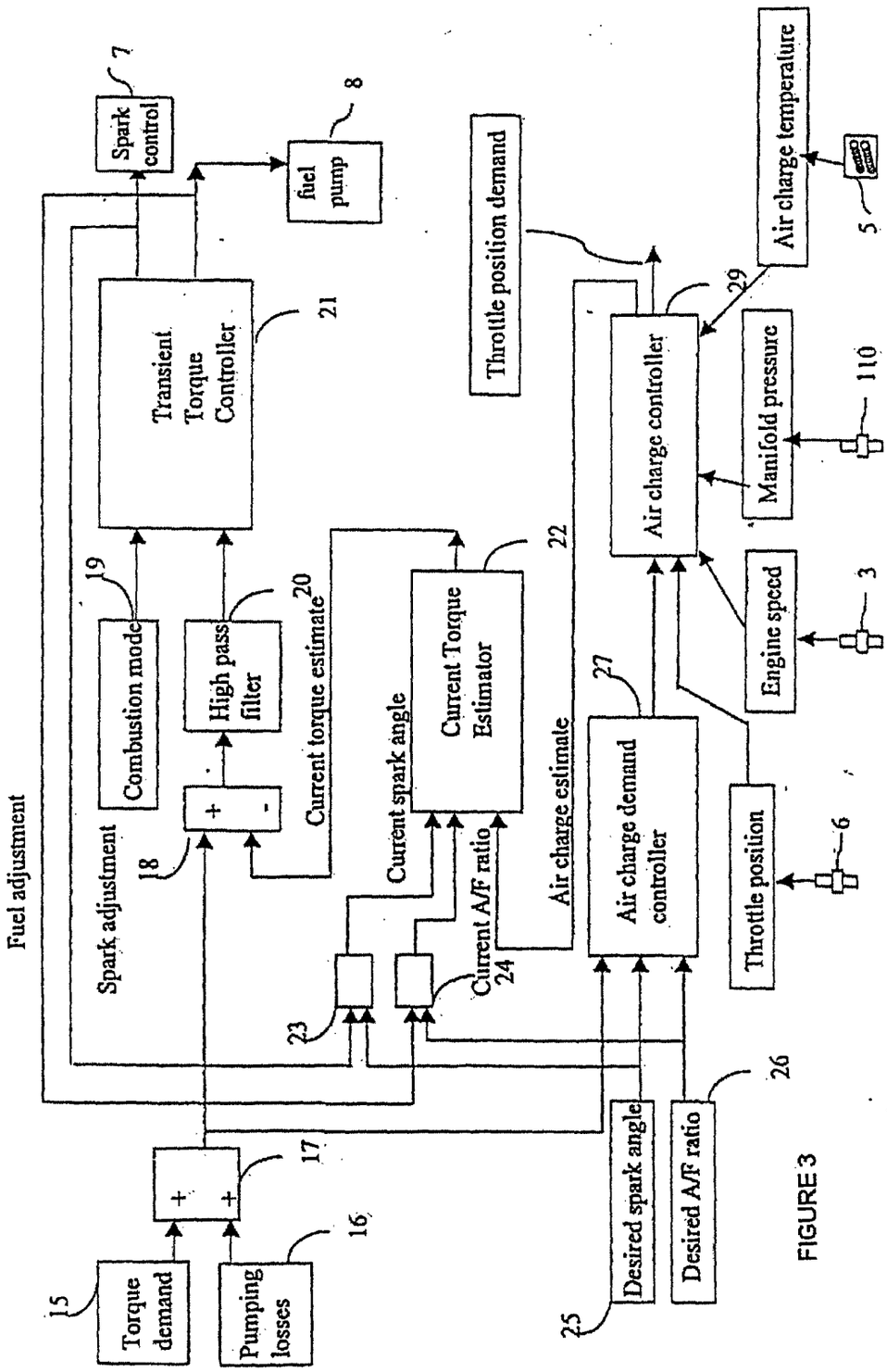

Fuel adjustment
Spark adjustment
Spark control
7
fuel pump
8
Transient Torque Controller
21
Throttle position demand
Air charge temperature
5
29
Air charge controller
Manifold pressure
110
19
Combustion mode
High pass filter
20
Current torque estimate
22
Current Torque Estimator
Current spark angle
Current A/F ratio
Air charge estimate
27
Air charge demand controller
Engine speed
3
18
+
-
23
24
Throttle position
6
17
+
+
16
15
Torque demand
Pumping losses
25
Desired spark angle
Desired A/F ratio
26

FIGURE 3

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Date of Deposit: July 9, 2002

Attorney Docket No. : 10541-1524

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
APPLICATION FOR UNITED STATES LETTERS PATENT

INVENTORS: GARON NIGEL HESLOP
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RICHARD STEPHEN BLACHFORD

TITLE: **ENGINE TORQUE CONTROLLER**

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10191641.070902

Attorney Docket No.: 10541-1524
Visteon Disclosure No.: V200-0895

ENGINE TORQUE CONTROLLER

TECHNICAL FIELD

[0001] This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines.

BACKGROUND

[0002] An engine torque controller is comprised of a torque demand controller and a torque producer. The torque demand controller determines a required target torque, in accordance with an accelerator pedal position, current engine speed, external loads and other factors. This determined torque is then used by the torque producer to produce the desired torque by controlling the spark angle and the air/fuel ratio.

[0003] Direct Injection Spark Ignition (DISI) engines inject fuel directly into cylinders where it is ignited by a spark from a spark plug. DISI engines operate in a stratified mode or a homogenous mode. When a DISI engine is in the stratified mode, the combustion chambers contain stratified layers having different air/fuel mixtures. The strata closest to the spark plug contains a stoichiometric mixture, which is a mixture in which the exact amount of air to combust the amount of fuel is present, i.e. when the combustion leaves no excess oxygen or unburned fuel. Subsequent strata contain progressively leaner mixtures. Operation in a stratified mode occurs at lower speeds and lower load conditions.

[0004] When the engine is in a homogenous mode, a homogenous mixture of air and fuel is introduced into the combustion chamber. Homogenous operation may

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be either lean of stoichiometry (i.e. higher air/fuel ratio), at stoichiometry, or rich of stoichiometry (i.e. lower air fuel ratio).

[0005] In engine torque controllers for DISI engines, when the engine is operating in stratified mode, spark angle has little influence on the torque produced. The torque producer modifies the air/fuel in order to control the torque produced. Conversely, when the engine is operating in homogenous mode, the air/fuel ratio is controlled tightly in order to maintain correct operation of the catalytic converter to reduce noxious emission. The torque producer modifies the timing of the spark ignition in order to control the torque produced.

[0006] A problem occurs in either of these modes of operation when there is a steady state error between the torque demanded and the estimate of the torque produced. In the stratified mode if a fuel adjustment occurs due to such a steady state error then the air/fuel ratio will not be ideal and fuel economy will suffer and performance of the catalytic converter will deteriorate. In the homogenous mode, if the timing of the spark ignition is altered due to such a steady state torque error then the fuel economy will once again suffer and the engine is more likely to stall when a load is imposed. Therefore, there is a need for a method of correction for a steady state error between the torque demanded and an estimate of the torque produced.

SUMMARY

[0007] In a preferred embodiment, the engine is a direct injection spark ignition engine and the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode. If the signal indicates that the engine is operating in

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the stratified mode then the fuel and spark controller is arranged to control the fuel adjustment signal. If the signal indicates that the engine is operating in the homogeneous mode then the fuel and spark controller is arranged to control the spark adjustment signal.

[0008] Preferably, the controller also has an air charge controller arranged to receive an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal. Preferably, there is also an air charge demand controller arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

[0009] According to another aspect of the invention, there is provided a method of controlling torque for an engine. The method includes estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal, comparing the estimated current torque signal with a desired torque signal to provide a difference signal, and filtering low frequency components from the difference signal. Finally, controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

[0010] These and other aspects and advantages of the present invention will become apparent upon reading the following detailed description of the invention in combination with the accompanying figures.

BRIEF DESCRIPTION OF THE FIGURES

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[0011] FIGURE 1 is a block diagram illustrating part of an engine and an engine controller, in accordance with the present invention;

[0012] FIGURE 2 is a block diagram of a torque demand controller, in accordance with the present invention; and

[0013] FIGURE 3 is a block diagram of a torque producer, in accordance with the present invention.

DETAILED DESCRIPTION

[0014] Figure 1 illustrates an embodiment of a direct injection spark ignition engine 100 which has an engine controller 1. The engine controller 1 receives signals from an accelerator pedal and sensor assembly 2, an engine speed sensor 3, an engine temperature sensor 4, an air charge temperature sensor 5, a manifold absolute pressure sensor 110 and a throttle position indicator 6.

[0015] A fuel injector 130 injects fuel directly into a combustion chamber 108. The injected fuel mixes with an air charge which enters through an air intake valve 102 via an air intake manifold 152. The air charge is controlled by a throttle 9 and the fuel injected is controlled by a fuel pump 8. A spark control unit 7 controls a spark plug 106, to generate a spark for ignition of the air/fuel mixture. Exhaust gases from the resulting combustion exit via an exhaust valve 104 into an exhaust manifold 154. The exhaust manifold 154 has a three way catalytic converter 142 and a Nox trap/catalyst 144.

[0016] Figure 2 illustrates an embodiment of a torque demand controller 11 that is part of the engine controller 1. The torque demand controller 11 calculates a required output torque signal 13, based on an accelerator pedal position signal

received from the accelerator pedal and sensor assembly 2, an engine speed signal received from the engine speed sensor 3 and an engine temperature signal received from the engine temperature sensor 4. A loss load torque signal 12, which represents losses due to losses in the engine and powertrain system, is added to the required output torque signal 13 by an adder 14 to generate a torque demand signal 15.

[0017] Referring now to Figure 3, an adder 17 receives as inputs the torque demand signal 15 and a pumping losses signal 16, which represents losses due to the inherent losses in the engine cycle (i.e. due to the energy required to draw air in and to push out exhaust gases). The adder 17 outputs a desired torque signal.

[0018] An air charge demand controller 27 receives as inputs the desired torque signal, a desired spark angle signal 25 and a desired air fuel ratio signal 26. The desired spark angle signal 25 and the desired air fuel ratio signal 26 are calculated elsewhere in the engine controller 1 and depend upon signals such as engine speed, engine load and engine temperature.

[0019] The air charge demand controller 27 generates an air charge demand signal that is received by an air charge controller 29. The air charge controller 29 also receives as inputs a signal indicating throttle position that is received from the throttle position indicator 6 (Figure 1), the engine speed sensor 3, the manifold absolute pressure sensor 110 and the air charge temperature meter 5. The air charge controller 29 generates a signal indicating desired throttle position that is sent to throttle 9 (Figure 1) and a signal representing an estimate of the air charge.

[0020] The estimated air charge may be different from the air charge demanded by the air charge demand controller 27 due to delays in the engine 100,

such as the time taken for the throttle 9 to move, the time taken for the pressure in the air intake manifold 152 to rise or fall, or any errors in position of the throttle. The air charge estimate signal is sent to a current torque estimator 22.

[0021] The current torque estimator 22 uses the air charge estimate signal, together with a signal representing the current spark angle and a signal representing the current air/fuel ratio to generate a signal representing an estimate of the current torque.

[0022] The estimate of the current torque is compared to the desired torque signal by a comparator 18 to generate an error signal which is then filtered by a high pass filter 20. The resulting filtered error signal is used by a transient torque controller 21 to generate signals for temporarily adjusting the torque produced by the engine 100.

[0023] A combustion mode signal 19, which is produced elsewhere in the engine controller 1, indicates whether the engine 100 is operating in a stratified mode or in a homogenous mode. If the engine 100 is operating in the stratified mode then a fuel adjustment signal is generated and sent to the fuel pump 8 in order to adjust the amount of fuel which is injected into the combustion chamber 108 by the fuel injector 130. If the engine 100 is operating in the homogenous mode then a spark adjustment signal is generated and sent to the spark control unit 7 to adjust the timing of the ignition spark generated by the spark plug 106.

[0024] The signal representing the current spark angle is calculated by a calculator 23 using the desired spark angle and any spark adjustment signal received from the transient torque controller 21. The signal representing the current air fuel ratio is calculated by a calculator 24 using the desired air fuel ratio and any

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fuel adjustment signal received from the transient torque controller 21. When the engine 100 is operating in stratified mode the current spark angle will be equal to the desired spark angle 25. When the engine 100 is operating in homogenous mode the current air/fuel ratio will be equal to the desired air fuel ratio 26.

[0025] As any person skilled in the art of systems and methods of controlling the torque output of an engine will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the invention without departing from the scope of this invention defined in the following claims.

Attorney Docket No.: 10541-1524
Visteon Disclosure No.: V200-0895

CLAIMS

1. A device for controlling a torque output of an engine, the device comprising:

a torque demand controller for generating a torque demand signal; and

a torque producer which receives the torque demand signal, the torque producer includes:

an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal;

a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal;

a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent; and

a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal.

2. The device in claim 1, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

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3. The device in claim 2, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel ratio.

4. The device of claim 1, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode, and

wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode, and

wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode.

5. The device in claim 4, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

6. The device in claim 5, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel.

7. A method for controlling a torque output of an engine, the method comprising:

estimating a current torque signal from a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;

comparing the estimated current torque signal with a desired torque signal to output a difference signal;

filtering out a plurality of low frequency components from the difference signal; and

controlling a fuel adjustment signal and a spark adjustment signal in dependence upon a filtered difference signal.

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US PATENT NO. 6,581,565

Attorney Docket No.: 10541-1524
Visteon Disclosure No.: V200-0895

ABSTRACT

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines. The invention provides a torque controller and a method of controlling torque for an engine in which torque is controlled in dependence upon a filtered difference signal where the filtered difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque.

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Attorney Docket No.: 10541-1524
Visteon Case No.: V200-0895

DECLARATION AND POWER OF ATTORNEY ORIGINAL APPLICATION

As a below named inventor, I hereby declare:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor or an original, first and joint inventor of the subject matter that is claimed and for which a patent is sought on the invention entitled:

ENGINE TORQUE CONTROLLER

the specification of which (check one)

X is attached hereto.

____ was filed on _____ as United States Application Serial No. _____ and was amended on _____ (if applicable).

I acknowledge my duty to disclose to the United States Patent and Trademark Office all information that I know to be material to the patentability of this application as defined in Title 37 C.F.R. § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s):			Priority Not Claimed
01306301.1 (Number)	Europe (Country)	23 July 2001 (Filing Date)	☐
(Number)	(Country)	(Filing Date)	☐
(Number)	(Country)	(Filing Date)	☐

I hereby claim the benefit under 35 U.S. C. Section 119(e) of any United States provisional application(s) listed below:

(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)
(Application Serial No.)	(Filing Date)

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US PATENT NO. 6,581,565

I hereby claim the benefit under 35 U.S.C. Section 120 of any United States applications(s), or Section 365(c) of any PCT International Application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C.F.R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the attorneys, agents, and each shareholder, attorney of counsel, associate, and employee of Brinks Hofer Gilson & Lione, who is a registered Patent Attorney or registered Patent Agent, and who is associated with the customer number printed below, my attorney with full power of substitution and revocation to prosecute this application and transact all business in the United States Patent and Trademark Office connected therewith and to act on my behalf before the competent International Authorities in connection with any and all international applications filed by me.

29074

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Third inventor's signature	Date 9th July 2002
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Full name of fourth inventor, if any	
Fourth inventor's signature	Date
Residence	
Citizenship	
Post Office Address	

Full name of fifth inventor, if any	
Fifth inventor's signature	Date
Residence	
Citizenship	
Post Office Address	

Full name of sixth inventor, if any	
Sixth inventor's signature	Date
Residence	
Citizenship	
Post Office Address	

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Application Assignment Record

According to the application transmittal letter, an assignment recording ownership was filed with this application; however, a copy of this record was not located in the original file history record obtained from the United States Patent and Trademark Office. Upon your request, we will attempt to obtain the assignment documents from the Assignment Recordation Branch of of the United States Patent and Trademark Office or from a related application case (if applicable). Please note that additional charges will apply for this service.

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#2

Europäisches Patentamt	European Patent Office	Office européen des brevets

PTO 1046 U.S. 10/049641 07/09/02

Bescheinigung | Certificate | Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

01306301.1

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.:
Application no.: 01306301.1
Demande n°:

Anmeldetag:
Date of filing: 23/07/01
Date de dépôt:

Anmelder:
Applicant(s):
Demandeur(s):
Visteon Global Technologies, Inc.
Dearborn,@Michigan 48126-2490
UNITED STATES OF AMERICA

Bezeichnung der Erfindung:
Title of the invention:
Titre de l'invention:
Engine torque controller

In Anspruch genommene Priorität(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Internationale Patentklassifikation:
International Patent classification:
Classification internationale des brevets:
F02D41/30, F02D41/14

Am Anmeldetag benannte Vertragstaaten:
Contracting states designated at date of filing: AT/BE/CH/CY/DE/DK/ES/FI/FR/GB/GR/IE/IT/LI/LU/MC/NL/PT/SE/TR
Etats contractants désignés lors du depôt:

Bemerkungen:
Remarks:
Remarques:

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ENGINE TORQUE CONTROLLER

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines.

An engine torque controller comprises a torque demand controller, and a torque producer. The torque demand controller determines a required target torque, in accordance with an accelerator pedal position, current engine speed, external loads and the like. This determined torque is then used by the torque producer to produce the desired torque by control of sparking angle and air/fuel ratio.

Direct Injection Spark Ignition (DISI) engines inject fuel directly into cylinders where it is ignited by a spark from a spark plug. DISI engines operate in a stratified mode or a homogenous mode. When a DISI engine is in the stratified mode, the combustion chambers contain stratified layers with different air/fuel mixtures. The strata closest to the spark plug contains a stoichiometric mixture, which is a mixture in which there is exactly the amount of air to combust the amount of fuel present, i.e. when combusted leaves no excess oxygen of unburned fuel. Subsequent strata contain progressively leaner mixtures. Operation in stratified mode occurs at lower speeds and lower load conditions.

When the engine is in the homogeneous mode, a homogeneous mixture of air and fuel is introduced into the combustion

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US PATENT NO. 6,581,565

chamber. Homogeneous operation may be either lean of stoichiometry (i.e. higher air/fuel ratio), at stoichiometry, or rich of stoichiometry (i.e. lower air/fuel ratio).

In engine torque controllers for DISI engines, when the engine is operating in stratified mode, spark angle has little influence on the torque produced. The torque producer modifies the air/fuel ratio in order to control the torque produced. Conversely, when the engine is operating in homogenous mode the air/fuel ratio is controlled tightly, in order to maintain correct operation of a catalytic converter to reduces noxious emissions, and the torque producer modifies the timing of the spark ignition in order to control the torque produced.

A problem occurs in either of these modes of operation when there is a steady state error between the torque demanded and an estimate of the torque produced. In the stratified mode if a fuel adjustment occurs due to such a steady state error then the air/fuel ratio will not be ideal, and fuel economy will suffer and performance of the catalytic converters will deteriorate. In the homogenous mode if the timing of the spark ignition is altered due to such a steady state torque error, then fuel economy will suffer once again, and the engine is more likely to stall when a load is imposed.

This invention serves to alleviate the aforementioned problems.

According to the present invention there is provided a

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torque controller for an engine, the torque controller comprising a torque demand controller and a torque producer, in which the torque producer comprises

an estimator arranged to receive a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal; and arranged to output an estimated torque signal;

a comparator arranged to receive the estimated torque signal and the desired torque signal, and arranged to output a difference signal; and

a high pass filter arranged to receive the difference signal and output a filtered signal in which low frequency components are absent; and

a transient torque controller arranged to receive the filtered signal and to output a fuel adjustment signal and a spark adjustment signal in dependence thereon.

In a preferred embodiment, the engine is a direct injection spark ignition engine and the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode. If the signal indicates that the engine is operating in the stratified mode then the fuel and spark controller is arranged to control the fuel adjustment signal. If the signal indicates that the engine is operating in the homogeneous mode then the fuel and spark controller is arranged to control the spark adjustment signal.

Preferably the controller also has an air charge controller arranged to receive an air charge demand signal, a throttle

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position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal. Preferably there is also an air charge demand controller arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

According to a second aspect of the invention there is provided a method of controlling torque for an engine comprising the steps of

estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;

comparing the estimated current torque signal with a desired torque signal to provide a difference signal;

filtering low frequency components from the difference signal; and

controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram illustrating part of an engine and an engine controller;

Figure 2 is a schematic block diagram of a torque demand

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controller; and

Figure 3 is a schematic block diagram of a torque producer.

Figure 1 illustrates an embodiment of a direct injection spark ignition engine 100 which has an engine controller 1. The engine controller 1 receives signals from an accelerator pedal and sensor assembly 2, an engine speed sensor 3, an engine temperature sensor 4, an air charge temperature sensor 5, a manifold absolute pressure sensor 110 and a throttle position indicator 6.

A fuel injector 130 injects fuel directly into a combustion chamber 108. The injected fuel mixes with an air charge which enters through an air intake valve 102 via an air intake manifold 152. The air charge is controlled by a throttle 9 and the fuel injected is controlled by a fuel pump 8. A spark control unit 7 controls a spark plug 106, to generate a spark for ignition of the air/fuel mixture. Exhaust gases from the resulting combustion exit via an exhaust valve 104 into an exhaust manifold 154. The exhaust manifold 154 has a three way catalytic converter 142 and a Nox trap/catalyst 144.

Figure 2 illustrates schematically a torque demand controller 11 which is part of the engine controller 1. The torque demand controller 11 calculates a required output torque signal 13, based on an accelerator pedal position signal received from the accelerator pedal and sensor assembly 2, an engine speed signal received from the engine speed sensor 3 and an engine temperature signal received from the engine temperature sensor 4. A loss load torque

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signal 12, which represents losses due to losses in the engine and power train system, is added to the required output torque signal 13, at an adder 14 to generate a torque demand signal 15.

Referring now to Figure 3, the torque demand signal 15 is added to a pumping losses signal 16, which represents losses due to the inherhent losses in the engine cycle (i.e. due to the energy required to draw air in and to push out exhaoust gases) at an adder 17 to generate a desired torque signal.

An air charge demand controller 27 is arranged to receive the desired torque signal, together with a desired spark angle signal 25 and a desired air fuel ratio signal 26. The desired spark angle signal 25 and the desired air fuel ratio signal 26 are calculated elsewhere in the engine controller 1, and depend upon signals such as engine speed, engine load and engine temperature.

The air charge demand controller 27 generates an air charge demand signal, which is received by an air charge controller 29, together with a signal indicating throttle position which is received from the throttle position indicator 6 (figure 1). The air charge controller 29 generates a signal indicating desired throttle position, which is sent to the throttle 9 (figure 1).

The air charge controller 29 also receives signals from the engine speed sensor 3, the manifold absolute pressure sensor 110 and the air charge temperature meter 5. The air charge controller uses these received signals to generate a

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signal representing an estimate of the air charge. This estimated air charge may be different to the air charge demanded by the air charge demand controller 27 due to delays in the engine 100, such as the time taken for the throttle 9 to move, or the time taken for the pressure in the air intake manifold 152 to rise or fall, or any errors in position of the throttle. The air charge estimate signal is sent to a current torque estimator 22.

The current torque estimator 22 uses the air charge estimate signal, together with a signal representing the current spark angle and a signal representing the current air/fuel ratio to generate a signal representing an estimate of the current torque.

The estimate of the current torque is compared to the desired torque signal by a comparator 18 to generate an error signal which is then filtered by a high pass filter 20. The resulting filtered error signal is used by a transient torque controller 21 to generate signals for temporarily adjusting the torque produced by the engine 100.

A combustion mode signal 19, which is produced elsewhere in the engine controller 1, indicates whether the engine 100 is operating in stratified mode or in homogenous mode. If the engine 100 is operating in stratified mode then a fuel adjustment signal is generated and sent to the fuel pump 8 in order to adjust the amount of fuel which is injected into the combustion chamber 108 by the fuel injector 130. If the engine 100 is operating in the homogenous mode then a spark adjustment signal is generated and sent to the

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spark control unit 7 to adjust the timing of the ignition spark generated by the spark plug 106.

The signal representing the current spark angle is calculated by a calculator 23 using the desired spark angle and any spark adjustment signal received from the transient torque controller 21. The signal representing the current air fuel ratio is calculated by a calculator 24 using the desired air fuel ratio and any fuel adjustment signal received from the transient torque controller 21. When the engine 100 is operating in stratified mode the current spark angle will be equal to the desired spark angle 25. When the engine 100 is operating in homogenous mode the current air/fuel ratio will be equal to the desired air fuel ratio 26.

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CLAIMS

1. A torque controller for an engine, the torque controller comprising a torque demand controller (1) and a torque producer, in which the torque producer comprises

an estimator (22) arranged to receive a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal; and arranged to output an estimated torque signal;

a comparator (18) arranged to receive the estimated torque signal and a desired torque signal, and arranged to output a difference signal; and

a high pass filter (20) arranged to receive the difference signal and output a filtered signal in which low frequency components are absent; and

a transient torque controller (21) arranged to receive the filtered signal and to output a fuel adjustment signal and a spark adjustment signal in dependence thereon.

2. A torque controller according to claim 1, in which

the engine is a direct injection spark ignition engine;

the transient torque controller (21) is arranged to receive a combustion mode signal (19) indicating whether the engine is operating in a stratified mode or a homogeneous mode;

the transient torque controller (21) is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode ; and

the transient torque controller is arranged to control

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the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode.

3. A torque controller according to claim 1 or claim 2, further comprising an air charge controller (29) arranged to receive an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal.

4. A torque controller according to claim 4 further comprising an air charge demand controller (20) arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

5. A method of controlling torque for an engine comprising the steps of

estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;

comparing the estimated current torque signal with a desired torque signal to provide a difference signal;

filtering low frequency components from the difference signal; and

controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

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ABSTRACT

Engine Torque Controller

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines. The invention provides a torque controller and a method of controlling torque for an engine, in which torque is controlled in dependence upon a filtered difference signal where the filtered difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque.

Figure 3

PETITIONER'S EXHIBIT 1002
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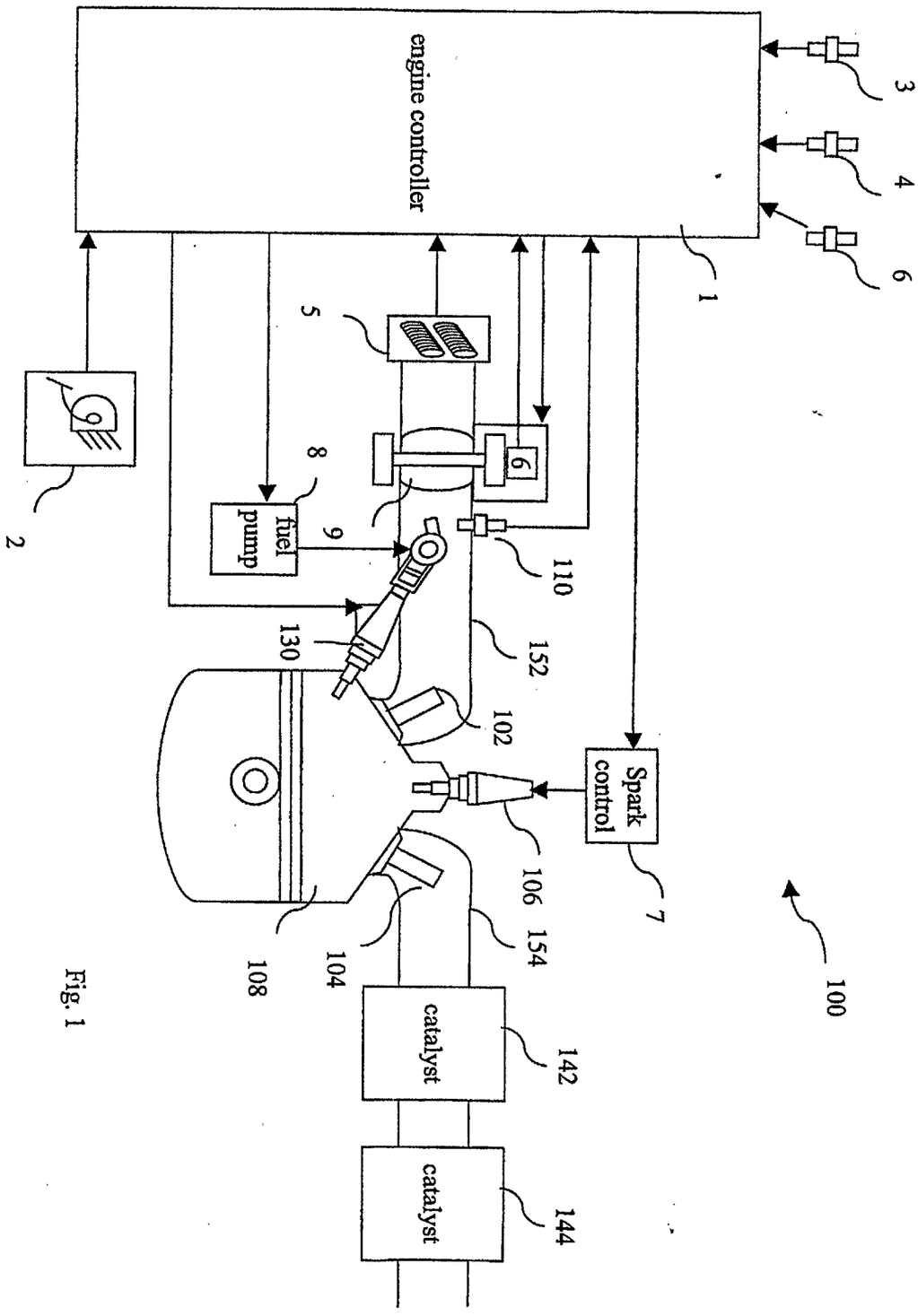

engine controller
1
3
4
6
5
2
8
fuel pump
9
6
110
130
152
102
Spark control
7
106
154
104
108
catalyst
142
catalyst
144
100

Fig. 1

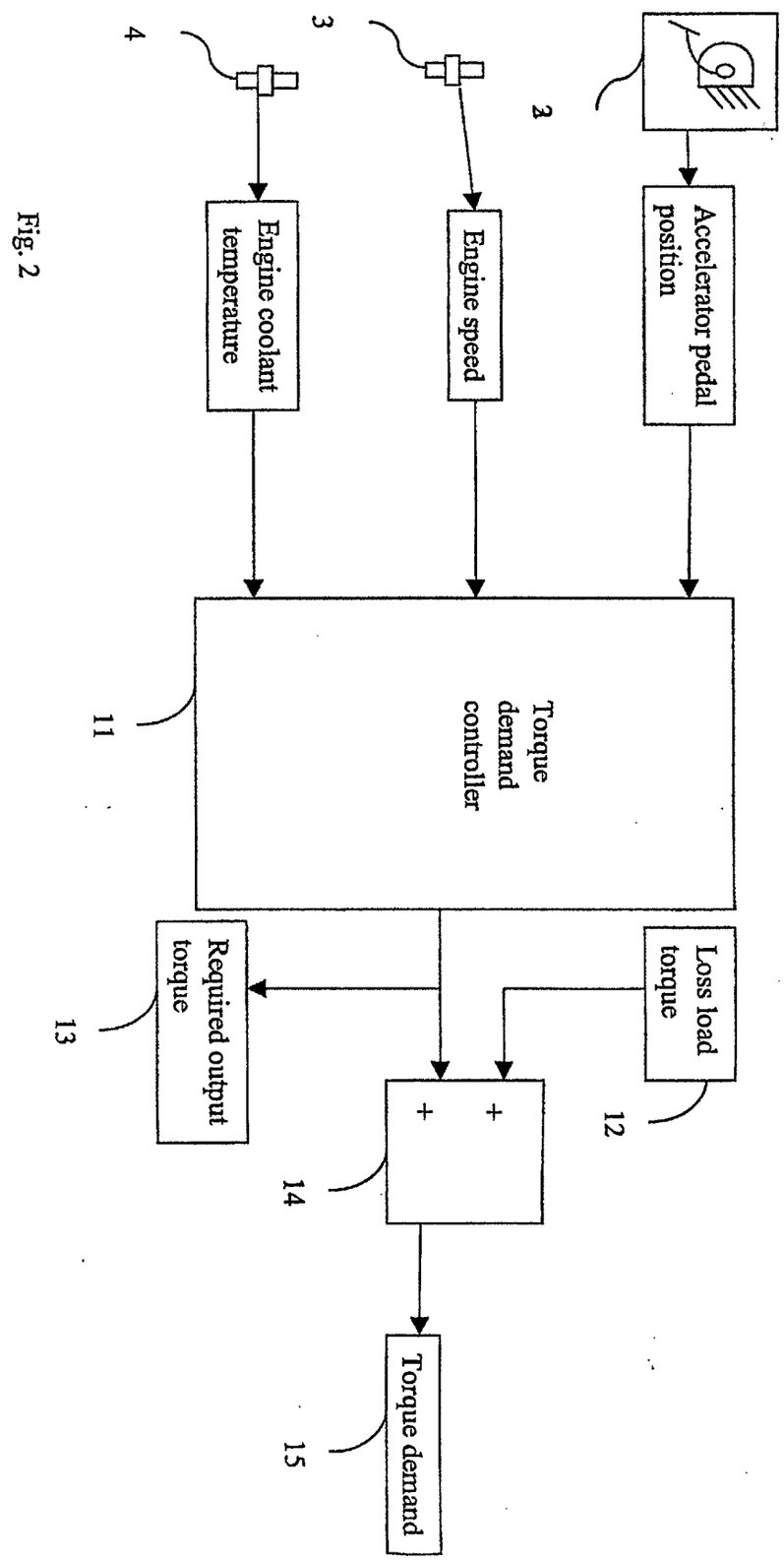

2
Accelerator pedal position
3
Engine speed
4
Engine coolant temperature
11
Torque demand controller
13
Required output torque
12
Loss load torque
14
+
+
15
Torque demand

Fig. 2

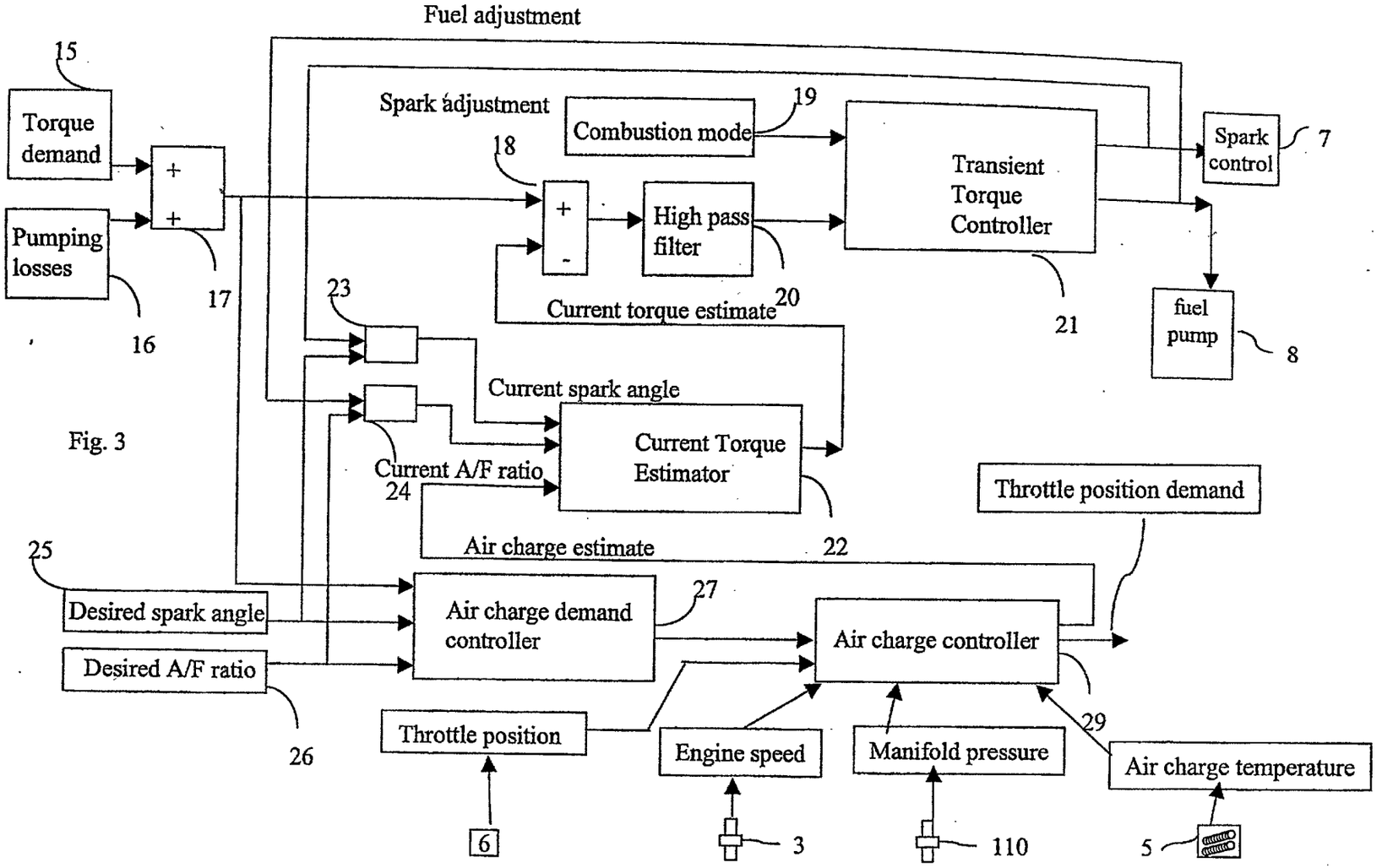


Fig. 3

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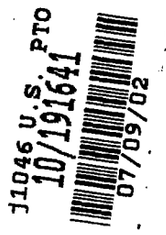
#3 IDS 8/16/02

PATENT
Attorney Docket No.: 10541-1524

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Group Art Unit:	Unknown
Examiner:	Unknown
Inventors:	Heslop et al.
Serial No:	Unknown
Filed:	Concurrent Herewith
For:	ENGINE TORQUE CONTROLLER

INFORMATION DISCLOSURE STATEMENT



Commissioner for Patents
Washington, DC 20231

Sir:

Under the duties of disclosure, candor, and good faith of 37 CFR §1.56, the Applicant hereby submits the references listed on the attached PTO-1449 form for consideration by the Examiner. In the opinion of the Applicant, the pending claims are patentably distinct from the listed references. Furthermore, the filing of this information disclosure statement shall not be construed to be an admission that the information cited in the statement is material to patentability (37 C.F.R §1.97(h)).

Under 37 CFR §1.97(b)(1), no fee should be required. If a fee is required, however, please charge any such fee pursuant to 37 CFR §1.16 or §1.17 to deposit account no. 06-1500.

Respectfully submitted,

Date: July 9, 2002

By: _____

Raymond J. Vivacqua
Reg. No. 45,369
Attorney for Applicant

BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610
(734) 302-6000

FORM PTO-1449	SERIAL NO.	CASE NO. 10541-1524
LIST OF PATENTS AND PUBLICATIONS FOR APPLICANT'S INFORMATION DISCLOSURE STATEMENT	FILING DATE	GROUP ART UNIT 3747
(use several sheets if necessary)	APPLICANT(S): Heslop et al.	

REFERENCE DESIGNATION **U.S. PATENT DOCUMENTS**

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS/ SUBCLASS	FILING DATE
~~—~~	~~A1~~	~~6,237,563~~	~~05/29/2001~~	~~Froehlich et al.~~ on 892	~~—~~	
TWS	A2	6,047,681	04/11/2000	Scherer et al.	123/406.46	
TWS	A3	5,954,026	09/21/1999	Stoss et al.	123/406.24	
	A4					
	A5					
	A6					
	A7					
	A8					
	A9					
	A10					
	A11					
	A12					
	A13					

PTO 1449 U.S. 10/196,747 07/19/02

FOREIGN PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	COUNTRY	CLASS/ SUBCLASS	TRANSLATION YES	TRANSLATION NO
TWS	A14	DE 42 32 974 A1	~~07/04~~/1994 04/07	Germany	—		X
	A15						
	A16						
	A17						
	A18						

EXAMINER INITIAL		OTHER ART (Including Author, Title, Date, Pertinent Pages, etc.)
	A19	
	A20	
	A21	
	A22	
	A23	
	A24	

EXAMINER	DATE CONSIDERED
Argenbright	3-19-03

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Rev. Dec.-99
F:\COMMON\rvivacqu\client matters\10541 (VISTEON)\1500\1524\PTO 1449.dot

Transaction History Date 2003-03-21
Date information retrieved from USPTO Patent Application Information Retrieval (PAIR) system records at www.uspto.gov

Notice of Allowability	Application No.	Applicant(s)	
	10/191,641	HESLOP ET AL.	
	Examiner	Art Unit	
	T. M. Argenbright	3747	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☐ This communication is responsive to _____.
2. ☒ The allowed claim(s) is/are *1-7*.
3. ☒ The drawings filed on *09 July 2002* are accepted by the Examiner.
4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☒ All b) ☐ Some* c) ☐ None of the:
      1. ☒ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____ .
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.
5. ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application).
   (a) ☐ The translation of the foreign language provisional application has been received.
6. ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application. **THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.**

7. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

8. ☐ CORRECTED DRAWINGS must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No. ____.
   (b) ☐ including changes required by the proposed drawing correction filed _____, which has been approved by the Examiner.
   (c) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No. _____.

Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the top margin (not the back) of each sheet. The drawings should be filed as a separate paper with a transmittal letter addressed to the Official Draftsperson.

9. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1☒ Notice of References Cited (PTO-892)
3☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
5☒ Information Disclosure Statements (PTO-1449), Paper No. *3*.
7☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
2☐ Notice of Informal Patent Application (PTO-152)
4☐ Interview Summary (PTO-413), Paper No.____ .
6☒ Examiner's Amendment/Comment
8☐ Examiner's Statement of Reasons for Allowance
9☐ Other

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

EXAMINER'S AMENDMENT

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

The application has been amended as follows:

In claims 3 and 6, last line, --ratio-- has been inserted after "air/fuel".

This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

Any inquiry concerning this communication or earlier communications from the examiner should be directed to T. M. Argenbright whose telephone number is 703-308-1955. The examiner can normally be reached 6:30am-3:00pm M-Th and 6:30am-2:00pm alt. Fridays.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Henry C. Yuen can be reached on 703-308-1946. The fax phone numbers for the organization where this application or proceeding is assigned are 703-872-9302 for regular communications and 703-872-9303 for After Final communications.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is 703-308-0861.

T. M. Argenbright
Primary Examiner
Art Unit 3747

March 19, 2003

Notice of References Cited	Application/Control No. 10/191,641	Applicant(s)/Patent Under Reexamination HESLOP ET AL.	
	Examiner T. M. Argenbright	Art Unit 3747	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6237563	05-2001	FROEHLICH ET AL	123/350
*	B	US-6227163	05-2001	ENOKI ET AL	123/295
*	C	US-6219611	04-2001	RUSSELL	123/399x
*	D	US-5638788	06-1997	SANVIDO ET AL	123/339.2
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

UNITED STATES PATENT AND TRADEMARK OFFICE

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Washington, D.C. 20231
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

EXAMINER	
ARGENBRIGHT, TONY MICHAEL	
ART UNIT	**CLASS-SUBCLASS**
3747	123-295000

DATE MAILED: 03/21/2003

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

TITLE OF INVENTION: ENGINE TORQUE CONTROLLER

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1300	$300	$1600	06/23/2003

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE REFLECTS A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE APPLIED IN THIS APPLICATION. THE PTOL-85B (OR AN EQUIVALENT) MUST BE RETURNED WITHIN THIS PERIOD EVEN IF NO FEE IS DUE OR THE APPLICATION WILL BE REGARDED AS ABANDONED.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:
A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status is changed, pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above and notify the United States Patent and Trademark Office of the change in status, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check the box below and enclose the PUBLICATION FEE and 1/2 the ISSUE FEE shown above.

☐ Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

II. PART B - FEE(S) TRANSMITTAL should be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). Even if the fee(s) have already been paid, Part B - Fee(s) Transmittal should be completed and returned. If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Box ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: **Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.**

PTOL-85 (REV. 04-02) Approved for use through 01/31/2004.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail Box ISSUE FEE
Commissioner for Patents
Washington, D.C. 20231
Fax (703)746-4000

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Box Issue Fee address above, or being facsimile transmitted to the USPTO, on the date indicated below.

(Depositor's name)

(Signature)

(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

TITLE OF INVENTION: ENGINE TORQUE CONTROLLER

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1300	$300	$1600	06/23/2003

EXAMINER	ART UNIT	CLASS-SUBCLASS
ARGENBRIGHT, TONY MICHAEL	3747	123-295000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____

2 _____

3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) ❑ individual ❑ corporation or other private group entity ❑ government

4a. The following fee(s) are enclosed:

❑ Issue Fee

❑ Publication Fee

❑ Advance Order - # of Copies _____

4b. Payment of Fee(s):

❑ A check in the amount of the fee(s) is enclosed.

❑ Payment by credit card. Form PTO-2038 is attached.

❑ The Commissioner is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number _____(enclose an extra copy of this form).

Commissioner for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature) (Date)

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Washington, DC 20231.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMIT THIS FORM WITH FEE(S)

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

EXAMINER	
ARGENBRIGHT, TONY MICHAEL	
ART UNIT	**PAPER NUMBER**
3747	

DATE MAILED: 03/21/2003

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)

(application filed on or after May 29, 2000)

The patent term adjustment to date is 0 days. If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the term adjustment will be 0 days.

If a continued prosecution application (CPA) was filed in the above-identified application, the filing date that determines patent term adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) system. (http://pair.uspto.gov)

Any questions regarding the patent term extension or adjustment determination should be directed to the Office of Patent Legal Administration at (703)305-1383.

PTOL-85 (REV. 04-02) Approved for use through 01/31/2004.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610
UNITED STATES

EXAMINER	
ARGENBRIGHT, TONY MICHAEL	
ART UNIT	**PAPER NUMBER**
3747	

DATE MAILED: 03/21/2003

Notice of Fee Increase on January 1, 2003

If a reply to a "Notice of Allowance and Fee(s) Due" is filed in the Office on or after January 1, 2003, then the amount due will be higher than that set forth in the "Notice of Allowance and Fee(s) Due" since there will be an increase in fees effective on January 1, 2003. See Revision of Patent and Trademark Fees for Fiscal Year 2003: Final Rule, 67 Fed. Reg. 70847, 70849 (November 27, 2002).

The current fee schedule is accessible from: http://www.uspto.gov/main/howtofees.htm.

If the issue fee paid is the amount shown on the "Notice of Allowance and Fee(s) Due," but not the correct amount in view of the fee increase, a "Notice to Pay Balance of Issue Fee" will be mailed to applicant. In order to avoid processing delays associated with mailing of a "Notice to Pay Balance of Issue Fee," if the response to the Notice of Allowance and Fee(s) due form is to be filed on or after January 1, 2003 (or mailed with a certificate of mailing on or after January 1, 2003), the issue fee paid should be the fee that is required at the time the fee is paid. If the issue fee was previously paid, and the response to the "Notice of Allowance and Fee(s) Due" includes a request to apply a previously-paid issue fee to the issue fee now due, then the difference between the issue fee amount at the time the response is filed and the previously paid issue fee should be paid. See Manual of Patent Examining Procedure, Section 1308.01 (Eighth Edition, August 2001).

Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (703) 305-8283.

PTOL-85 (REV. 04-02) Approved for use through 01/31/2004.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Transaction History Date 2003-05-12
Date information retrieved from USPTO Patent Application Information Retrieval (PAIR) system records at www.uspto.gov

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HM

OIPE MAY 12 2003 PATENT & TRADEMARK OFFICE

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail Box ISSUE FEE
Commissioner for Patents
Washington, D.C. 20231
Fax (703)746-4000

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Box Issue Fee address above, or being facsimile transmitted to the USPTO, on the date indicated below.

Raymond J. Vivacqua (Depositor's name)
(Signature)
5/9/03 (Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

TITLE OF INVENTION: ENGINE TORQUE CONTROLLER

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1300	$300	$1600	06/23/2003

EXAMINER	ART UNIT	CLASS-SUBCLASS
ARGENBRIGHT, TONY MICHAEL	3747	123-295000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Brinks Hofer Gilson & Lione
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Visteon Global Technologies, Inc.

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Dearborn, Michigan

Please check the appropriate assignee category or categories (will not be printed on the patent) ☐ individual ☒ corporation or other private group entity ☐ government

4a. The following fee(s) are enclosed:

☒ Issue Fee
☒ Publication Fee
☐ Advance Order - # of Copies _____

4b. Payment of Fee(s):

☐ A check in the amount of the fee(s) is enclosed.
☐ Payment by credit card. Form PTO-2038 is attached.
☒ The Commissioner is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number 06-1500 (enclose an extra copy of this form).

Commissioner for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature) (Date) 5/9/03

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

05/13/2003 BSAYASI2 00000106 061500 10191641

01 FC:1501 1300.00 CH
02 FC:1504 300.00 CH

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Washington, DC 20231.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMIT THIS FORM WITH FEE(S)

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

File History Content Report

The following content is missing from the original file history record obtained from the United States Patent and Trademark Office. No additional information is available.

Document Date - 2003-06-24

Document Title - USPTO Grant

This page is not part of the official USPTO record. It has been determined that content identified on this document is missing from the original file history record.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

P CRC

Certificate
SEP 0 8 2003
of Correction
M
#5

I hereby certify that this correspondence is being deposited with the United States Postal Service, with sufficient postage, as first class mail in an envelope addressed to the Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on

8/28/03
(Date of Deposit)

Raymond J. Vivacqua - Reg. No. 45,369
Name of applicant, assignee, or Registered Representative

Signature

8/28/03
Date of Signature

PTO JC1356 SEP 0 2 2003 PATENT & TRADEMARK OFFICE

Our File No. 10541/1524

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	
Garon N. Heslop et al.	Examiner: Tony M. Argenbright
Patent No.: 6,581,565 B2	
Issue Date: June 24, 2003	Group Art Unit: 3747
Serial No.: 10/191,641	
Filing Date: July 9, 2002	
For: ENGINE TORQUE CONTROLLER	

REQUEST FOR CERTIFICATE OF CORRECTION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Attn: Certificate of Corrections Branch

Sir:

Please issue a Certificate of Correction for the above-identified patent to correct the errors listed on the accompanying PTO Form 1050. This request is being made pursuant to 35 U.S.C. § 254, since the errors comprise minor or typographical errors by the Patent and Trademark Office.

SEP 0 9 2003

The Commissioner is hereby authorized to charge any fees required to Deposit Account No. 06-1500 (Visteon Global Technologies, Inc.). A duplicate copy of this sheet is enclosed.

Respectfully submitted,

Raymond J. Vivacqua
Registration No. 45,369
Attorney for Applicants

BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, Illinois 60610
(312) 321-4200

Staple Here Only !

PRINTER'S TRIM LINE

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al. Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

~~In the Claims~~

Col. 4 30
~~In claim 3~~, line ~~4~~, after "air/fuel" insert --ratio-- before "." (period).

Col. 4 53
~~In claim 6~~, line ~~4~~, after "air/fuel" insert --ratio-- before "." (period).

MAILING ADDRESS OF SENDER:
Raymond J. Vivacqua
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, Illinois 60610

PATENT NO. 6,581,565 B2

No. of add'l copies @ 50¢ per page

SEP 09 2003

FORM PTO 1050 (Rev. 2-93)

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Staple Here Only !

PRINTER'S TRIM LINE

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al. Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

In claim 3, line 4, after "air/fuel" insert --ratio-- before "." (period).

In claim 6, line 4, after "air/fuel" insert --ratio-- before "." (period).

6,581,565 B2

PATENT NO.

MAILING ADDRESS OF SENDER:
Raymond J. Vivacqua
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, Illinois 60610

No. of add'l copies @ 50¢ per page

SEP 09 2003

FORM PTO 1050 (Rev. 2-93)

File History Content Report

The following content is missing from the original file history record obtained from the United States Patent and Trademark Office. No additional information is available.

Document Date - 2003-09-08

Document Title - USPTO Communication Re: Change of Address

This page is not part of the official USPTO record. It has been determined that content identified on this document is missing from the original file history record.

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

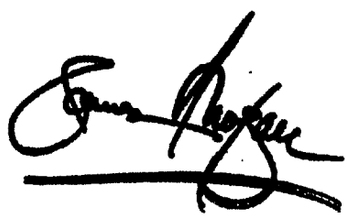
PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4,
Lines 30 and 53, after "air/fuel" insert -- ratio -- before "." (period).

Signed and Sealed this

Twenty-eighth Day of October, 2003



JAMES E. ROGAN
Director of the United States Patent and Trademark Office

File History Content Report

The following content is missing from the original file history record obtained from the United States Patent and Trademark Office. No additional information is available.

Document Date - 2006-02-02

Document Title - Certificate of Correction - Post Issue Communication

This page is not part of the official USPTO record. It has been determined that content identified on this document is missing from the original file history record.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

504528526 08/31/2017

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT4575232

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT

CONVEYING PARTY DATA

Name	Execution Date
GODO KAISHA IP BRIDGE	09/02/2016

RECEIVING PARTY DATA

Name:	MOBILE AUTOMOTIVE TECHNOLOGIES, LLC
Street Address:	951 GOVERNMENT STREET, SUITE B
City:	MOBILE
State/Country:	ALABAMA
Postal Code:	36604

PROPERTY NUMBERS Total: 42

Property Type	Number
Patent Number:	6345604
Patent Number:	6347680
Patent Number:	6379281
Patent Number:	6443128
Patent Number:	6510839
Patent Number:	6557540
Patent Number:	6561166
Patent Number:	6571157
Patent Number:	6581565
Patent Number:	6581574
Patent Number:	6588260
Patent Number:	6598581
Patent Number:	6607302
Patent Number:	6609497
Patent Number:	6612287
Patent Number:	6619106
Patent Number:	6644115
Patent Number:	6736122
Patent Number:	6741441
Patent Number:	6752741

Property Type	Number
Patent Number:	6757149
Patent Number:	6758885
Patent Number:	6763804
Patent Number:	6766788
Patent Number:	6817592
Patent Number:	6847882
Patent Number:	6856209
Patent Number:	6874362
Patent Number:	6976477
Patent Number:	6988031
Patent Number:	7089894
Patent Number:	7116081
Patent Number:	7124963
Patent Number:	7137577
Patent Number:	7143501
Patent Number:	7168637
Patent Number:	7191755
Patent Number:	7198207
Patent Number:	7293554
Patent Number:	7487761
Patent Number:	7712451
Patent Number:	7982358

CORRESPONDENCE DATA

Fax Number: (302)449-9010

Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.

Phone: 3024499010
Email: mmcclain@devlinlawfirm.com
Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/TIMOTHY DEVLIN/
DATE SIGNED:	08/31/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 3
source=MobileAutoSignedPAA#page1.tif

source=MobileAutoSignedPAA#page2.tif
source=MobileAutoSignedPAA#page3.tif

EXHIBIT B

U.S. PATENT ASSIGNMENT

WHEREAS, Godo Kaisha IP Bridge 1 ("Assignor"), is the owner of (i) United States Patent and Patent Applications listed in Schedule A and the following (ii) through (iv) to the extent Assignor owns, controls or has the right to license or enforce them at any time: (ii) any patents or patent applications that claim priority directly or indirectly from any of the foregoing patent(s) in subsection (i), or from which priority is directly or indirectly claimed by any such patent(s) in subsection (i), or that have common priority with any such patent(s) in subsection (i); (iii) any foreign counterparts, foreign related patents, continuations, divisionals, continuations-in-part, extensions, substitutions, reissues, renewals and all results of oppositions, reexaminations, supplemental examinations, requests for continued examination and other review procedures of any of the foregoing in subsections (i) and (ii); and (iv) all patents issuing on patent applications covered by any of the foregoing subsections (i) through (iii) (together the "Assigned Patents").

WHEREAS, Mobile Automotive Technologies, LLC, an Alabama limited liability company ("Assignee") is desirous of acquiring title in and to the Assigned Patents.

WHEREAS, Assignor is the owner of any and all right, title, and interest in and to the Assigned Patents.

WHEREAS, Assignor desires to sell, assign, and transfer all its right, title, and interest in the Assigned Patents to Assignee, and Assignee desires to obtain all such right, title, and interest in the Assigned Patents from Assignor.

NOW, THEREFORE, in consideration of good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, Assignor hereby sells, assigns, transfers and conveys unto Assignee, its permitted successors and assigns, all of Assignor's right, title, and interest in and to the Assigned Patents, together with all claims, demands, or causes of action that Assignor has or might have by reason of any infringement of the Assigned Patents prior to the effective date of this assignment, including the right to sue and collect damages for all past, present and future infringement and all lost profits resulting therefrom.

IN WITNESS WHEREOF, this Agreement has been executed by duly authorized representatives of the Parties on the dates below.

Signature

Hideyuki Ogata
Name

Date: Sept. 2, 2016

Signature

KEVIN C. BRADY
Name

Date: AUG 27, 2016

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

SCHEDULE A

Patents:

US6345604
US6347680
US6379281
US6443128
US6510839
US6557540
US6561166
US6571157
US6581565
US6581574
US6588260
US6598581
US6607302
US6609497
US6612287
US6619106
US6644115
US6736122
US6741441
US6752741
US6757149
US6758885
US6763804
US6766788
US6817592
US6847882
US6856209
US6874362
US6976477
US6988031
US7089894
US7116081
US7124963
US7137577
US7143501
US7168637
US7191755
US7198207

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

US7293554
US7487761
US7712451
US7982358

DE103 44 494.7-34
GB2385013
GB2422688
JP4235485

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

504528590 08/31/2017

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT4575296

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT

CONVEYING PARTY DATA

Name	Execution Date
GODO KAISHA IP BRIDGE	11/02/2016

RECEIVING PARTY DATA

Name:	MOBILE AUTOMOTIVE TECHNOLOGIES, LLC
Street Address:	951 GOVERNMENT STREET, SUITE B
City:	MOBILE
State/Country:	ALABAMA
Postal Code:	36604

PROPERTY NUMBERS Total: 42

Property Type	Number
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Patent Number:	6752741

Property Type	Number
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CORRESPONDENCE DATA

Fax Number: (302)449-9010

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Phone: 3024499010
Email: mmcclain@devlinlawfirm.com
Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/TIMOTHY DEVLIN/
DATE SIGNED:	08/31/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 3
source=MobileAutoAmend-2#page1.tif

source=MobileAutoAmend-2#page2.tif
source=MobileAutoAmend-2#page3.tif

504528678 08/31/2017

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT4575384

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT

CONVEYING PARTY DATA

Name	Execution Date
MOBILE AUTOMOTIVE TECHNOLOGIES, LLC	08/28/2017

RECEIVING PARTY DATA

Name:	MICHIGAN MOTOR TECHNOLOGIES LLC
Street Address:	2360 ORCHARD LAKE ROAD SUITE 100
City:	SYLVAN LAKE
State/Country:	MICHIGAN
Postal Code:	48320

PROPERTY NUMBERS Total: 42

Property Type	Number
Patent Number:	6345604
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Patent Number:	7487761
Patent Number:	7712451
Patent Number:	7982358

CORRESPONDENCE DATA

Fax Number: (302)449-9010

Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.

Phone: 3024499010
Email: mmcclain@devlinlawfirm.com
Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/TIMOTHY DEVLIN/
DATE SIGNED:	08/31/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 2
source=michmotorassn#page1.tif

source=michmotorassn#page2.tif

EXHIBIT B

U.S. PATENT ASSIGNMENT

WHEREAS, Mobile Automotive Technologies, LLC, an Alabama limited liability company ("Assignor"), is the owner of (i) United States Patent and Patent Applications listed in Schedule A and the following (ii) through (iv) to the extent Assignor owns, controls or has the right to license or enforce them at any time: (ii) any patents or patent applications that claim priority directly or indirectly from any of the foregoing patent(s) in subsection (i), or from which priority is directly or indirectly claimed by any such patent(s) in subsection (i), or that have common priority with any such patent(s) in subsection (i); (iii) any foreign counterparts, foreign related patents, continuations, divisionals, continuations-in-part, extensions, substitutions, reissues, renewals and all results of oppositions, reexaminations, supplemental examinations, requests for continued examination and other review procedures of any of the foregoing in subsections (i) and (ii); and (iv) all patents issuing on patent applications covered by any of the foregoing subsections (i) through (iii) (together the "Assigned Patents").

WHEREAS, Michigan Motor Technologies LLC ("Assignee") is desirous of acquiring title in and to the Assigned Patents.

WHEREAS, Assignor is the owner of any and all right, title, and interest in and to the Assigned Patents.

WHEREAS, Assignor desires to sell, assign, and transfer all its right, title, and interest in the Assigned Patents to Assignee, and Assignee desires to obtain all such right, title, and interest in the Assigned Patents from Assignor.

NOW, THEREFORE, in consideration of good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, Assignor hereby sells, assigns, transfers and conveys unto Assignee, its permitted successors and assigns, all of Assignor's right, title, and interest in and to the Assigned Patents, together with all claims, demands, or causes of action that Assignor has or might have by reason of any infringement of the Assigned Patents prior to the effective date of this assignment, including the right to sue and collect damages for all past, present and future infringement and all lost profits resulting therefrom.

IN WITNESS WHEREOF, this Agreement has been executed by duly authorized representatives of the Parties on the dates below.

Signature

Name John Mello
Mobile Automotive Technology LLC

Date: 8/25/17

Signature

Name KEVIN C BRADY
MICHIGAN MOTOR TECHNOLOGY LLC

Date: 8/28/17

SCHEDULE A

Patents:

US6345604
US6347680
US6379281
US6443128
US6510839
US6557540
US6561166
US6571157
US6581565
US6581574
US6588260
US6598581
US6607302
US6609497
US6612287
US6619106
US6644115
US6736122
US6741441
US6752741
US6757149
US6758885
US6763804
US6766788
US6817592
US6847882
US6856209
US6874362
US6976477
US6988031
US7089894
US7116081
US7124963
US7137577
US7143501
US7168637
US7191755
US7198207
US7293554
US7487761
US7712451
US7982358
DE103 44 494.7-34
GB2385013
GB2422688
JP4235485
DE103 22 529.3

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

504584165 10/06/2017

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT4630877

SUBMISSION TYPE:	RESUBMISSION
NATURE OF CONVEYANCE:	ASSIGNMENT
RESUBMIT DOCUMENT ID:	504528590

CONVEYING PARTY DATA

Name	Execution Date
GODO KAISHA IP BRIDGE	11/02/2016

RECEIVING PARTY DATA

Name:	MOBILE AUTOMOTIVE TECHNOLOGIES, LLC
Street Address:	951 GOVERNMENT STREET, SUITE B
City:	MOBILE
State/Country:	ALABAMA
Postal Code:	36604

PROPERTY NUMBERS Total: 42

Property Type	Number
Patent Number:	6345604
Patent Number:	6347680
Patent Number:	6379281
Patent Number:	6443128
Patent Number:	6510839
Patent Number:	6557540
Patent Number:	6561166
Patent Number:	6571157
Patent Number:	6581565
Patent Number:	6581574
Patent Number:	6588260
Patent Number:	6598581
Patent Number:	6607302
Patent Number:	6609497
Patent Number:	6612287
Patent Number:	6619106
Patent Number:	6644115
Patent Number:	6736122
Patent Number:	6741441

Property Type	Number
Patent Number:	6752741
Patent Number:	6757149
Patent Number:	6758885
Patent Number:	6763804
Patent Number:	6766788
Patent Number:	6817592
Patent Number:	6847882
Patent Number:	6856209
Patent Number:	6874362
Patent Number:	6976477
Patent Number:	6988031
Patent Number:	7089894
Patent Number:	7116081
Patent Number:	7124963
Patent Number:	7137577
Patent Number:	7143501
Patent Number:	7168637
Patent Number:	7191755
Patent Number:	7198207
Patent Number:	7293554
Patent Number:	7487761
Patent Number:	7712451
Patent Number:	7982358

CORRESPONDENCE DATA

Fax Number: (302)449-9010

Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.

Phone: 3024499010
Email: mmcclain@devlinlawfirm.com
Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/Timothy Devlin/
DATE SIGNED:	10/06/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 6

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source=Full page photo 3#page1.tif
source=MobileAutoSignedPAA#page1.tif
source=MobileAutoSignedPAA#page2.tif
source=MobileAutoSignedPAA#page3.tif

AMENDMENT NO. 1 TO THE PATENT ASSIGNMENT AGREEMENT

This Amendment No. 1 (the "**Amendment**"), dated as of the latest execution date below, is entered into by Mobile Automotive Technologies, LLC, an Alabama limited liability company and Godo Kaisha IP Bridge 1, with its principal offices at c/o Sakura Sogo Jimusho, 1-11 Kanda Jimbocho, Chiyoda-ku, Tokyo 102-0083, Japan, and amends the Patent Assignment Agreement entered into by the parties, executed on September 2, 2016 (the "**PTA**"). Capitalized terms not defined herein are defined in the PTA.

The parties agree to retroactively amend the PTA as follows:

1. Exhibit A to the PTA is hereby retroactively amended and restated in its entirety in the form of Exhibit A attached hereto.

2. The parties intend and agree that this Amendment shall be effective as of the Effective Date of the PTA with the same force and effect as if executed on that date. Except as expressly amended by this Amendment, all other terms, conditions and provisions of the PTA shall apply.

IN WITNESS WHEREOF, the parties have executed this Amendment through their duly authorized representatives.

Mobile Automotive Technologies, LLC

By: _____

Name: Kevin C. Brady

Title: Managing Member

Date: 10-21-2016

Godo Kaisha IP Bridge 1

By: _____

Name: Hideyuki Ogata

Title: Executive Manager

Date: 11-2-2016

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

EXHIBIT A

Patents:

1. US6345604
2. US6347680
3. US6379281
4. US6443128
5. US6510839
6. US6557540
7. US6561166
8. US6571157
9. US6581565
10. US6581574
11. US6588260
12. US6598581
13. US6607302
14. US6609497
15. US6612287
16. US6619106
17. US6644115
18. US6736122
19. US6741441
20. US6752741
21. US6757149
22. US6758885
23. US6763804
24. US6766788
25. US6817592
26. US6847882
27. US6856209
28. US6874362
29. US6976477
30. US6988031
31. US7089894
32. US7116081
33. US7124963
34. US7137577
35. US7143501
36. US7168637

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

37 US7191755
38 US7198207
39 US7293554
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41 US7712451
42 US7982358
43 DE103 44 494.7-34
44 GB2385013
45 GB2422688
46 JP4235485
47 DE103 22 529.3

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

EXHIBIT B

U.S. PATENT ASSIGNMENT

WHEREAS, Godo Kaisha IP Bridge 1 ("Assignor"), is the owner of (i) United States Patent and Patent Applications listed in Schedule A and the following (ii) through (iv) to the extent Assignor owns, controls or has the right to license or enforce them at any time: (ii) any patents or patent applications that claim priority directly or indirectly from any of the foregoing patent(s) in subsection (i), or from which priority is directly or indirectly claimed by any such patent(s) in subsection (i), or that have common priority with any such patent(s) in subsection (i); (iii) any foreign counterparts, foreign related patents, continuations, divisionals, continuations-in-part, extensions, substitutions, reissues, renewals and all results of oppositions, reexaminations, supplemental examinations, requests for continued examination and other review procedures of any of the foregoing in subsections (i) and (ii); and (iv) all patents issuing on patent applications covered by any of the foregoing subsections (i) through (iii) (together the "Assigned Patents").

WHEREAS, Mobile Automotive Technologies, LLC, an Alabama limited liability company ("Assignee") is desirous of acquiring title in and to the Assigned Patents.

WHEREAS, Assignor is the owner of any and all right, title, and interest in and to the Assigned Patents.

WHEREAS, Assignor desires to sell, assign, and transfer all its right, title, and interest in the Assigned Patents to Assignee, and Assignee desires to obtain all such right, title, and interest in the Assigned Patents from Assignor.

NOW, THEREFORE, in consideration of good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, Assignor hereby sells, assigns, transfers and conveys unto Assignee, its permitted successors and assigns, all of Assignor's right, title, and interest in and to the Assigned Patents, together with all claims, demands, or causes of action that Assignor has or might have by reason of any infringement of the Assigned Patents prior to the effective date of this assignment, including the right to sue and collect damages for all past, present and future infringement and all lost profits resulting therefrom.

IN WITNESS WHEREOF, this Agreement has been executed by duly authorized representatives of the Parties on the dates below.

Signature

Hideyuki Ogata
Name

Date: Sept. 2, 2016

Signature

KEVIN C. BRADY
Name

Date: AUG 27, 2016

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

SCHEDULE A

Patents:

US6345604
US6347680
US6379281
US6443128
US6510839
US6557540
US6561166
US6571157
US6581565
US6581574
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US7116081
US7124963
US7137577
US7143501
US7168637
US7191755
US7198207

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US PATENT NO. 6,581,565

US7293554
US7487761
US7712451
US7982358

DE103 44 494.7-34
GB2385013
GB2422688
JP4235485

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

AO 120 (Rev. 08/10)

TO:	**Mail Stop 8** **Director of the U.S. Patent and Trademark Office** **P.O. Box 1450** **Alexandria, VA 22313-1450**	**REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK**

In Compliance with 35 U.S.C. § 290 and/or 15 U.S.C. § 1116 you are hereby advised that a court action has been filed in the U.S. District Court Eastern District of Michigan on the following

☐ Trademarks or ☑ Patents. (☐ the patent action involves 35 U.S.C. § 292.):

DOCKET NO.	DATE FILED	U.S. DISTRICT COURT
	2/15/2019	Eastern District of Michigan

PLAINTIFF	DEFENDANT
MICHIGAN MOTOR TECHNOLOGIES LLC	VOLKSWAGEN AKTIENGESELLSCHAFT

	PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1	US 6,588,260 B1	7/8/2003	MICHIGAN MOTOR TECHNOLOGIES LLC
2	US 6,443,128 B1	9/3/2002	MICHIGAN MOTOR TECHNOLOGIES LLC
3	US 6,581,565 B2	6/24/2003	MICHIGAN MOTOR TECHNOLOGIES LLC
4	US 6,379,281 B1	4/30/2002	MICHIGAN MOTOR TECHNOLOGIES LLC
5	US 6,763,804 B2	7/20/2004	MICHIGAN MOTOR TECHNOLOGIES LLC

In the above—entitled case, the following patent(s)/ trademark(s) have been included:

DATE INCLUDED	INCLUDED BY ☐ Amendment ☐ Answer ☐ Cross Bill ☐ Other Pleading	
PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
1		
2		
3		
4		
5		

In the above—entitled case, the following decision has been rendered or judgement issued:

DECISION/JUDGEMENT

CLERK	(BY) DEPUTY CLERK	DATE

Copy 1—Upon initiation of action, mail this copy to Director **Copy 3—Upon termination of action, mail this copy to Director**
Copy 2—Upon filing document adding patent(s), mail this copy to Director **Copy 4—Case file copy**

REPORT ON THE FILING OR DETERMINATION OF AN ACTION REGARDING A PATENT OR TRADEMARK (CON'D)

PATENT OR TRADEMARK NO.	DATE OF PATENT OR TRADEMARK	HOLDER OF PATENT OR TRADEMARK
6. US 6,347,680 B1	2/19/2002	MICHIGAN MOTOR TECHNOLOGIES LLC
7. US 6,561,166 B2	5/13/2003	MICHIGAN MOTOR TECHNOLOGIES LLC
8. US 6,988,031 B2	1/17/2006	MICHIGAN MOTOR TECHNOLOGIES LLC
9. US 6,612,287 B2	9/2/2003	MICHIGAN MOTOR TECHNOLOGIES LLC
10. US 7,487,761 B1	2/10/2009	MICHIGAN MOTOR TECHNOLOGIES LLC
11. US 6,644,115 B2	11/11/2003	MICHIGAN MOTOR TECHNOLOGIES LLC
12. US 6,581,574 B1	6/24/2003	MICHIGAN MOTOR TECHNOLOGIES LLC
13. US 6,609,497 B2	8/26/2003	MICHIGAN MOTOR TECHNOLOGIES LLC
14. US 6,571,157 B1	5/27/2003	MICHIGAN MOTOR TECHNOLOGIES LLC
15. US 6,736,122 B2	5/18/2004	MICHIGAN MOTOR TECHNOLOGIES LLC
16. US 6,757,149 B2	6/29/2004	MICHIGAN MOTOR TECHNOLOGIES LLC
17. US 7,116,081 B2	10/3/2006	MICHIGAN MOTOR TECHNOLOGIES LLC
18. US 8,909,482 B2	12/9/2014	MICHIGAN MOTOR TECHNOLOGIES LLC
19. US 6,557,540 B1	5/6/2003	MICHIGAN MOTOR TECHNOLOGIES LLC
20. US 6,345,604	2/12/2002	MICHIGAN MOTOR TECHNOLOGIES LLC

Transaction History Date 2020-01-31
Date information retrieved from USPTO Patent Application Information Retrieval (PAIR) system records at www.uspto.gov

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

VOLKSWAGEN GROUP OF AMERICA, INC.
Petitioner

v.

MICHIGAN MOTOR TECHNOLOGIES LLC
Patent Owner

Case IPR2020-00444
Patent 6,581,565

PETITIONER VOLKSWAGEN GROUP OF AMERICA, INC.'S POWER OF ATTORNEY

Mail Stop "PATENT BOARD"
Patent Trial and Appeal Board
U.S. Patent and Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

Petitioner Volkswagen Group of America, Inc.'s Power of Attorney

Pursuant to 37 C.F.R. § 42.10(b), Petitioner Volkswagen Group of America, Inc., hereby appoints the practitioners of Customer No. 26111 as its attorneys to transact all business in the United States Patent & Trademark Office associated with the above-captioned *inter partes* review of U.S. Patent No. 6,581,565.

These attorneys include at least:

Lead Counsel Michael D. Specht, Reg. No. 54,463
mspecht-PTAB@sternekessler.com

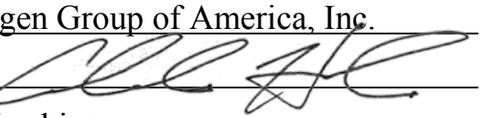
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jfitzsimmons-PTAB@sternekessler.com

Daniel E. Yonan, Reg. No. 53,812
dyonan-PTAB@sternekessler.com

Kyle Conklin, Reg. No. 59,425
dyonan-PTAB@sternekessler.com

John D. Higgins, Reg. No. 74,992
jhiggins-PTAB@sternekessler.com

Address STERNE, KESSLER, GOLDSTEIN & FOX P.L.L.C.
1100 New York Avenue, N.W.
Washington, D.C. 20005
Tel.: 202-371-2600
Fax: 202-371-2540

FOR: Volkswagen Group of America, Inc.
SIGNATURE: 
BY: Charles Hawkins
TITLE: Assistant General Counsel IP & Litigation
DATE: December 9, 2019

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

VOLKSWAGEN GROUP OF AMERICA, INC.,
Petitioner

v.

MICHIGAN MOTOR TECHNOLOGIES LLC,
Patent Owner

Case IPR2020-00444
Patent 6,581,565

PETITIONER VOLKSWAGEN GROUP OF AMERICA, INC.'S NOTICE RANKING PETITIONS FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 6,581,565

Mail Stop "PATENT BOARD"
Patent Trial and Appeal Board
U.S. Patent & Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

I. Introduction

Petitioner Volkswagen Group of America, Inc. (VWGoA) is simultaneously filing petitions IPR2020-00444 and IPR2020-00445 challenging the patentability of all claims in U.S. Patent No. 6,581,565 and asks the Board to institute both petitions. This paper is submitted with each petition to "identify: (1) a ranking of the petitions in the order in which it wishes the Board to consider the merits … , and (2) a succinct explanation of the differences between the petitions, why the issues addressed by the differences are material, and why the Board should exercise its discretion to institute additional petitions…." Consolidated Trial Practice Guide (Nov. 2019) at 60.

II. Ranking of the Petitions

Although institution of both petitions is appropriate for the reasons below, in view of the Board's guidance to provide a "ranking" when two or more petitions are filed against the same patent, VWGoA asks the Board to consider the merits of the petitions in the following order:

1. IPR2020-00444 ("Suzuki Petition"); and
2. IPR2020-00445 ("Robichaux Petition").

III. Succinct Explanation of Differences Between the Petitions

	Suzuki Petition	Robichaux Petition
Ground 1 References	Suzuki, Cullen, Scherer	Robichaux, Scherer
Ground 1: Primary	Suzuki discloses a torque	Robichaux discloses a torque

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Reference Teaching	demand controller; a torque producer, including a torque estimator and a comparator that outputs a difference signal; and a transient torque controller	demand controller; a torque producer, including a torque estimator that determines estimated torque based on current spark angle, current air/fuel ratio, and an estimated air charge signal, and a comparator that outputs a difference signal
Ground 1: Modification by Secondary References	Cullen discloses estimating torque output based on current spark angle, current air/fuel ratio, and estimated air charge; Scherer discloses a high-pass filter that removes a torque signal's low-frequency component	Scherer discloses a transient controller, including a high-pass filter, for adjusting torque during transient conditions
Additional Grounds: Modification of Ground 1 by Secondary References	Ground 2: Takahashi discloses an air charge controller that receives the claimed inputs and an air charge demand controller	Ground 2: Takahashi discloses an air charge controller that receives the claimed inputs and air charge demand controller Ground 3: Suzuki discloses a direct injection spark ignition engine operating in stratified and homogeneous modes Ground 4: Suzuki and Takahashi for same reasons as Grounds 2 and 3

IV. The Board should exercise its discretion to institute both petitions because the equities favor VWGoA and doing so would not significantly burden the Board or Patent Owner.

VWGoA simultaneously files the Suzuki Petition and the Robichaux Petition against claims 1-7 of the '565 patent. While the Board has the discretion to deny multiple petitions filed against the same patent under Section 314(a), it should institute both petitions here because every *General Plastic* factor weighs in VWGoA's favor. 37 C.F.R. § 314(a); *see General Plastic Industrial Co., Ltd. v. Canon Kabushiki Kaisha*, IPR2016-01357, Paper 19 at 5 (P.T.A.B. Sep. 6, 2017) (precedential).

First, the two simultaneous petitions here do not present the potential inefficiency or prejudice that concerned the Board in *General Plastic*, which examined so-called "staggered" or "follow-on" petitions that are not filed simultaneously. *General Plastic*, Paper 19 at 17. Here, the two petitions are being filed on the same day, and no entity, including VWGoA, has filed a previous petition against the '565 patent. Thus, no time has elapsed between petitions and VWGoA has not gained any advantage by using earlier preliminary responses or institution decisions as a "roadmap" for its petitions. *See id.* at 16-17. Accordingly, *General Plastic* Factors 1–5 weigh in favor of VWGoA. *Id.*

Second, regarding *General Plastic* Factor 6, the Board's finite resources, the Board has provided further guidance on "parallel" petitions filed at or about the

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

same time. Consolidated Trial Practice Guide at 59-61. Specifically, the Board's concern that filing two or more petitions against the same patent "may place a substantial and unnecessary burden on the Board and the patent owner and could raise fairness, timing, and efficiency concerns" is not present here. *Id.* at 59. Here, VWGoA is filing only two petitions, each with a single "primary reference" (Suzuki and Robichaux, respectively). Thus, VWGoA is not presenting an excessive number of prior-art references by filing two separate petitions. Further, even with the two petitions, each claim is only challenged under two grounds, which will not be unduly burdensome for the Board or Patent Owner. To further illustrate the minimal burden in moving forward with both petitions, both petitions apply Scherer, Suzuki, and Takahashi. Notably, though, this similarity does not make the petitions redundant because the base references are different in each petition. Instead, this similarity further indicates that there is no excessive burden on the Board or Patent Owner in instituting a second trial. On balance, the incremental burden on the Board or Patent Owner is significantly outweighed by the potential prejudice to Petitioner VWGoA from a discretionary denial of an *inter partes* review against a patent it was accused of infringing.

Accordingly, *General Plastic* Factor 6 weighs in favor of instituting both petitions.

Third, *General Plastic* Factor 7 also favors VWGoA because these two petitions are being filed on the same day, and thus their respective schedules (or schedule if consolidated) may be aligned and will not hinder the Board's ability to issue a final determination within one year of institution. Indeed, VWGoA would be amenable to consolidated depositions and hearings in these two proceedings, further minimizing any burden on the Board and Patent Owner.

Thus, all *General Plastic* Factors weigh in VWGoA's favor so "the potential for abuse of the review process by repeated attacks on patents"—the concern expressed in *General Plastic*—is not an issue here. *General Plastic*, Paper 19 at 17.

V. Conclusion

Because all seven *General Plastic* factors weigh in favor of VWGoA, the Board should institute both petitions and thus decline to use its discretion to deny institution of either petition under Section 314(a).

Respectfully Submitted,

STERNE, KESSLER, GOLDSTEIN & FOX P.L.L.C.

/Michael D. Specht/

Michael D. Specht (Reg. No. 54,463)
Attorney for Petitioner
Volkswagen Group of America, Inc.

Date: January 31, 2020

1100 New York Avenue, N.W.
Washington, D.C. 20005-3934
(202) 371-2600

CERTIFICATION OF SERVICE (37 C.F.R. § 42.6(e))

The undersigned hereby certifies that on January 31, 2020 a true and correct copy of the foregoing **PETITIONER VOLKSWAGEN GROUP OF AMERICA, INC.'S NOTICE RANKING PETITIONS FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 6,581,565** was served in its entirety on the following parties via FedEx® Express:

VISTEON GLOBAL TECHNOLOGIES, INC.
Intellectual Property Department
One Village Center Drive
Van Buren Township, MI 48111
PAIR Correspondence Address for US Patent No. 6,581,565

DEVLIN LAW FIRM LLC
1526 Gilpin Avenue
Wilmington, DE 19806
Other address known to the petitioner as likely to effect service

STERNE, KESSLER, GOLDSTEIN & FOX P.L.L.C.

/Michael D. Specht/

Michael D. Specht (Reg. No. 54,463)
Attorney for Petitioner
Volkswagen Group of America, Inc.

Date: January 31, 2020

1100 New York Avenue, N.W.
Washington, D.C. 20005-3934
(202) 371-2600

14284978.docx

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

VOLKSWAGEN GROUP OF AMERICA, INC.,
Petitioner

v.

MICHIGAN MOTOR TECHNOLOGIES, LLC,
Patent Owner

Case IPR2020-00444
Patent 6,581,565

PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 6,581,565

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Patent Trial and Appeal Board
U.S. Patent & Trademark Office
P.O. Box 1450
Alexandria, VA 22313-1450

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2. Torque Feedback Control....7
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PETITIONER'S EXHIBIT LIST

Exhibit No.	Description
1001	U.S. Patent No. 6,581,565 B2 to Heslop *et al*. ("'565 Patent")
1002	Prosecution File History of U.S. Patent No. 6,581,565 B2 ("'565 history")
1003	Declaration of C. Arthur MacCarley, Ph.D., P.E.
1004	Curriculum Vitae of C. Arthur MacCarley, Ph.D., P.E.
1005	U.S. Patent No. 6,006,717 A to Suzuki *et al.*, titled "Direct-Injection Spark-Ignition Type Engine Control Apparatus," issued December 28, 1999 ("Suzuki")
1006	U.S. Patent No. 5,241,855 A to Cullen *et al.*, titled "Method and Apparatus for Inferring Engine Torque," issued September 7, 1993 ("Cullen")
1007	U.S. Patent No. 6,07,681 A to Scherer *et al.*, titled "Process and Apparatus for Adjusting the Torque of an Internal-Combustion Engine," issued April 11, 2000 ("Scherer")
1008	U.S. Patent No. 5,282,449 A to Takahashi *et al.*, titled "Method and System for Engine Control," issued February 1, 1994 ("Takahashi")
1009	"Bosch Fuel Injection Systems," F. Aird, Berkeley Publishing Group, 2001, ISBN 1-55788-365-3 ("Aird")
1010	U.S. Patent No. 6,209,519 B1 to Melchior *et al.*, titled "Method and Arrangement for Controlling the Quiet Running of an Internal Combustion Engine," issued April 3, 2001 ("Melchior")
1011	U.S. Patent No. 5,692,471 A to Zhang, titled "Method and Arrangement for Controlling a Vehicle," issued December 2, 1997 ("Zhang")
1012	"Bosch Automotive Handbook," Robert Bosch GmbH, 2000, ISBN 0-7680-0669-4 ("Bosch")
1013	*Intentionally Left Blank*
1014	John B. Heywood, Internal Combustion Engine Fundamentals, 1st Ed. McGraw-Hill, Inc., 1988. ("Heywood")
1015	Ronald K. Jurgen, "Automotive Electronics Handbook," McGraw-

Exhibit No.	Description
	Hill, Inc., ISBN0-07-033189-8, c.1994 (selected portions) ("Jurgen")
1016	*Intentionally Left Blank*
1017	*Intentionally Left Blank*
1018	*Intentionally Left Blank*
1019	Understanding Automotive Electronics, Fifth Edition (1998), William B. Ribbens, Ph.D. ("Ribbens")
1020	*Intentionally Left Blank*
1021	*Intentionally Left Blank*
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1028	*Intentionally Left Blank*
1029	Amended Complaint for Patent Infringement, *Michigan Motor Technologies LLC v. Volkswagen AG*, Case No. 2:19-cv-10485 (E.D. Mich.), filed April 30, 2019

I. Introduction

Volkswagen Group of America, Inc. ("VWGoA") petitions for *inter partes* review of claims 1-7 of U.S. Patent No. 6,581,565 to Heslop *et al.* ("the '565 patent"), titled "Engine Torque Controller."

The '565 patent is directed to a device and a method for controlling engine torque output. The '565 patent broadly claims controlling engine torque output by fuel and spark adjustments that compensate for the difference between a demand torque and an estimated torque. The claims recite basic components of an engine controller: a controller for determining a demand torque, an estimator for outputting an estimated torque signal, a comparator for comparing the estimated torque signal to a desired torque to output a difference signal, a high-pass filter for removing the low frequency component from the difference signal, and a transient controller for outputting fuel and spark adjustment signals in response to receiving the filtered difference signal.

The claimed solution for compensating between estimated and demand torques was well-known. Indeed, the claimed elements were all independently known in the prior art. And combining the prior art references would have simply involved programming a known engine torque controller to collectively perform the prior-art techniques disclosed in the references—a trivial task for a POSA.

And as the references expressly recognize, a POSA would have sought to do so for precise control of engine torque output with a faster, more accurate response.

The Petition, supported by Dr. MacCarley's expert declaration, who has over 30 years of experience related to internal combustion engines and methods and systems of controlling them, demonstrates that all claims of the '565 patent are unpatentable. Therefore, Petitioner respectfully requests that the Board institute review and ultimately find all claims unpatentable.

II. Mandatory Notices (37 C.F.R. § 42.8(a)(1))

REAL PARTY IN INTEREST: Volkswagen Group of America, Inc. and Volkswagen Aktiengesellschaft, which is the parent corporation of Volkswagen Group of America, Inc., are real parties-in-interest.

RELATED MATTERS: The '565 patent is the subject of the following civil actions: *Michigan Motor Technologies LLC v. Volkswagen AG*, Case No. 2:19-cv-10485 (E.D. Mich.), filed February 18, 2019. However, on January 6, 2020, MMT filed a second amended complaint, which no longer alleged infringement of the '565 patent. Second Amended Complaint for Patent Infringement, *Michigan Motor Technologies LLC v. Volkswagen AG*, No. 2:19-cv-10485 (E.D. Mich. Jan. 6, 2020).

Petitioner is concurrently filing a second Petition for *Inter Partes* Review of the '565 Patent (IPR2020-00445).

LEAD AND BACKUP COUNSEL: Under 37 C.F.R. § 42.8(b)(3) and 42.10(a), Petitioner appoints **Michael D. Specht** (Reg. No. 54,463) as lead counsel; **Jason A. Fitzsimmons** (Reg. No. 65,367) as first back-up counsel; and **Daniel E. Yonan** (Reg. No. 53,812), **Kyle E. Conklin** (Reg. No. 59,425), and **John Higgins** (74,992) as additional back-up counsel, all at the address: STERNE, KESSLER, GOLDSTEIN & FOX P.L.L.C., 1100 New York Avenue, N.W., Washington, D.C., 20005, phone (202) 371-2600, and facsimile (202) 371-2540.

SERVICE INFORMATION: Petitioner consents to electronic service by email at: **mspecht-PTAB@sternekessler.com, jfitzsimmons-PTAB@sternekessler.com**, **dyonan-PTAB@sternekessler.com**, **kconklin-PTAB@sternekessler.com**, **jhiggins-PTAB@sternekessler.com**, and **PTAB@sternekessler.com**.

III. Grounds for Standing (37 C.F.R. § 42.104(a))

The undersigned and Petitioner certify that the ’565 patent is available for *inter partes* review. Petitioner is not barred or estopped from requesting *inter partes* review on the grounds herein. On February 18, 2019, Michigan Motor Technologies LLC (“MMT”) filed a complaint against Volkswagen Aktiengesellschaft alleging infringement of the ’565 patent. VWGoA was added via amended complaint on April 30, 2019. A Certificate of Service on VWGoA

was filed with the court on May 22, 2019. This Petition is filed within one year of service by MMT.

IV. Identification of Challenge (37 C.F.R. § 42.104(b))

A. Citation of Prior Art

The '565 patent issued June 24, 2003, from U.S. Application No. 10/191,641 ("the '641 application"), which was filed on July 9, 2002. EX1001, (21), (22), (45).

The '565 patent claims priority to European Application No. 01306301, filed July 23, 2001. Thus, the '565 patent's earliest possible priority date is July 23, 2001.

U.S. Patent No. 6,006,717 to Suzuki *et al.*, "Direct-Injection Spark-Ignition Type Engine Control Apparatus" (EX1005, "Suzuki"), issued December 28, 1999, more than one year before the '565 patent's earliest possible priority date. Therefore, Suzuki is prior art at least under 35 U.S.C. § 102(b) (pre-AIA).

U.S. Patent No. 5,241,855 to Cullen *et al.*, "Method and Apparatus for Inferring Engine Torque" (EX1006, "Cullen"), issued September 7, 1993, more than seven years before the '565 patent's earliest possible priority date. Therefore, Cullen is prior art at least under 35 U.S.C. § 102(b) (pre-AIA).

U.S. Patent No. 6,047,681 to Scherer *et al.*, "Process and Apparatus for Adjusting the Torque of an Internal-Combustion Engine" (EX1007, "Scherer"),

issued April 11, 2000, more than one year before the '565 patent's earliest possible priority date. Therefore, Scherer is prior art at least under 35 U.S.C. § 102(b) (pre-AIA).

U.S. Patent No. 5,282,449 to Takahashi *et al.*, "Method and System for Engine Control" (EX1008, "Takahashi"), issued February 1, 1994, more than seven years before the '565 patent's earliest possible priority date. Therefore, Takahashi is prior art at least under 35 U.S.C. § 102(b) (pre-AIA).

B. Statutory Grounds for the Challenge

Ground	References	Basis	Claims Challenged
1	Suzuki, Cullen, Scherer	§103	1, 4, 7
2	Suzuki, Cullen, Scherer, Takahashi	§103	2, 3, 5, 6

V. The '565 Patent

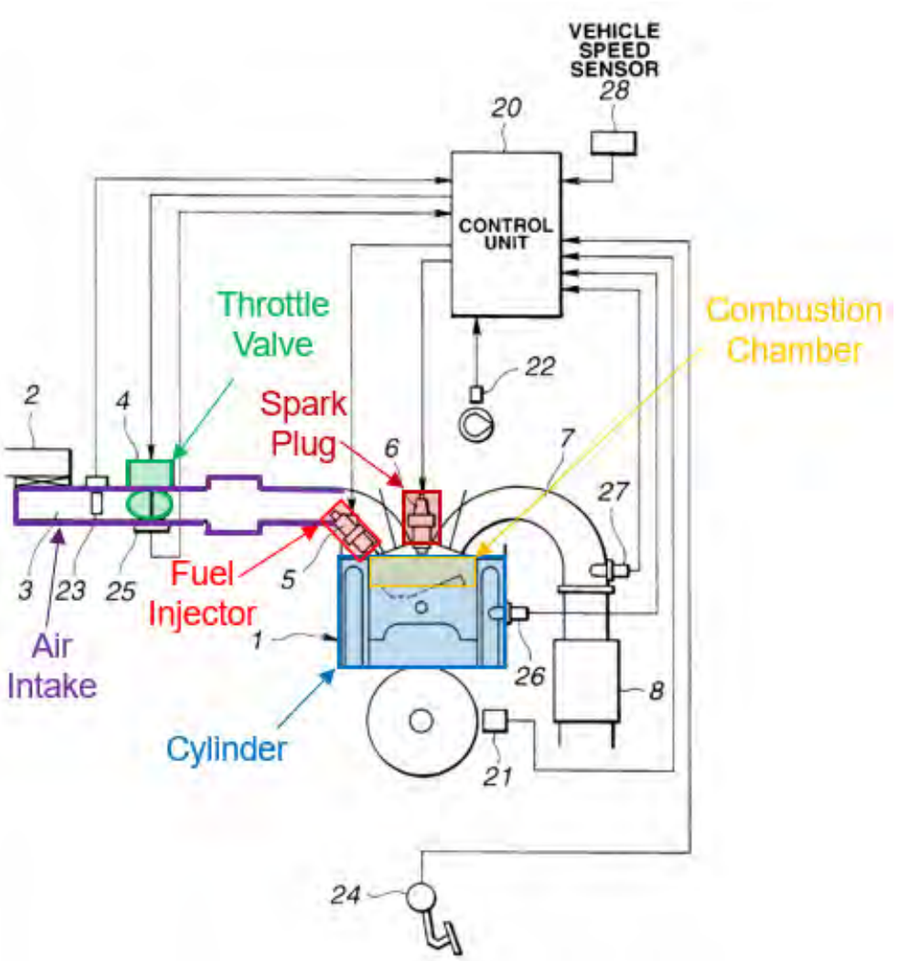
A. Technology Overview

1. Direct Injection Spark Ignition Engines Operating in Two Combustion Modes

Direct injection spark ignition (DISI) engines were well-known for decades before the '565 patent. EX1003, ¶42; EX1009, 19-21, 26, 30-32.

Suzuki discloses an example prior-art DISI engine, shown below in Figure 2. A DISI engine 1 typically includes an air intake 3 and an adjustable throttle valve 4 for controlling the volume of air drawn through the air intake 3. EX1003, ¶¶43-44; EX1005, 3:23-31. Each DISI engine cylinder includes a fuel injector 5

for injecting fuel directly into the combustion chamber and a spark plug 6 for igniting the cylinder's air/fuel mixture. EX1003, ¶44; EX1005, 3:23-51.



EX1005, FIG. 2 (annotated).

Operating DISI engines in either a stratified mode or a homogenous mode was well-known before the '565 patent. EX1003, ¶45; EX1005, 1:18-28; EX1012, 464, 509; EX1014, 37-38. In the homogenous mode, fuel is injected during the intake stroke to allow maximum time for air and fuel to combine evenly throughout the entire combustion chamber. EX1003, ¶45; EX1005, 1:18-28;

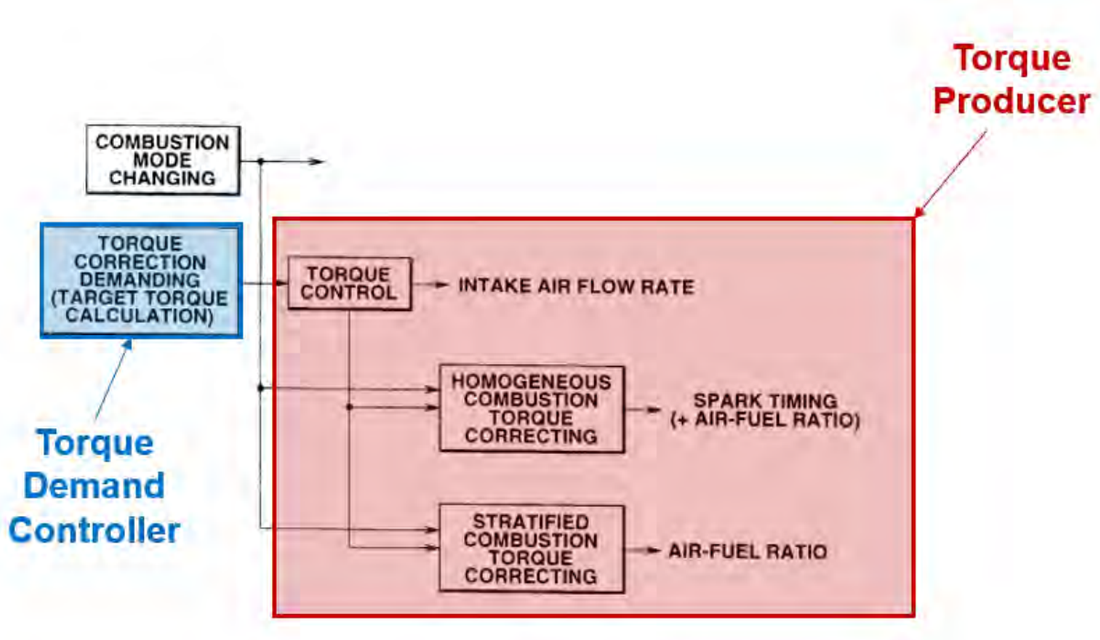
EX1012, 464. In the stratified mode, fuel is injected during the compression stroke to provide a stoichiometric mixture near the spark plug, while the overall mixture in the combustion chamber is lean. EX1003, ¶¶45-46; EX1005, 1:18-28; EX1012, 464; EX1014, 38.

2. Torque Feedback Control

Long before the ’565 patent, using torque feedback control via an engine controller was common practice. EX1003, ¶¶47-49; EX1012, 498; EX1011, 139; EX1019, 224.

As the ’565 patent recognizes, an engine controller typically includes a demand torque controller and a torque feedback controller (i.e., a torque producer). EX1001, 1:11-15; EX1005, 3:10-22; EX1012, 507. The demand torque controller generates a demand torque signal in accordance with a change in engine operation, such as a depressed accelerator pedal. EX1003, ¶50; EX1001, 1:11-15; EX1005, 4:48-58; EX1012, 507. The torque producer receives the torque demand signal, and in response adjusts the torque output of the engine by modifying the air supply, the fuel supply, or the spark timing so that the output torque meets the demanded torque. EX1003, ¶50; EX1001, 1:11-15; EX1005, 3:5-22; EX1012, 452, 498, 507.

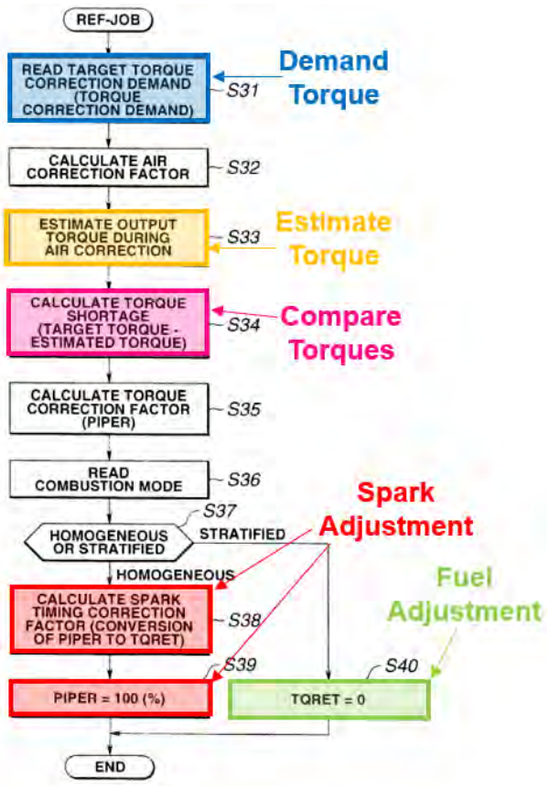
Suzuki discloses an example prior-art engine controller having a torque demand controller and a torque producer, shown below in Figure 1B. EX1003, ¶51; EX1005, 3:5-22.



EX1005, FIG. 1B (annotated).

Using feedback control to align the produced torque with the demanded torque was common before the '565 patent. EX1003, ¶52; EX1005, 1:7-17; EX1011, 1:25-31; EX1012, 498, 503, 507, 508. This alignment typically included estimating a current torque output and modifying engine parameters (e.g., spark timing and air/fuel ratio) to converge the estimated torque to the demand torque. EX1003, ¶52; EX1005, 1:7-17; EX1011, 3:49-61, 4:42-45; EX1012, 503, 504, 507, 508. As shown below in Figure 6, Suzuki discloses an example prior-art

feedback control routine that compensates for the difference between the demand torque and estimated torque. EX1005, 7:7-67, FIG. 6.



EX1005, FIG. 6 (annotated).

Compensating for the difference between the demand torque and estimated torque in dual-mode DISI engines was also well-known before the '565 patent to adjust fuel delivery during stratified mode and spark timing during homogeneous mode. EX1003, ¶53; EX1005, 3:10-22; EX1010, 6:5-9, 7:8-15, 8:34-37.

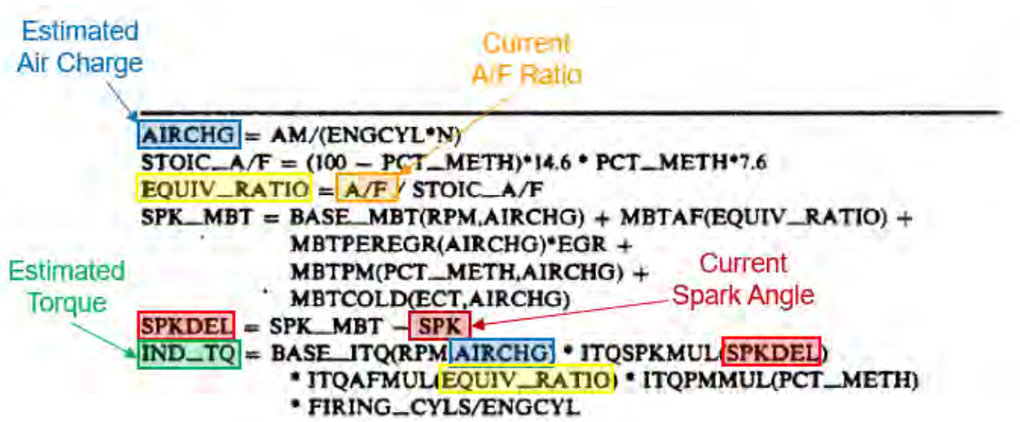
3. Engine Parameter Estimation Techniques

As explained above, using torque feedback control was well-known. And estimating various engine parameters, such as current output torque and cylinder

air charge, was also common for executing feedback torque control before the '565 patent. EX1003, ¶54.

Measuring engine torque directly in real time is challenging and expensive, so engine controllers commonly estimated the current output torque. EX1003, ¶55. The engine controller typically estimated torque based on numerous operational parameters, accounting for various factors that influence actual torque output. EX1005, 4:48-57; EX1006, 2:26-42; EX1011, 2:58-67.

Cullen discloses an example prior-art technique for calculating an estimated torque output. EX1003, ¶56; EX1006, 5:32-54. To estimate the current torque output more accurately, Cullen uses "a spark timing input 13, … an air/fuel ratio input 16, an engine rpm input 17, [and] an engine air charge input 18." EX1006, 1:13-15, 2:32-34, 5:32-53, 5:57-6:2.



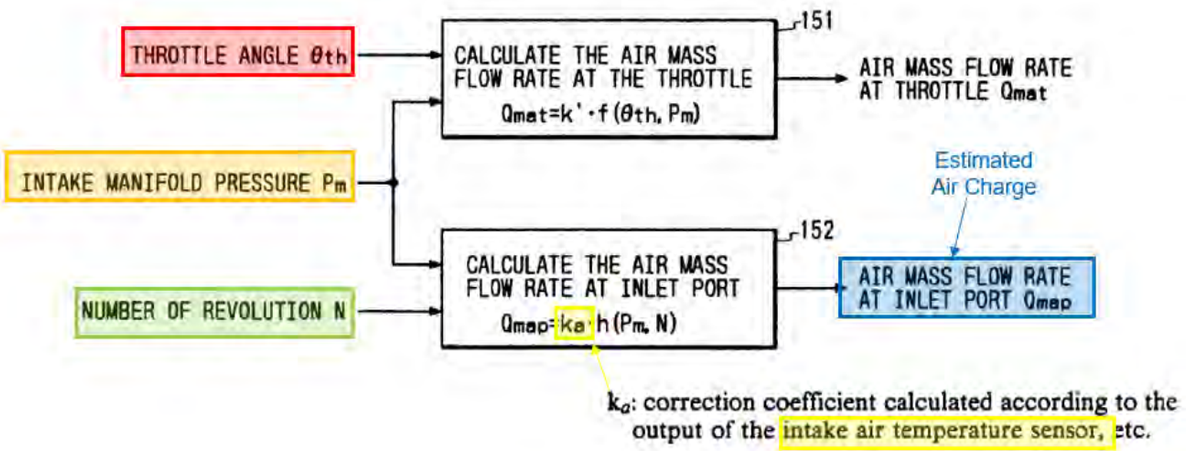
EX1006, 5:35-45 (annotated).

One common input for estimating torque is air charge—the air mass drawn into the engine cylinder. EX1003, ¶57; EX1006, 5:32-52; EX1008, 3:42-53; EX1012, 452, 501-02; EX1015, 12.6; EX1019, 176. Because there is no feasible way to measure the cylinder's air mass directly, engine controllers estimate the current air charge. EX1012, 503; EX1014, 294-96; EX1015, 12.6; EX1019, 176-77; EX1003, ¶57.

There are two primary techniques for estimating air charge: (1) speed-density model and (2) air-flow measurement model. EX1003, ¶58; EX1006, 4:5-9; EX1012, 501-502; EX1014, 294-97; EX1015, 12.6; EX1019, 177. With the speed-density model, the controller determines cylinder air charge based on intake manifold pressure, engine speed, and intake manifold temperature. EX1012, 501-02; EX1014, 296; EX1015, 12.6; EX1019, 177-179. With the air-flow measurement model, the engine controller calculates air charge as function of the measured mass flow rate in the intake and the measured engine speed. EX1006, 4:5-8; EX1014, 297; EX1015, 12.6; EX1019, 230.

Takahashi discloses an example prior-art air charge controller that calculates an estimated air charge according to the speed-density model. As shown below in Figure 15, Takashi discloses a throttle controller with a status-estimating block that calculates air charge based on intake pressure P_m, engine

speed N, and a correction coefficient k_a determined from current intake temperature. EX1008, 10:54-66; EX1003, ¶59.



EX1008, FIG. 15 (annotated).

4. Steady State and Transient Components of Demand Torque

Long before the '565 patent, it was known that the demand torque signal includes a steady state (low frequency) component and a transient (high frequency) component. EX1003, ¶60. The low frequency component represents torque demand changes during quasi-static conditions (e.g., idle condition), and the high frequency component represents abrupt torque demand changes resulting from transients (e.g., rapidly depressed accelerator pedal). EX1003, ¶60; EX1005, 4:48-55; EX1007, 1:25-29; EX1012, 478, 505.

It was also well-known that these transient torque components were not adequately corrected by an electronic (drive-by-wire) throttle actuator. EX1003,

¶¶61-62; EX1005, 1:13-17 ("In order to achieve the target torque, the torque control … requires a faster response than intake air flow rate control can provide."); EX1007, 1:21-25. Accordingly, control systems commonly addressed dynamic torque demands by isolating the transient component from the demand torque signal. EX1003, ¶61; EX1007, 2:38-3:10. For example, Scherer discloses an example prior-art controller with a high-pass filter outputting an isolated transient torque component to a torque controller to expedite the torque correction response time. EX1007, 4:20-53, 5:9-14.

Thus, the recited elements of the '565 patent's claims—generating torque demand, estimating torque output, comparing the estimated and demand torques, using a high-pass filter, and outputting fuel and spark adjustments based on the filtered signal—were well-known techniques executed by a generic electronic controller for a DISI engine at the time of the alleged invention. EX1003, ¶63.

B. Alleged Problem in the Prior Art

The '565 patent is directed to compensating for differences between the estimated torque and the demand torque, even during rapid transients in torque demand. EX1001, 1:57-59, 3:23-29. But as explained above, the purported problem of compensating for these differences, as well as solutions for this problem, were well-known long before the '565 patent. EX1003, ¶64. And as

discussed below, the ’565 patent adds nothing to the realm of previously known solutions.

C. Alleged Invention of the ’565 Patent

The ’565 patent admits that a DISI engine controller that modified torque output by fuel adjustment in stratified mode and spark timing in homogeneous mode was known. EX1001, 1:36-45; EX1003, ¶65. But according to the ’565 patent, these known DISI engine controllers allegedly could not provide adjustments that accounted for differences between the estimated output torque and the demand torque. EX1001, 1:46-58.

To allegedly solve this known problem, the ’565 patent provides “a torque controller and a method…in which torque is controlled in dependence upon a filtered difference signal…between a desired torque signal and a signal representing an estimate of the current torque.” EX1001, Abstract. The ’565 patent’s control system includes (1) a torque estimator 22 outputting an estimated torque signal; (2) a comparator 18 outputting a difference signal between estimated and desired torque; (3) a high-pass filter 20 outputting a filtered difference signal; and (4) a transient torque controller 21 for adjusting spark timing and fuel delivery. *Id.*, 3:29-50, FIG. 3; EX1003, ¶66.

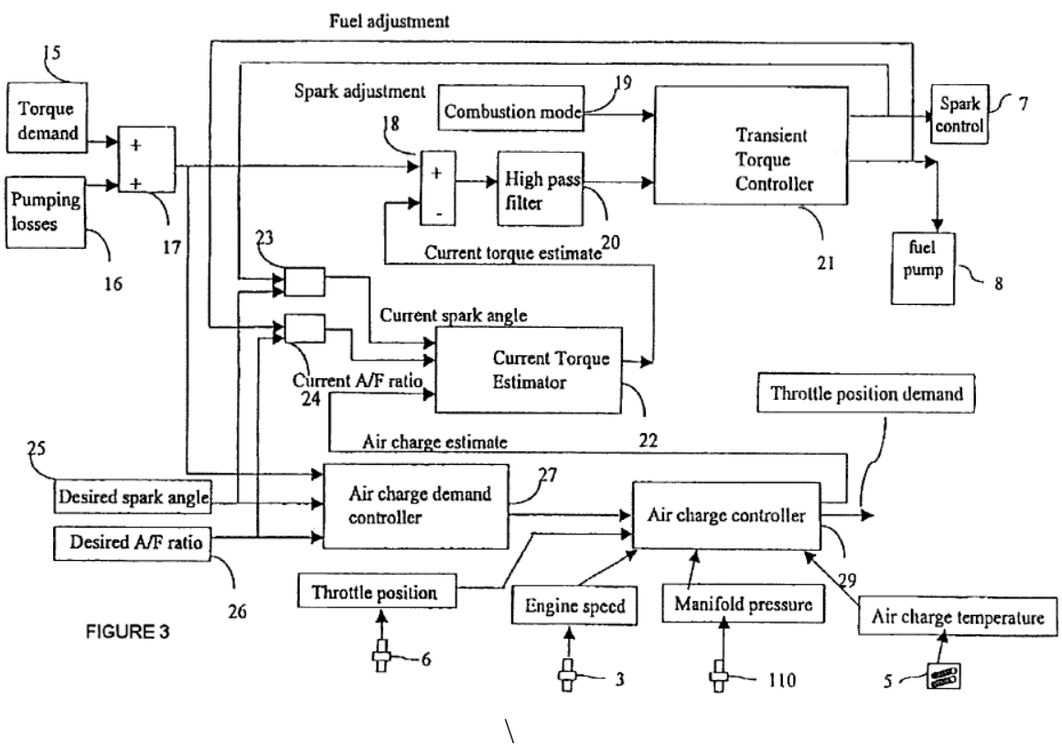


FIGURE 3

EX1001, FIG. 3.

But well before the '565 patent's earliest possible priority date, this problem had been solved in the same way. EX1003, ¶67. Again, Suzuki controls torque output through spark and fuel adjustments based on the difference between the estimated and demand torques. EX1005, 7:7-8:5. Cullen uses current spark angle, a current air/fuel ratio, and an estimated air charge to estimate a torque output. EX1006, 5:32-56. And Scherer uses a high-pass filter to isolate the torque signal's transient component to adjust torque output with a quicker response time. EX1007, 4:20-56.

Thus, the claim elements that purportedly capture the ’565 patent’s alleged inventive concept recite nothing more than what was already taught in the prior art and would have been well-known to a POSA. EX1003, ¶68.

D. Prosecution History Summary

The application that issued as the ’565 patent underwent very limited prosecution at the U.S. Patent and Trademark Office. The Examiner issued a Notice of Allowance without a single Office Action. *See generally* EX1002. The Examiner did not provide any reasons for allowing the claims in the Notice of Allowance. *See* EX1002, 0045-52.

Suzuki, Cullen, and Takahashi, references upon which this Petition rely, were not before the Examiner during prosecution. *Id*. And Scherer was never expressly considered or applied by the Examiner.

E. Level of Ordinary Skill in the Art

A POSA at the time of the alleged invention would have had a B.S. degree in Electrical Engineering or Mechanical Engineering (or equivalent), as well as at least 2–4 years of academic or industry experience in the relevant field of engine control systems. EX1003, ¶¶40-41.

F. Claim Construction

In an *inter partes* review, claims are “construed using the same claim construction standard that would be used to construe the claim in a civil action under 35 U.S.C. 282(b).” 37 C.F.R. § 42.100 (b). If trial is instituted, all claim

terms must be given their ordinary and customary meaning as understood by one of ordinary skill in the art at the time of the invention, in light of the specification and the prosecution history of the patent. *Id.*; *Phillips v. AWH Corp.*, 415 F.3d 1303, 1312-1313 (Fed. Cir. 2015) (en banc); *see also* 83 Fed. Reg. 51,340 (Oct. 11, 2018).

None of the claim terms require specific construction and should receive their plain and ordinary meaning, in the context of the ’565 patent specification, under the *Phillips* standard. EX1003, ¶71.

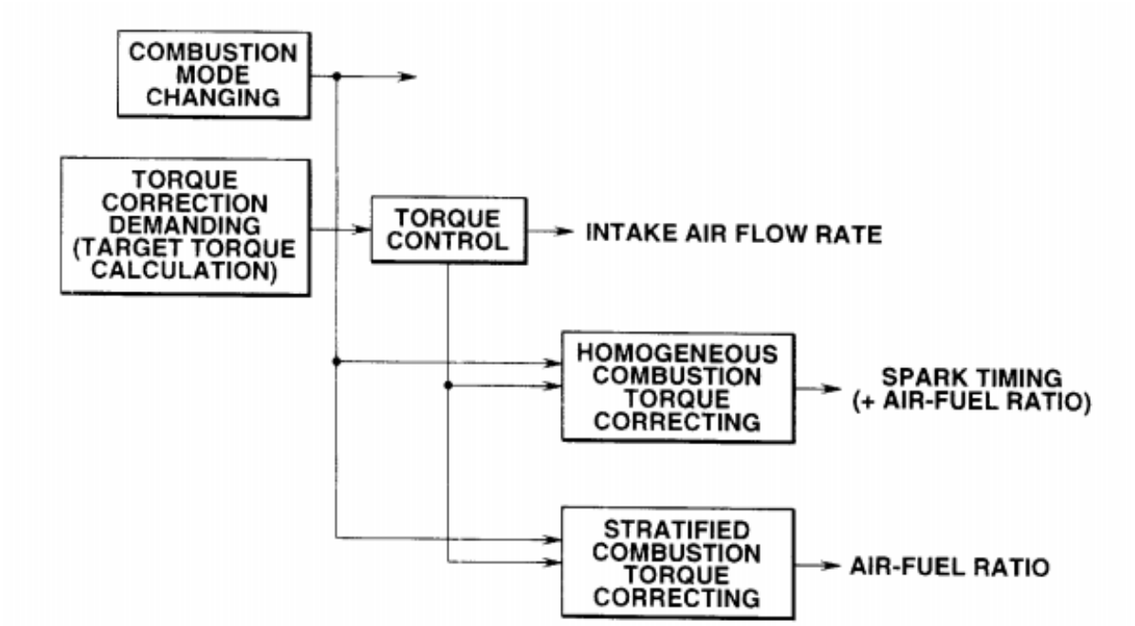
VI. Overview of the Applied References

Each applied reference discloses a control system for an engine and, thus, is from the same field of endeavor as the ’565 patent. EX1003, ¶72.

A. Suzuki

Suzuki, like the ’565 patent, discloses a DISI engine controller for correcting torque output by controlling fuel delivery and spark timing. EX1005, 1:39-43.

As shown below in Figure 1B, the controller includes a combustion mode changing section that switches engine operation between a homogenous mode and a stratified mode. *Id*., 3:5-10.



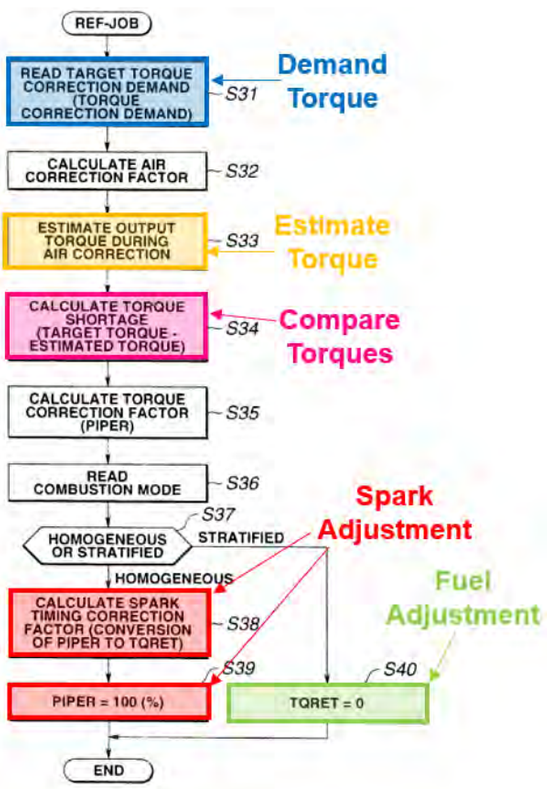
EX1005, FIG. 1B.

The controller includes a torque correction demanding section that generates a torque demand signal in response to detecting a load change. EX1005, 2:61-63. A torque control section controls the airflow rate in response to receiving the torque demand signal. *Id*., 3:12-15. The controller also includes a homogenous combustion torque correcting section and a stratified combustion torque correcting section that modify torque output in response to receiving the torque correction demand signal. *Id*., 2:64-3:22, 15:53-16:6; EX1003, ¶¶73-75.

Suzuki's engine controller addresses the same problem as the '565 patent—compensating for differences between a demand torque and an estimated current torque. EX1003, ¶76; EX1005, 7:35-67. And, importantly, Suzuki addresses this

problem the same way as the ’565 patent—through executing the torque correction routine, as shown in Figure 6 below. EX1005, 7:7-67.

The torque demand section initiates the routine by generating a demand torque signal in response to detecting a load change (e.g., air conditioner). *Id*., 7:14-19. Responding to the demand torque signal, the torque correction section estimates an output torque that compensates for the time required by the electronic throttle to change the volume of air drawn through the engine intake. *Id*., 7:33-34, 8:52-56, 15:53-56, 16:11-22; EX1003, ¶77.

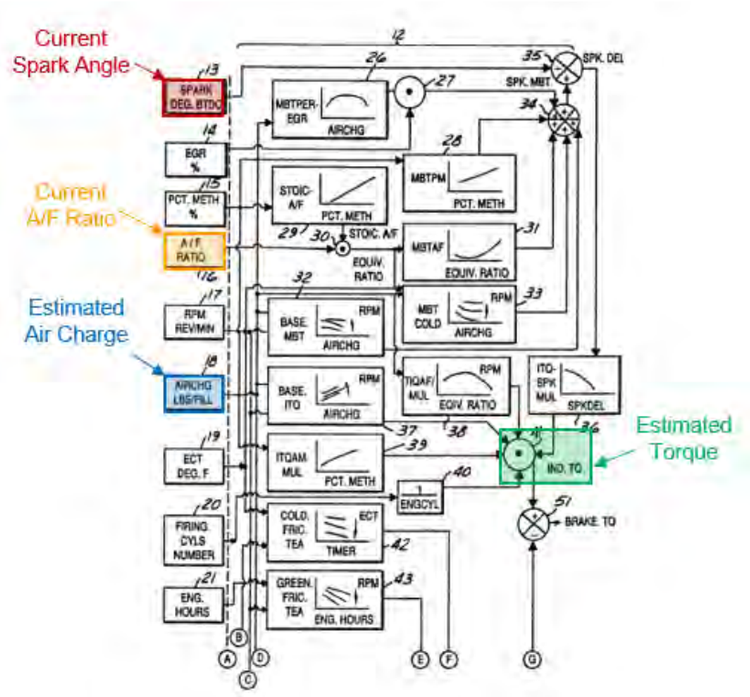


EX1005, FIG. 6 (annotated).

After estimating an output torque (S33), the torque correction section subtracts the estimated torque from the target torque to calculate a torque shortage (S34). EX1005, 7:33-39. If the engine is set in a homogenous combustion mode, the torque correction section adjusts the spark timing based on the calculated torque shortage (S38 and S39). *Id.*, 5:59-6:6, 7:51-54, 8:1-2, 15:56-58. If the engine is set in a stratified combustion mode, the torque correction section adjusts the fuel delivery to the engine based on the calculated torque shortage (S40, as well as S22-25 in Figure 5). *Id*., 6:20-57, 7:60-64, 8:3-4, 16:1-2; EX1003, ¶78.

B. Cullen

Cullen, like Suzuki and the ’565 patent, discloses an engine controller that uses a torque estimator for feedback torque control. EX1006, 1:7-11. Specifically, Cullen’s engine controller estimates the current torque based on a current spark timing angle 13, a current air/fuel ratio 16, and an estimated air charge 18, among other engine parameters. *Id*., 4:5-14, 5:35-50, 5:60-6:2; EX1003, ¶79.

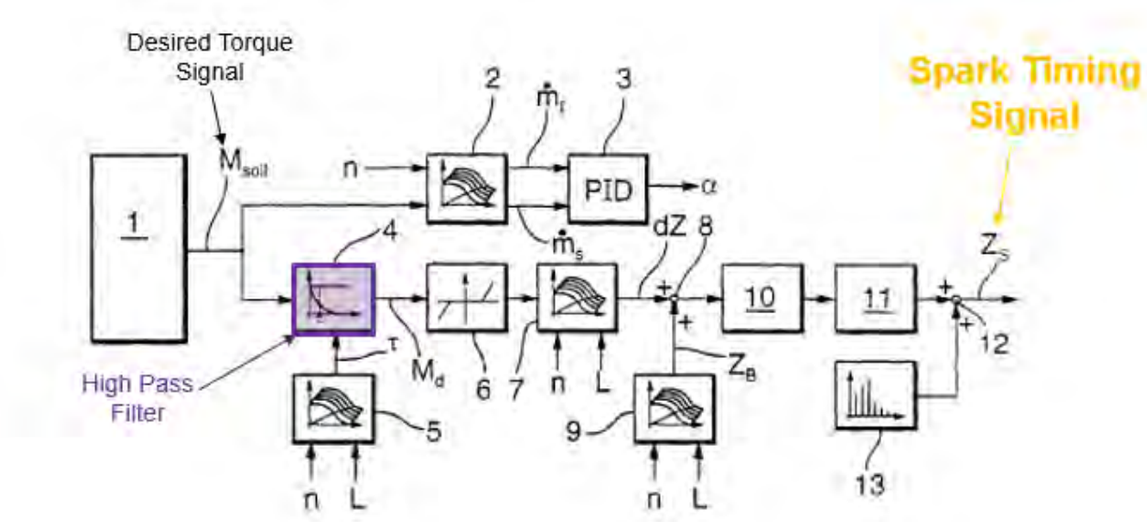


EX1006, FIG. 3 (annotated).

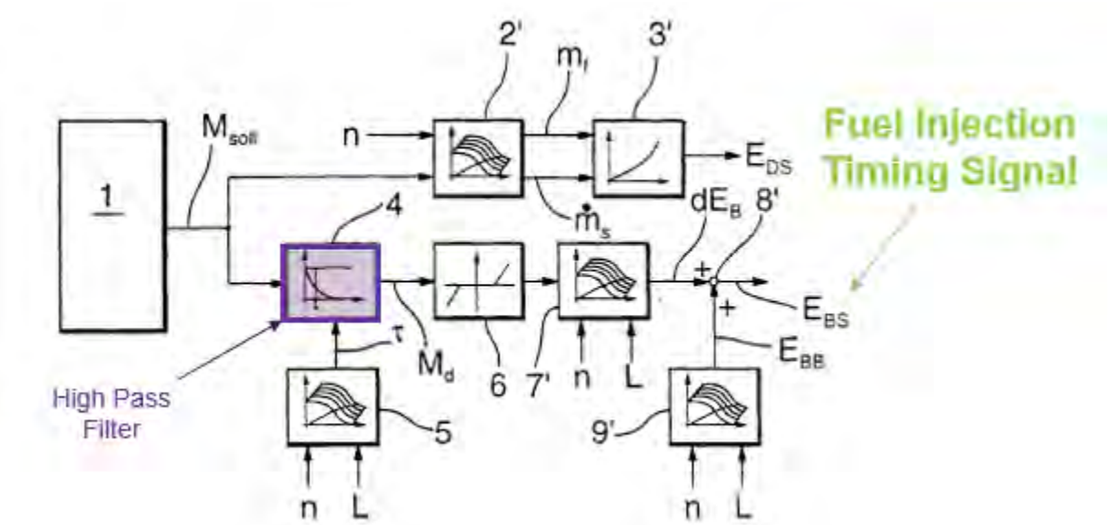
C. Scherer

Like Suzuki, Cullen, and the ’565 patent, Scherer is directed to an engine controller. EX1007, 1:7-11. Scherer’s controller adjusts torque output through airflow, spark timing, and fuel delivery adjustments. *Id*., 2:47-3:7. A signal-processing block (implementing a high-pass filter 4) receives a desired engine torque signal and outputs a dynamic torque component to a torque controller, which adjusts torque output through correcting spark timing for homogeneous fuel-charged engines or fuel delivery for heterogeneous fuel-charged engines. *Id*., 2:51-55, 4:20-45, 5:35-55, 8:26, FIGS. 1, 2. The high-pass filter allows the engine

controller to more quickly correct transient torque demand. *Id*., 2:38-42, 5:10-15; EX1003, ¶¶80-82.



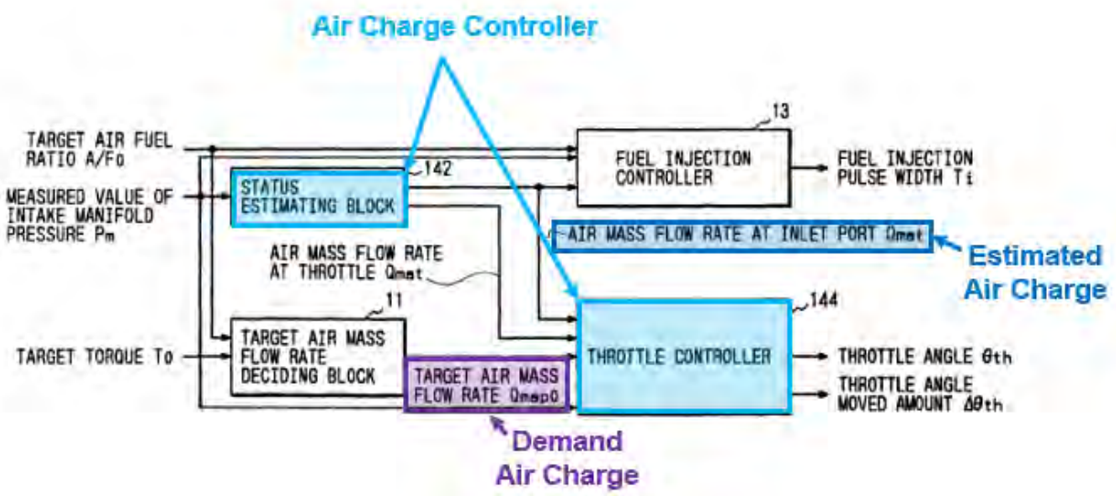
EX1007, FIG. 1 (annotated).



EX1007, FIG. 2 (annotated).

D. Takahashi

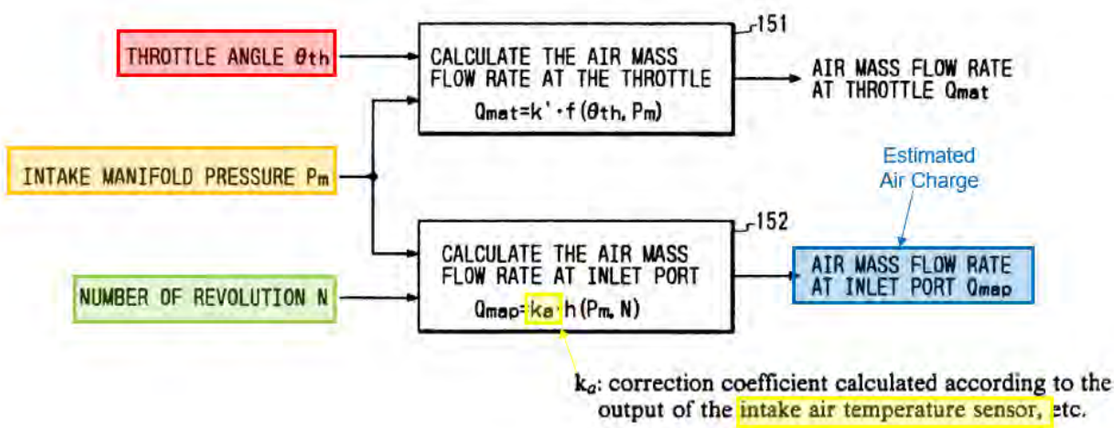
Like Suzuki, Cullen, Scherer, and the '565 patent, Takahashi is directed to an engine controller. Takahashi's controller adjusts torque output with fuel and throttle control adjustments. EX1008, 1:5-9, 3:4-16. Takahashi's controller includes a target air mass flow rate block 11, a status-estimating block 142, a fuel injection controller 13, and a throttle controller 144. *Id.*, 3:16-24, 10:32-50, FIG. 14. The throttle controller 144 calculates a desired throttle position for setting the cylinder air charge at a desired air charge value. *Id.*, 3:20-27, 6:10-12, 7:50-58.



EX1008, FIG. 14 (annotated).

The throttle controller 144 determines the desired throttle position based on a target air mass flow rate and an estimated air mass flow rate at the cylinder inlet port (i.e., target and estimated air charge). EX1008, 10:42-47, FIG. 14. The throttle controller 144 receives the target air mass flow rate from a target air-mass-flow-

rate deciding block 11 and estimates the current air mass flow rate using a status-estimating block 142. *Id.*, 10:43-60, FIG. 14. The status-estimating block 142 estimates the current air mass flow rate based on throttle position, engine speed, intake manifold pressure, and intake air temperature. *Id.*, 10:43-66, FIG. 15. The target air-mass-flow-rate block 11 receives a target air/fuel ratio signal, a target torque signal, an engine speed signal, and a spark advance signal and outputs a target air mass flow rate signal. *Id.*, 3:20-41; EX1003, ¶¶83-84.



EX1008, FIG. 15 (annotated).

VII. Ground 1: The combination of Suzuki, Cullen, and Scherer renders obvious claims 1, 4, and 7.

A. The Board should not deny institution under Section 325(d) because the Office did not consider the straightforward combination of references applied here.

The Board has discretion to deny institution when "the same or substantially the same prior art or arguments previously were presented to the Office." 35 U.S.C. § 325(d). In *Becton* decision's precedential portion, the Board articulated

six non-exclusive factors for considering whether to exercise its discretion to deny institution under § 325(d). *Becton, Dickinson & Co. v. B. Braun Melsungen AG,* IPR2017-01586, Paper 8 at 17-18 (P.T.A.B. Dec. 15, 2017) (informative; precedential as to § III.C.5, first para.). Here, even though Scherer was cited on the '565 patent's face, the *Becton* factors firmly establish that the Board **should not** exercise its discretion to deny institution. This Petition does not recycle prior art and arguments. Instead, it relies on a reference (namely, Scherer) that was cited in an Informational Disclosure Statement ("IDS"), accompanying the filed application. Scherer was never the basis for any prior-art rejection. Moreover, the Petition applies Scherer to modify, according to straightforward techniques, previously unconsidered prior art references for reasons known in the prior art.

Regarding *Becton* factors (a)-(b)—the similarities, material differences, and cumulative nature of the asserted prior art—although Scherer was cited in an IDS, the asserted prior art ***combination*** here is materially different because it is applied in a combination that was not considered by the Office. Particularly, Suzuki—the primary reference—and Cullen were not cited in the '565 patent, and thus, Scherer was never applied in combination with these two references. Moreover, the two references combined with Scherer are not cumulative of other prior art evaluated during examination, but rather disclose the precise claimed elements.

Regarding *Becton* factor (c), Scherer did **not** serve as the basis for rejection. *See Intel Corp. v. Qualcomm Inc.*, IPR2019-00128, Paper 9 at 16 (P.T.A.B. May 29, 2019) ("The fact that [a reference] was not the basis of rejection weighs strongly against exercising our discretion to deny institution under 35 U.S.C. § 325(d)."). In fact, no reference served as the basis of a rejection during prosecution. The claims were allowed without any substantive rejection. Thus, the applicant did not "overcome" Scherer, or any other reference (including Suzuki and Cullen) for that matter, as prior art. This directly relates to *Becton* factor (d)—the applicant made no arguments whatsoever during examination against the prior art applied here, or any other prior art. Thus, there is no overlap between arguments made during examination and the manner in which this Petition uses Scherer. Accordingly, regarding *Becton* factor (e), the Examiner erred in evaluating the cited prior art through his broad, unsupported statement in the reasons for allowance, which failed to identify any feature that would have allegedly patentably distinguished the alleged invention over the prior art. EX1002, 45-52.

Furthermore, under *Becton* factor (f), additional facts and evidence here—including Dr. MacCarley's declaration—warrant institution and ultimately a finding of unpatentability based on the combination of Suzuki in view of Cullen and Scherer or additionally in view of Takahashi.

The Board has instituted review in myriad cases with facts similar to this one. *See e.g.*, *Pure Storage, Inc. v. Realtime Data LLC*, Case No. IPR2018-00549, Paper 7 at 11 (P.T.A.B. July 23, 2018) (noting "there is no evidence of record that [the prior art references] were substantively considered by the Examiner."); *Synaptic Medical Inc. v. Karl Storz Endoscopy-America, Inc*., Case No. IPR2018-00462, Paper 6 at 10 (P.T.A.B. July 16, 2018) (stating "the references here were not applied to reject the claims of the '360 Patent and there is no evidence that the Examiner considered the particular disclosures cited in the Petition or addressed arguments similar to those Petitioner now presents"); *Unified Patents Inc. v. John L. Berman*, IPR2016-01571, Paper 10 at 12-13 (P.T.A.B. Dec. 14, 2016) (declining to deny institution under § 325(d) where previously applied reference was combined with reference not previously considered). Indeed, the facts here demonstrate that the *Becton* factors weigh heavily in favor of the Board granting institution to consider this Petition's merits.

Thus, the Board should not deny institution merely because Scherer was cited in an applicant-filed IDS. Scherer is presented *in combination* with Suzuki and Cullen, which were *not* considered by the Office. As the Petition demonstrates, Suzuki's torque controller generates a demand torque, estimates a torque output, compares the demand torque to the estimated torque to determine the difference, and controls torque output through fuel quantity and spark timing adjustments

based on the calculated difference. *See infra* Sections VII.C.1-7. Cullen's engine controller estimates torque output based on current spark angle, current air/fuel ratio, and estimated air charge. *See infra* Section VII.C.4. Scherer's transient torque control system uses a high-pass filter for its typical purpose, here, to remove the low frequency component of a torque signal and output the filtered signal to a torque controller. *See infra* Section VII.C.6. And as discussed below, a POSA would have been motivated to combine Cullen's and Scherer's teachings with Suzuki's torque controller, providing the predictable result of precisely controlling engine torque output. *See infra* Section VII.B. Accordingly, combining Suzuki, Cullen, and Scherer does not present the same or substantially similar prior art or arguments before the Office, so the Board should **not** deny institution under § 325(d).

B. Rationale for Combining Suzuki with Cullen and Scherer

Suzuki, Cullen, and Scherer are from the same field of endeavor—control systems for an internal combustion engine. EX1003, ¶86. Particularly, Suzuki, Cullen, and Scherer are directed to engine controllers that adjust operational parameters, such as fuel quantity, spark timing, and air intake based on torque feedback control. *Id.* Indeed, Suzuki's "invention is directed to a direct-injection spark-ignition type engine control apparatus for correcting engine torque based on engine operating conditions." EX1005, 1:4-6. Likewise, Cullen's "invention relates

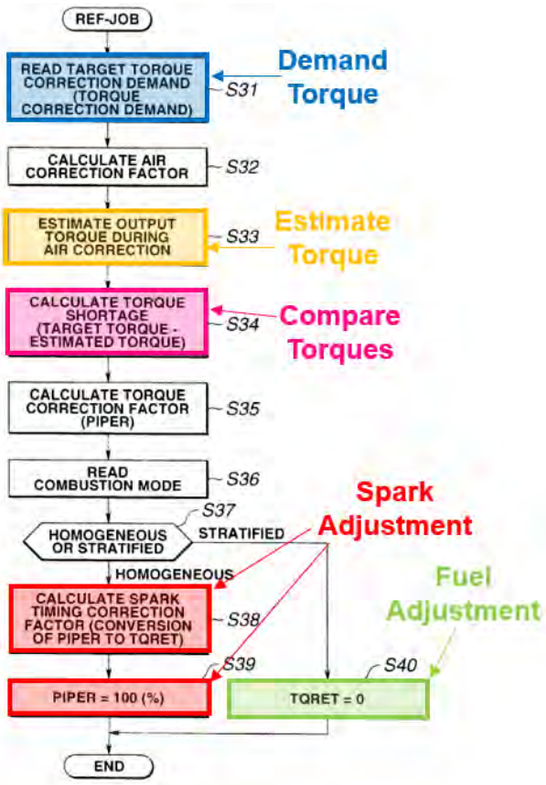
to … inferring the torque produced by an engine," whereby "such an inferred engine torque is … an input parameter for a control system." EX1006, 1:7-11. Similarly, Scherer's "invention relates to a process and apparatus for adjusting the torque of an internal-combustion engine by regulating the ignition point and the airflow rate in an Otto engine." EX1007, 1:7-11. A POSA would have been motivated to combine the teachings of Suzuki, Cullen, and Scherer for at least the reasons discussed below and would have had a reasonable expectation of success in doing so. EX1003, ¶¶85-86.

Suzuki, Cullen, and Scherer each disclose controllers receiving similar measured engine parameters (e.g., engine speed, airflow rate, and air/fuel ratio) as inputs and using these inputs to control ignition timing and air/fuel ratio to achieve a target torque. EX1003, ¶87; EX1005, 4:17-31; EX1006, 5:57-6:2; EX1007, 4:60-67. Accordingly, combining their teachings would have simply involved modifying the engine controller (e.g., programming stored instructions in the microcomputer of Suzuki's control unit 20) to perform the steps taught in the references—a basic task for a POSA. EX1003, ¶87; EX1019, 102, 223.

1. Combining Suzuki and Cullen

Suzuki discloses a DISI engine controller for adjusting torque by controlling fuel delivery and spark timing. EX1001, 1:62-2:4; EX1003, ¶88; EX1005, 1:39-63. Suzuki's control unit 20 generates a demand torque signal, estimates an engine

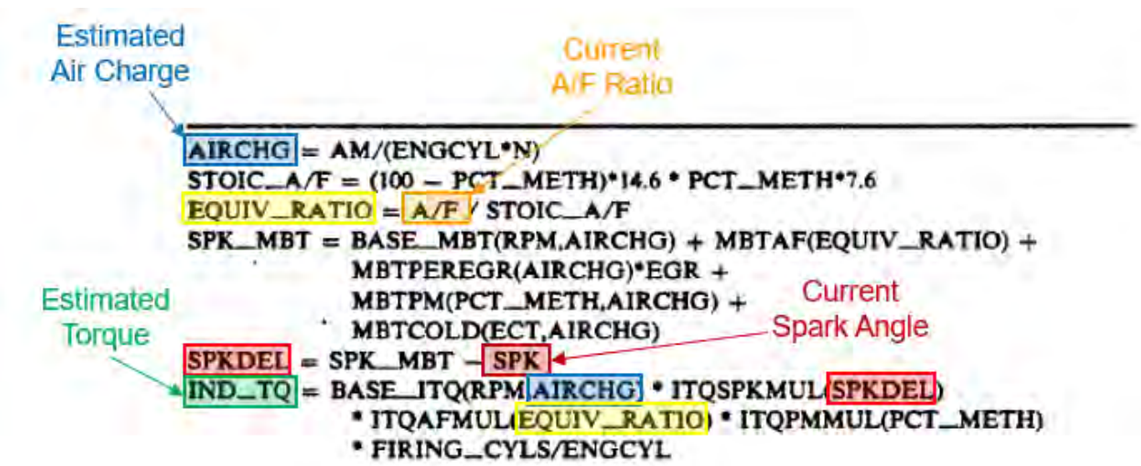
torque output, compares the demand and estimated torques to determine a torque differential, and determines fuel quantity and spark timing adjustments based on the calculated torque differential, as shown below in Figure 6. EX1001, 4:2-22; EX1005, 7:7-67, FIGS. 4-6; EX1003, ¶88.



EX1005, FIG. 6 (annotated).

While Suzuki discloses an estimator outputting an estimated torque signal, Suzuki does not expressly disclose an estimator receiving a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal. EX1003, ¶89.

However, Cullen discloses specific implementation details for estimating torque that would have been readily applicable to Suzuki's control unit 20. EX1003, ¶90. Specifically, Cullen discloses a controller that calculates a predicted torque by processing "**a spark timing input 13**," "**an air/fuel ratio input 16**," "**an engine air charge input 18**," and "a flag input 25." EX1006, 5:59-6:2.[1] Furthermore, as shown below, Cullen discloses estimating the torque (i.e., "IND_TQ") as a function of the current spark angle ("SPK"), a current air/fuel ratio ("A/F"), and an estimated air charge ("AIRCHG"), among other inputs. EX1006, 5:32-52; EX1003, ¶90.



EX1006, 5:34-45 (annotated).

Because Suzuki is silent on the torque estimation details, a POSA would have sought out these details provided by Cullen's analogous control module. EX1003, ¶91. Combining Suzuki's and Cullen's teachings would have yielded

[1] Emphasis added throughout unless indicated.

predictable benefits and results—for example, making a more accurate output torque estimation. EX1003, ¶91; EX1006, 2:32-42 ("This invention recognizes that a predicted torque calculation can be made **more accurate** by predicting the air conditioning torque requirement versus head pressure, power steering torque requirements versus power steering pressure switch, cold engine friction versus time since start and engine coolant temperature…."). A POSA would have understood that combining Cullen's torque estimating routine with Suzuki's control unit 20 would have more accurately estimated the engine torque, thereby allowing Suzuki's control unit 20 to converge current torque output to the desired torque output more precisely. EX1003, ¶91; EX1006, 2:21-42. Thus, combining Cullen's torque estimating routine with Suzuki's control unit 20 would have been applying a known technique with a known device in the same way. EX1003, ¶91*; KSR Int'l Co. v. Teleflex Inc.*, 550 U.S. 398, 416 (2007) ("[I]f a technique has been used to improve one device, and a person of ordinary skill in the art would recognize that it would improve similar devices in the same way, using the technique is obvious."); EX1003, ¶91.

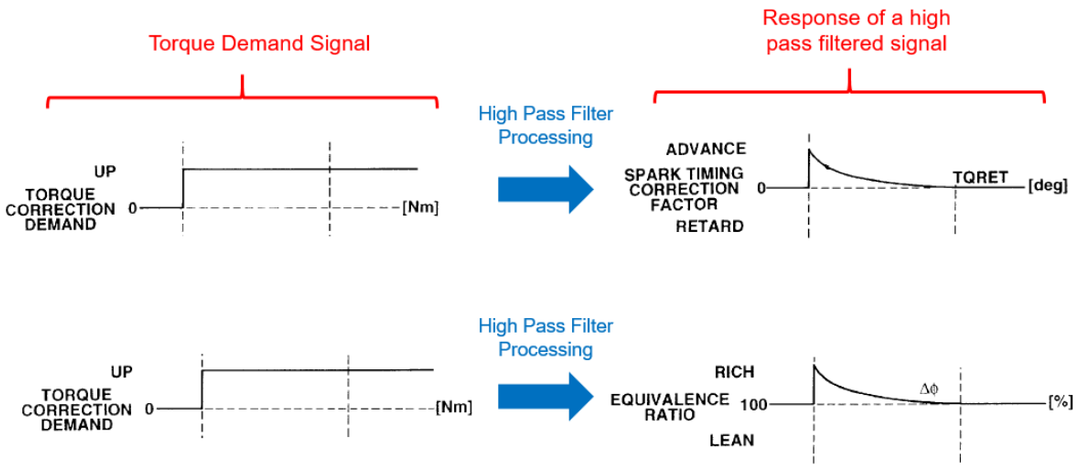
Moreover, a POSA would have had a reasonable expectation of success in combining Suzuki and Cullen. *Id.*, ¶92. Indeed, a POSA would have recognized that Cullen's torque estimation technique would have been easily implemented with Suzuki's control unit 20 by modifying the software instructions stored in

Suzuki's control unit 20 such that the estimator section receives a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal as inputs. *Id.* Considering the similarities in Suzuki's and Cullen's control systems, any modification to implement Cullen's teachings into Suzuki's system would have been trivial and well within the skill of a POSA. *Id.*

Accordingly, it would have been obvious to combine the teachings of Suzuki and Cullen. *Id.*, ¶93.

2. Combining Scherer with Suzuki and Cullen

Suzuki does not expressly disclose using a high-pass filter to receive the torque difference signal as an input and to output a filtered difference signal in which low frequency components are removed. EX1003, ¶94. But Suzuki's spark and fuel correction factor curves in Figures 12-15 suggest that a high-pass filter is, in fact, being used. *Id.* To a POSA, the shape of these curves suggests that the torque correction demand signal is filtered with a high-pass filter. *Id.*



EX1005, FIG. 13 (annotated).

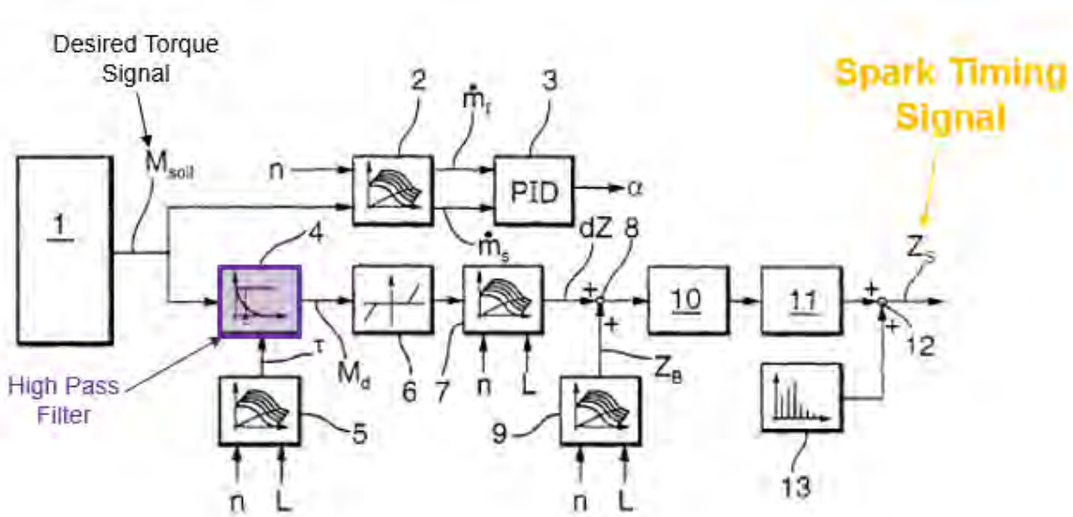
Scherer expressly discloses using a high-pass filter to remove a low frequency component from a torque signal, thereby isolating the torque signal's high frequency, dynamic component. EX1007, 4:40-45; EX1003, ¶95. And Scherer's high-pass filter would have been readily applicable to Suzuki's control unit 20. EX1003, ¶95.

Specifically, Scherer discloses that a high-pass filter isolates the dynamic desired engine torque component from the entire desired engine torque signal: "the high-pass filter 4 filters the dynamic desired engine torque part (M_d), as a function of the engine operating point, from the desired engine torque (M_{des}) supplied to it, and in turn provides the dynamic desired engine torque (M_d)."[2] EX1007, 4:40-45;

[2] In Scherer, there is a discrepancy between the reference symbols in the specification and the reference symbols shown in the figures regarding the element

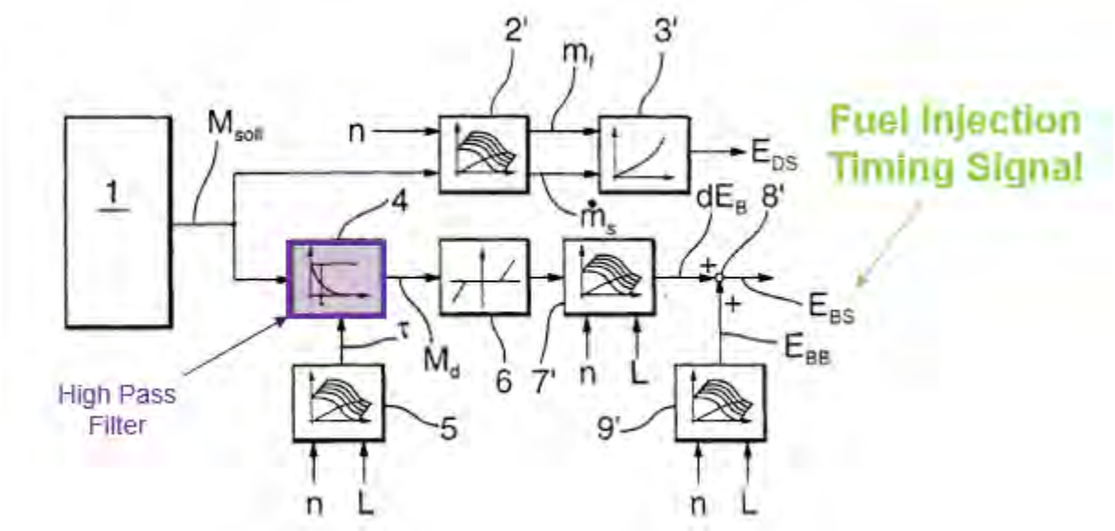
EX1003, ¶96. Removing the desired torque signal's low frequency component allows Scherer's controller to "react very rapidly to sudden changes of the engine torque," arising during transient engine operations. EX1003, ¶96; EX1007, 4:20-25, 4:40-45, 5:10-15.

Scherer also discloses that the desired torque signal's filtered dynamic component is used for both spark ignition timing adjustments (Figure 1) and for fuel injection adjustment (Figure 2). EX1003, ¶97; EX1007, 2:51-54; 4:20-52, 5:16-55, FIGS. 1, 2.



"desired engine torque signal." The specification refers to the "desired engine torque signal" using the reference symbol M_{des}. EX1007, 3:62, 3:64, 4:5, 5:30, 6:58. However, in Figures 1-4, the "desired engine torque signal" is represented by the reference symbol M_{soil}. EX1003, ¶128.

EX1007, FIG. 1 (annotated).



EX1007, FIG. 2 (annotated).

To improve the response of Suzuki's controller to dynamic changes in demand torque, a POSA would have sought to use a high-pass filter to remove the low frequency component from the torque difference signal, as provided by Scherer's analogous controller. EX1003, ¶98. Specifically, a POSA would have understood that Scherer's technique for adjusting ignition timing and fuel injection based on the demanded torque signal filtered with a high-pass signal corresponds to Suzuki's homogeneous and stratified torque correction sections, which output an ignition timing adjustment signal and fuel injection adjustment signal like Scherer. EX1003, ¶98; EX1007, 4:20-5:9; EX1012, 372-73, 376. Moreover, combining Suzuki's and Scherer's teachings would have yielded predictable benefits and results—for example, adjusting the torque output with a quicker response time

during transient engine operations. EX1008, 4:41-45, 5:6-10; EX1003, ¶98. Thus, combining Scherer's high-pass filter 4 with Suzuki's control unit 20 would have merely been applying a known technique in a similar, known device in the same way. *KSR*, 550 U.S. at 416; EX1003, ¶98.

Furthermore, a POSA would have had a reasonable expectation of success in combining Suzuki and Scherer. EX1003, ¶99. Suzuki suggests the use of a high-pass filter. *Id*. And a POSA would have recognized that Scherer's high-pass filter 4 would have been easily implemented in Suzuki's control unit 20 by modifying the software instructions stored in the microcomputer of Suzuki's control unit 20 so that the torque difference signal is inputted into a high-pass filter. EX1003, ¶99; EX1019, 138. In view of Scherer, a POSA would have understood that the high-pass filter may be represented in the software instructions as a transfer function having a variable time constant adjusted according to detected engine speed. EX1003, ¶99; EX1007, 4:31-38. Moreover, a POSA would have understood that Scherer teaches that the high-pass filter should output the filtered signal to the transient torque controller (i.e., the ignition point adjustment branch or injection start adjusting branch). EX1003, ¶99; EX1007, 4:53-56 ("The device for the ignition point adjustment receives the dynamic desired torque component (M_d) from the high-pass filter 4."); *see also* EX1007, 5:58-64 ("The comparatively rapidly reacting injection start adjusting branch regulates precisely that dynamic

desired engine torque part (M_d) …for adjusting the injection duration in the case of sudden changes of the desired engine torque."). Accordingly, a POSA would have recognized that in combining Scherer's and Suzuki's teachings, the high-pass filter would output the filtered signal to Suzuki's transient torque control sections (i.e., the homogeneous and stratified torque correction sections). EX1003, ¶99.

A POSA would have further understood that combining Scherer's high-pass filter 4 with Suzuki's control unit 20 would have expedited the response time for correcting the transient component of the demand torque. EX1003, ¶100; EX1007, 4:40-45, 5:10-15 ("The embodiment of FIG. 1 therefore permits a comparatively rapid engine torque adjustment which can follow very fast desired engine torque changes."). Given that the homogeneous and stratified torque correction sections in Suzuki's control unit 20 are intended to respond to dynamic changes in torque demand, a POSA would have been motivated to use Scherer's high-pass filter 4 to receive Suzuki's torque difference signal and output the dynamic component of the torque difference signal to Suzuki's homogeneous and stratified torque correction sections. EX1005, 1:44-63, 3:10-22; EX1003, ¶100.

Considering the similarities in Suzuki's and Scherer's control systems, any modification to implement Scherer's teachings into Suzuki's system would have been trivial and well within the skill of a POSA. EX1003, ¶101.

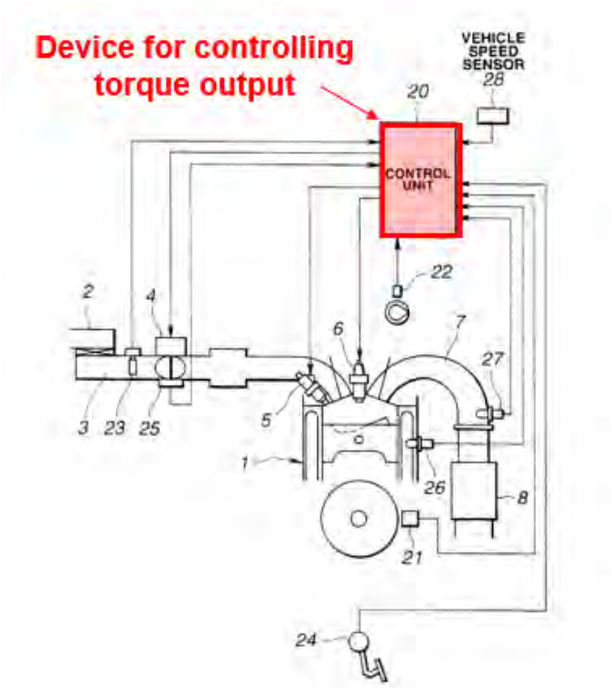
Suzuki's control unit 20 for controlling torque output with fuel and spark adjustments, Cullen's control module for estimating engine output torque, and Scherer's high-pass filter for removing the low frequency component of a desired torque signal were known elements that a POSA would have been motivated to and known how to combine in known ways to provide the predictable benefits disclosed in the references for providing precise control of engine torque output. *KSR*, 550 U.S. at 419-421 (2007); EX1003, ¶102.

Accordingly, it would have been obvious to a POSA to combine the teachings of Suzuki, Cullen, and Scherer. EX1003, ¶103.

C. Suzuki, Cullen, and Scherer render obvious claim 1.

1. [1.P] "A device for controlling a torque output of an engine, the device"

Suzuki discloses a device for controlling an engine's torque output as claimed. EX1003, ¶104. As shown below in Figure 2, Suzuki discloses a DISI engine 1 with a control unit 20 that receives input signals from various sensors, including a crank angle sensor 21, an airflow meter 23, an accelerator sensor 24, a throttle valve sensor 25, and an O_2 sensor 27. Suzuki's control unit 20 includes a microcomputer that makes calculations based on the sensor input "to control the degree of opening of the electronic controlled throttle valve 4, the amount of fuel injected to the engine by the fuel injector 5, and the spark timing of the spark plug 6." EX1005, 4:33-38.



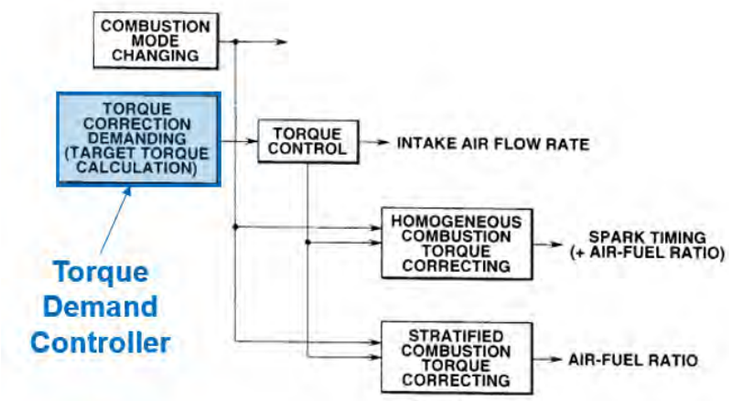
EX1005, FIG. 1 (annotated).

Suzuki's control unit 20 further includes a torque correction demanding section that produces a torque correction demand and a torque correction section that responds to the torque correction demand by modifying the engine torque output through spark timing and air/fuel ratio adjustment. EX1003, ¶105; EX1005, 3:5-22, 15:53-56; *see also id*. 4:3-5 ("The sections described herein are implemented in hardware, software, or a combination of both, in the control unit 20.").

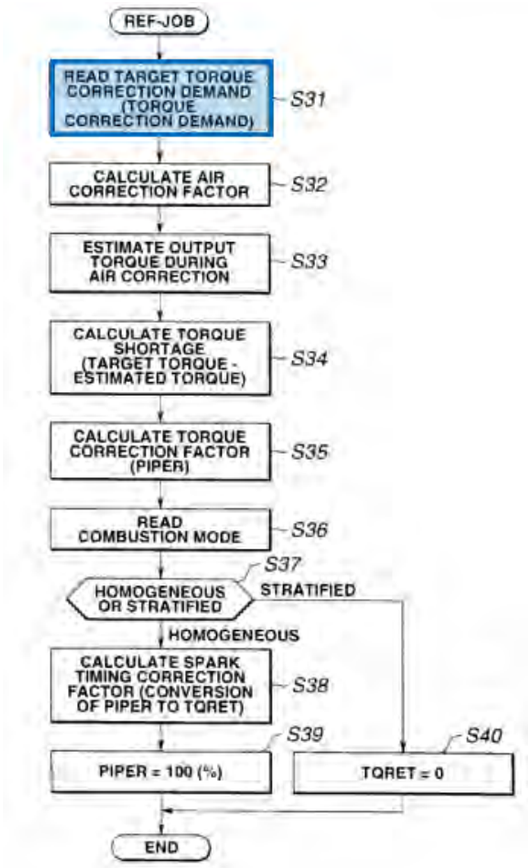
Thus, Suzuki discloses [1.P]. EX1003, ¶106.

2. [1.A] "a torque demand controller for generating a torque demand signal"

Suzuki discloses a torque demand controller as claimed. EX1003, ¶107. As shown below in FIG. 1B, Suzuki's control unit 20 includes a "torque correction demanding section [that] produces a torque correction demand based on engine operating conditions." EX1005, 3:10-12; EX1003, ¶107. The torque correction demanding section calculates a target torque representing an increase or decrease in torque output to account for a change in engine operation, such as shifting a transmission gear, cranking the air conditioner, or recovering from a fuel cut. *Id.*, 7:14-19.



EX1005, FIG. 1B (annotated).



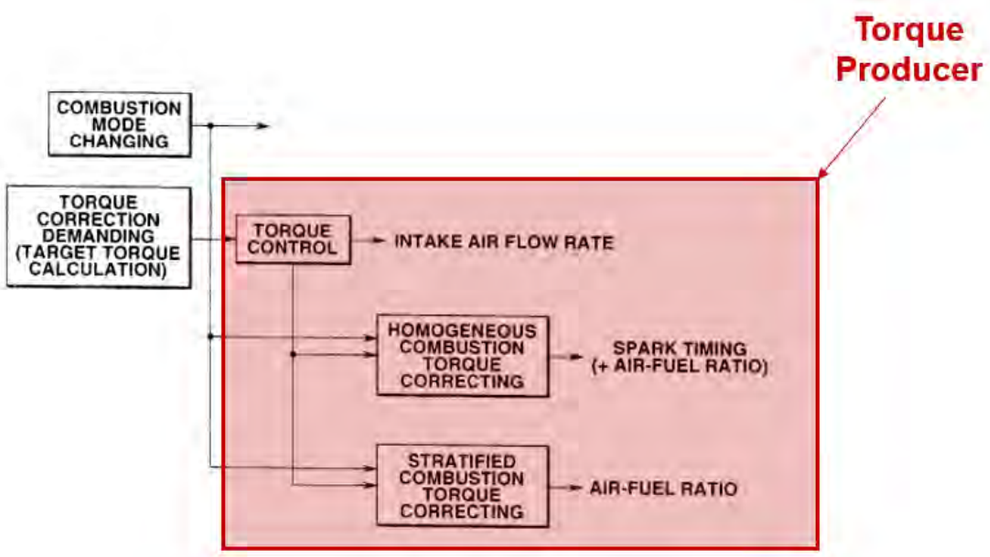
EX1005, FIG. 6 (annotated).

A POSA would have understood that Suzuki's torque correction demanding section is a "torque demand controller," as recited in claim 1, because the torque correction demanding section generates a torque demand signal indicating a desired torque output, which is used to control torque output. EX1003, ¶108. Indeed, Suzuki's torque correction demanding section operates in the same manner as the torque demand controller 11 disclosed by the '565 patent, which calculates a required output torque signal based on a changing engine operation for controlling torque output. EX1001, 2:57-67; EX1003, ¶108.

Thus, Suzuki discloses [1.A]. EX1003, ¶109.

3. [1.B] "a torque producer which receives the torque demand signal"

Suzuki discloses a torque producer as claimed. EX1003, ¶110. Specifically, Suzuki discloses that the control unit 20 includes "a torque correction section…which receives a torque correction demand and produces a torque correction output in response to the torque correction demand." EX1005, 15:53-56. As shown below in Figure 1B, Suzuki's torque correction section includes a torque control section for adjusting intake airflow, a homogeneous combustion torque correction section for adjusting spark timing (and fuel quantity), and a stratified combustion torque correction section for adjusting fuel quantity in response to receiving the torque correction demand signal. *Id.*, 3:12-22; EX1003, ¶110.



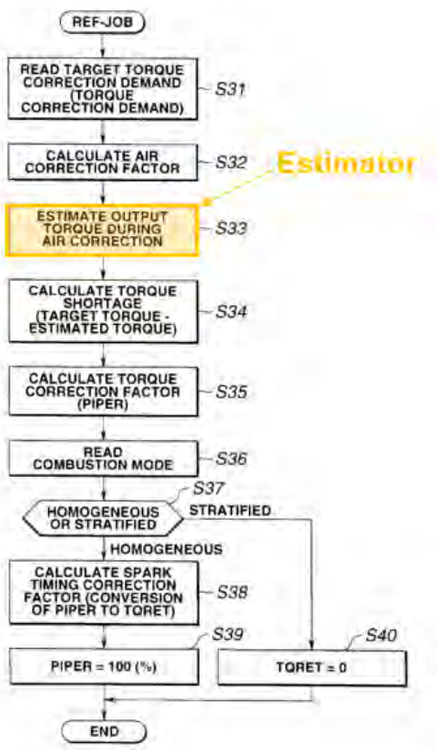
EX1005, FIG. 1B (annotated).

A POSA would have understood that Suzuki's torque correction section, homogeneous combustion torque correction section, and stratified combustion torque correction section collectively form a torque producer, as recited in claim 1. EX1003, ¶111. Each of these sections adjusts a parameter (e.g., airflow rate, spark timing, and air-fuel ratio (i.e., fuel delivery)) for producing torque. Accordingly, these sections compose, at least in part, Suzuki's torque producer. EX1003, ¶111.

Thus, Suzuki discloses [1.B]. EX1003, ¶112.

4. [1.C] "the torque producer includes: an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal"

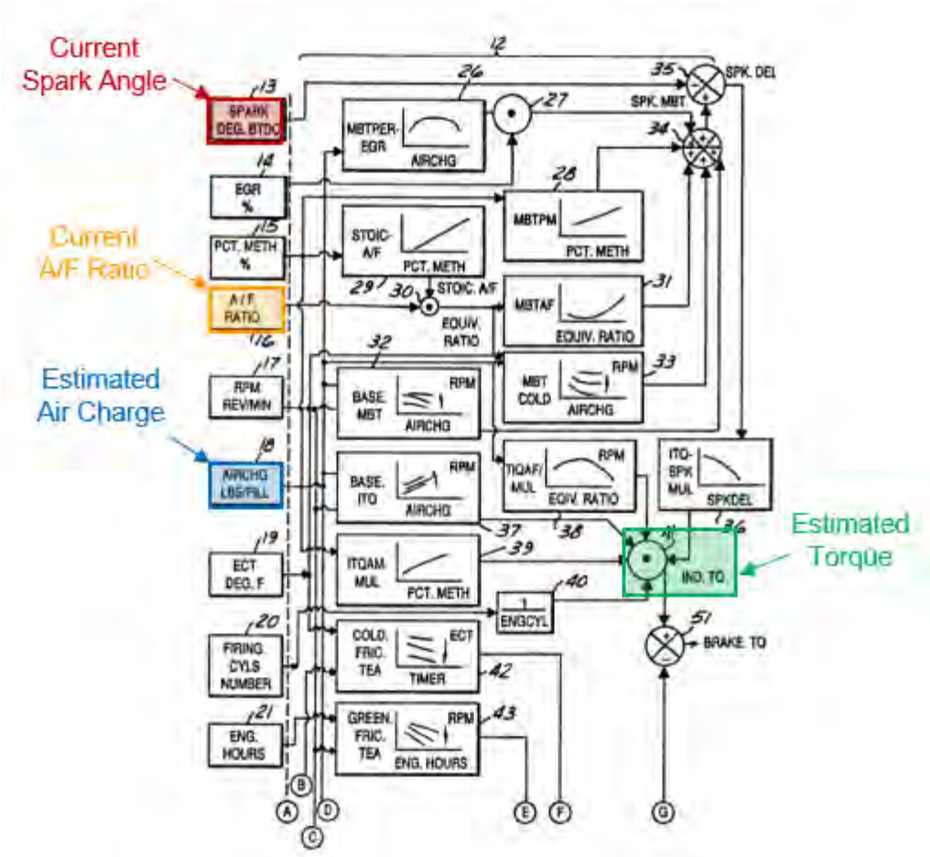
Suzuki and Cullen render obvious the torque estimator as claimed. EX1003, ¶113. As shown below in FIG. 6, Suzuki discloses that the torque correction section, which is part of Suzuki's torque producer, receives a torque demand (S31) and, in response, estimates an output torque that accounts for an intake air correction factor (S33). EX1005, 7:33-34 ("In step S33, the output torque during intake air correction is estimated.").



EX1005, FIG. 6 (annotated).

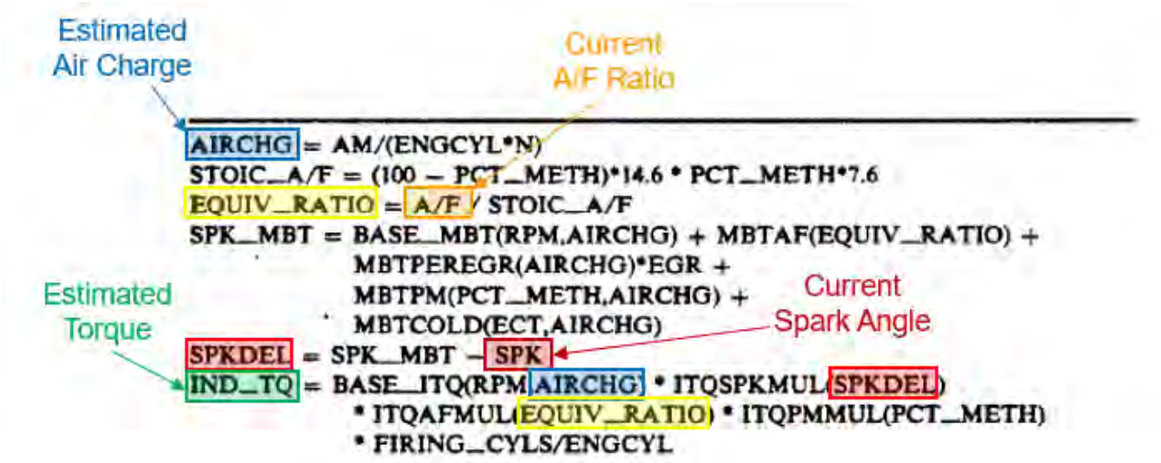
Thus, Suzuki's torque correction section includes an "estimator," as recited in claim 1, that estimates a torque output. EX1003, ¶114.

Although Suzuki does not expressly disclose that its estimator receives as inputs a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal, Cullen explicitly disclosed this feature. EX1003, ¶115. As shown below in FIG. 3, Cullen discloses a control module that calculates a predicted torque ("IND_TQ") by processing "**a spark timing input 13**," "**an air/fuel ratio input 16**," and "**an engine air charge input 18.**" EX1003, ¶116; EX1006, 5:59-6:2.



EX1006, FIG. 3 (annotated).

As shown below, Cullen estimates the torque ("IND_TQ") by inputting a current spark angle ("SPK"), a current air/fuel ratio ("A/F"), and an estimated air charge ("AIRCHG"). EX1003, ¶117; EX1006, 4:5-14, 5:34-50.



EX1006, 5:34-45 (annotated).

It would have been obvious for a POSA to program Suzuki's controller 20, in view of Cullen, to receive, as inputs, a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal so that Suzuki's controller estimates torque output more accurately. EX1003, ¶¶91, 93, 118. Indeed, Cullen explains that using these inputs accounts for various engine operations that influence torque output, thereby providing a more accurate torque estimation. EX1003, ¶118; EX1006, 1:13-15, 2:26-42 ("Thus an improved torque prediction algorithm would be desirable to account for operating variables which influence torque output."). A POSA would have further understood that engine control systems, such as Suzuki's control system, would include sensors detecting the spark angle, air/fuel ratio, and air charge. EX1003, ¶¶91, 92, 118. Accordingly, such modification would have been applying a known technique of calculating torque to a known engine control device to yield the predictable result of

calculating torque more accurately. *Id*. Accordingly, a POSA would have been motivated to modify Suzuki's control unit 20 so that the estimator receives a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal as inputs. *Id.*; *see also supra* Section VII.B.1.

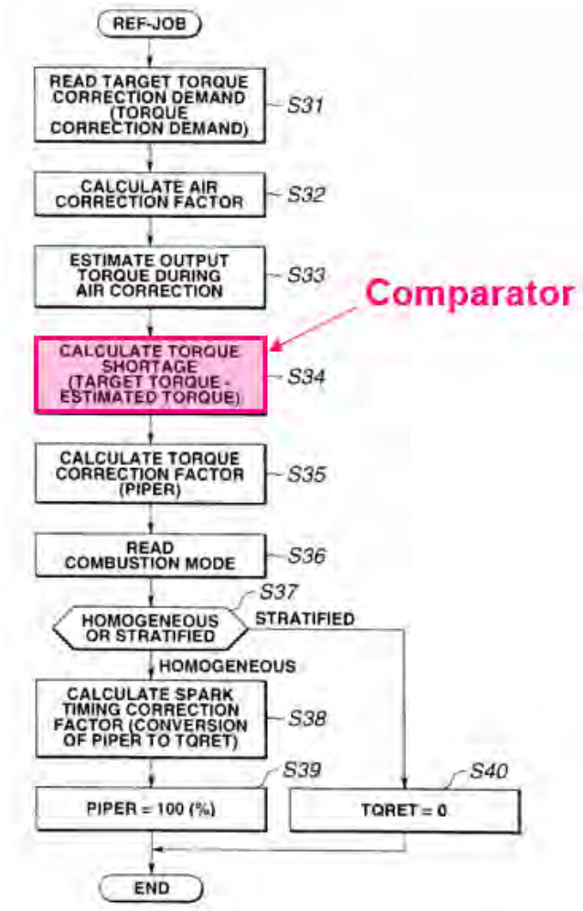
Likewise, a POSA would have been able to easily implement Cullen's teachings simply by modifying the application instructions stored in the microcomputer of Suzuki's control unit 20 such that the estimator section receives a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal as inputs for generating a torque estimate. EX1003, ¶¶92, 119; *see also supra* Section VII.B.1.

Thus, Suzuki and Cullen render obvious [1.C]. EX1003, ¶120.

5. [1.D] "a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal"

Suzuki discloses a comparator as claimed. EX1003, ¶121. As shown below in FIG. 6, Suzuki discloses that, after estimating an output torque, the torque correction section subtracts the estimated torque from the demand torque to output a torque shortage signal (S34). EX1005, 7:35-39 ("In step S34, the estimated torque is subtracted from the target torque…to calculate the torque shortage due to the delay involved with changing the amount of intake air."). Thus, Suzuki's torque correction section includes a "comparator" that subtracts the estimated

torque from the target torque (S4). EX1003, ¶122. Indeed, Suzuki's torque correction section at S4 operates in the same manner as the '565 patent's comparator, which generates a signal representing a shortage between the estimated torque and the desired torque. EX1001, 3:34-39; EX1003, ¶122. Moreover, Suzuki's calculated torque shortage is a "difference signal," representing the difference between the estimated torque and the desired torque. EX1003, ¶122. Specifically, Suzuki discloses that "the estimated torque is subtracted from the target torque…to calculate the torque shortage due to the delay involved with changing the amount of intake air." EX1005, 7:35-39.



EX1005, FIG. 6 (annotated).

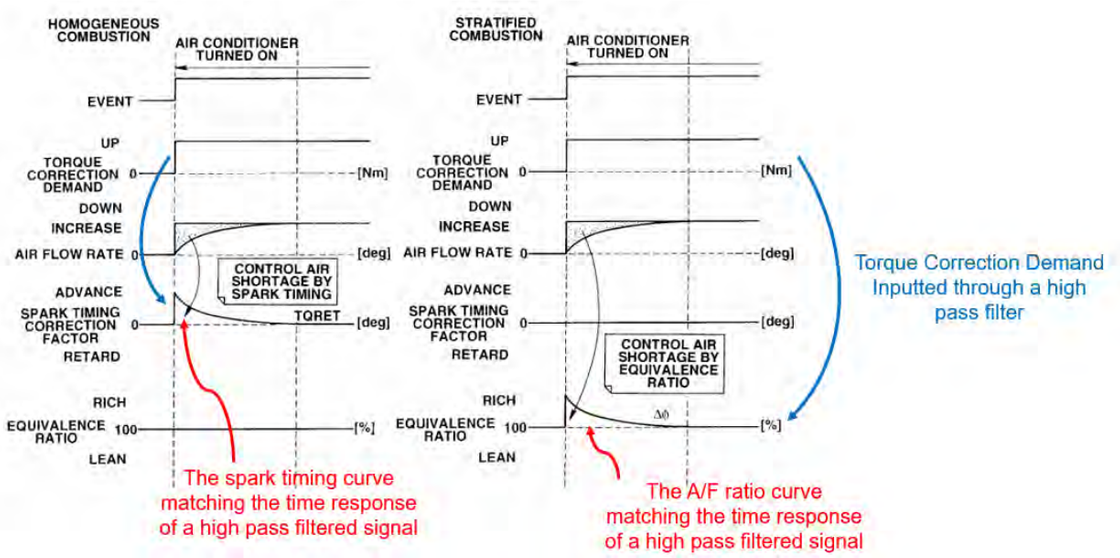
Thus, Suzuki discloses [1.D]. EX1003, ¶123.

6. [1.E] "a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent"

Suzuki and Scherer render obvious the high-pass filter as claimed. EX1003, ¶124. Although Suzuki does not expressly disclose a high-pass filter, a POSA would have understood that Suzuki suggests using a high-pass filter based

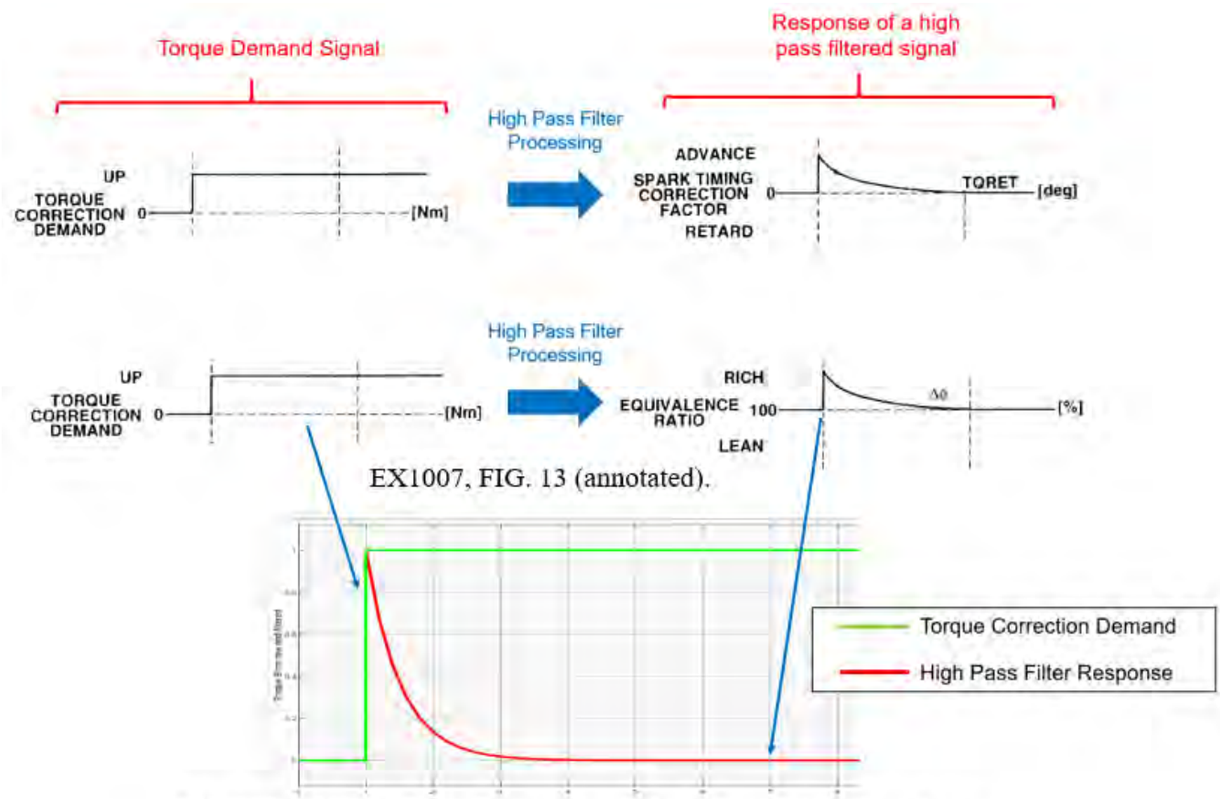
on the correction factor response curves shown in Figures 12-15 of Suzuki. *Id.*, ¶¶94, 124.

For example, as shown below in FIG. 13, Suzuki discloses a torque correction demand signal indicating an abrupt demand for increased torque output from the air conditioner starting. EX1003, ¶125; EX1005, 7:51-63, 8:51-60. Under the homogeneous mode, Suzuki discloses a spark timing correction factor signal that is generated from processing the torque correction demand signal through the torque correction routine shown in FIGS. 4 and 6. *Id.*, 7:51-58, 8:1-2. Under the stratified mode, Suzuki discloses an equivalence ratio correction factor signal (i.e., a signal representing a fuel injection adjustment) generated from processing the torque correction demand signal through the torque correction routine shown in Figures 5 and 6. *Id.*, 7:60-64, 8:2-4.



EX1005, FIG. 13 (annotated).

A POSA would have recognized that both the spark timing and equivalence ratio correction factor signals match the time response curve of a high-pass filter. EX1003, ¶126. For example, the below simulated correction signal (red) outputted from a high filter in response to a step function (green) matches Suzuki's spark timing and equivalence ratio correction factor signals in response to step correction demands. *Id*.



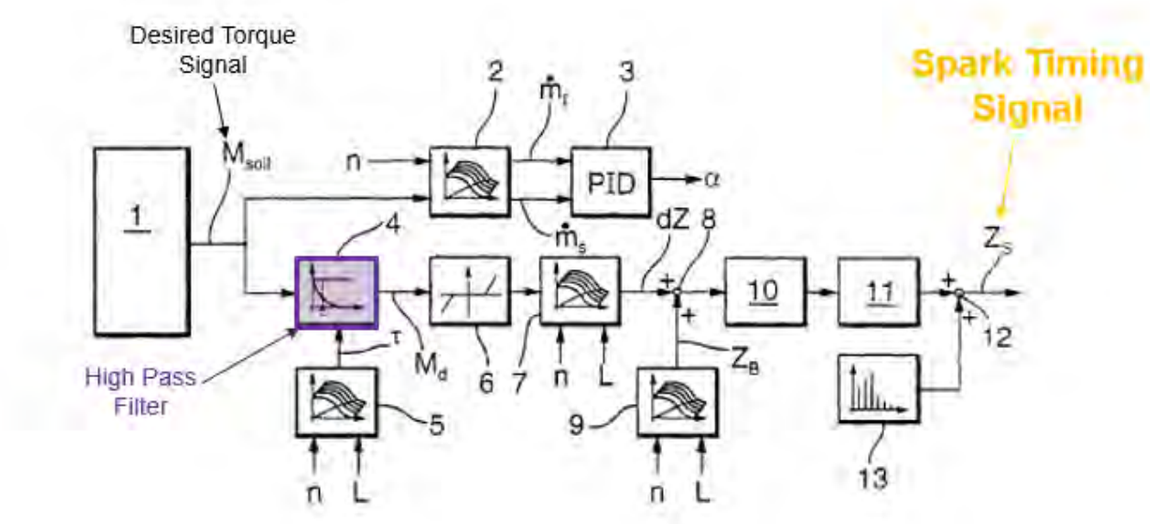
EX1007, FIG. 13 (annotated).

EX1003, FIG. A: Time Response of High-Pass Filter Simulation.

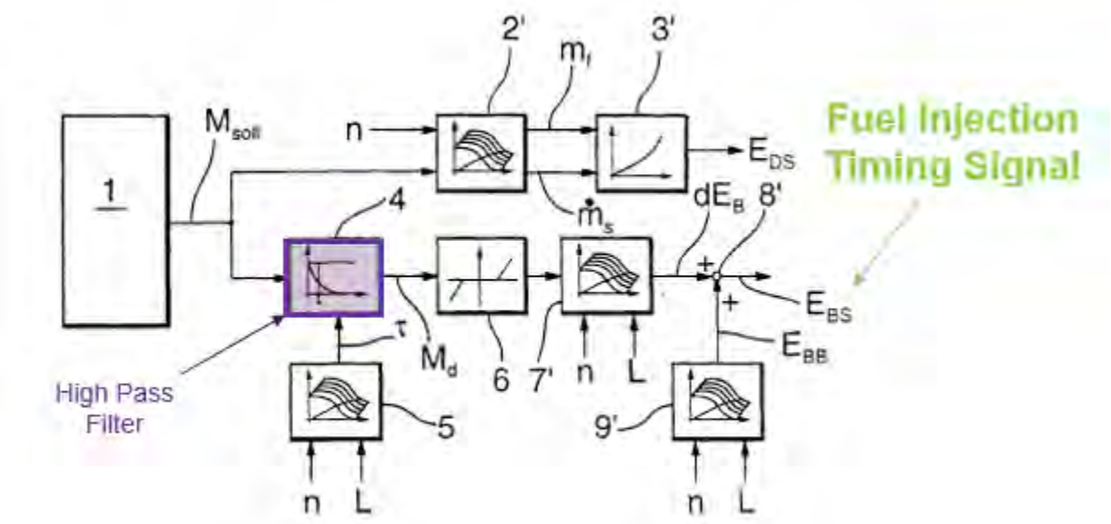
Suzuki's spark timing and equivalence ratio correction factors provide significant adjustments within a short time period and then disappear over time, as the torque demand signal reaches a steady-state. EX1003, ¶127. Accordingly, a

POSA would have understood that Suzuki implicitly discloses a high-pass filter. *Id.*

Even assuming that Suzuki does not disclose or suggest a high-pass filter, Scherer explicitly discloses this feature. EX1003, ¶128; EX1007, 4:40-44. Scherer discloses a device for controlling engine torque output through airflow, spark timing, and fuel delivery adjustments. EX1007, 3:59-60. As shown below in Figures 1 and 2, the device includes an engine torque coordination unit 1 that generates a desired engine torque signal M_{soil} and a high-pass filter 4 that receives the desired engine torque signal M_{soil} as an input and generates a dynamic desired torque component as an output for a torque controller. *Id.*, 3:60-63, 4:20-45, 8:26. Specifically, Scherer discloses a "high-pass filter 4 filter[ing] the dynamic desired engine torque part (M_d), as a function of the engine operating point, from the desired engine torque (M_{des}) supplied to it, and in turn provid[ing] the dynamic desired engine torque (M_d)." *Id.*, 4:40-45.



EX1007, FIG. 1 (annotated).



EX1007, FIG. 2 (annotated).

Additionally, Scherer discloses adjusting both spark and fuel injection timing based on the isolated dynamic component of desired torque signal outputted from the high-pass filter 4. EX1007, 2:51-54, 4:20-5:9, 5:16-55, FIGS.

1, 2. Specifically, Scherer discloses a controller that adjusts torque output by adjusting the spark timing for homogeneous fuel-charged engines or by adjusting fuel delivery for heterogeneous fuel-charged engines. *Id*., 2:51-55, 4:20-45, 5:35-55, 8:26; FIGS 1, 2; EX1003, ¶129.

Moreover, Scherer's high-pass filter 4 functions the same as the '565 patent's high-pass filter, removing the low frequency component of the torque signal to isolate and pass the transient component of the torque signal for correcting dynamic torque changes. EX1003, ¶130.

It would have been obvious for a POSA to incorporate Scherer's high-pass filter 4 into Suzuki's control unit 20 to remove the low frequency component from Suzuki's target shortage signal so that Suzuki's torque correction section adjusts torque output to a desired value more quickly during transient operation conditions. *Id.*, ¶¶98, 103, 131. Indeed, Scherer expressly discloses that using the high-pass filter allows the controller to provide a dynamic desired engine torque signal to the transient torque controller, thereby "permit[ing] a comparatively rapid engine torque adjustment which can follow very fast desired engine torque changes." EX1007, 4:40-45, 5:10-15. A POSA would have been motivated to incorporate Scherer's high-pass filter 4 into Suzuki's control unit 20 to remove the low frequency components from the torque shortage signal so that Suzuki's control unit 20 "adjusts the engine torque to a desired value with the least

possible expenditures in both steady-state and transient engine operation with a comparatively short reaction time." EX1007, 2:38-42; EX1003, ¶¶98, 100-102, 131.

Likewise, a POSA would have been able to easily implement Scherer's teachings by modifying the software instructions stored in the microcomputer of Suzuki's control unit 20 such that torque shortage signal is inputted into a high-pass filter. EX1003, ¶¶99, 132. In view of Scherer, a POSA would have understood that the high-pass filter is represented by a transfer function having a variable time constant adjusted according to the detected engine speed. EX1007, 4:31-38. A POSA would have recognized that such a transfer function may be implemented into Suzuki's control unit through a minor software modification. EX1003, ¶¶99, 132.

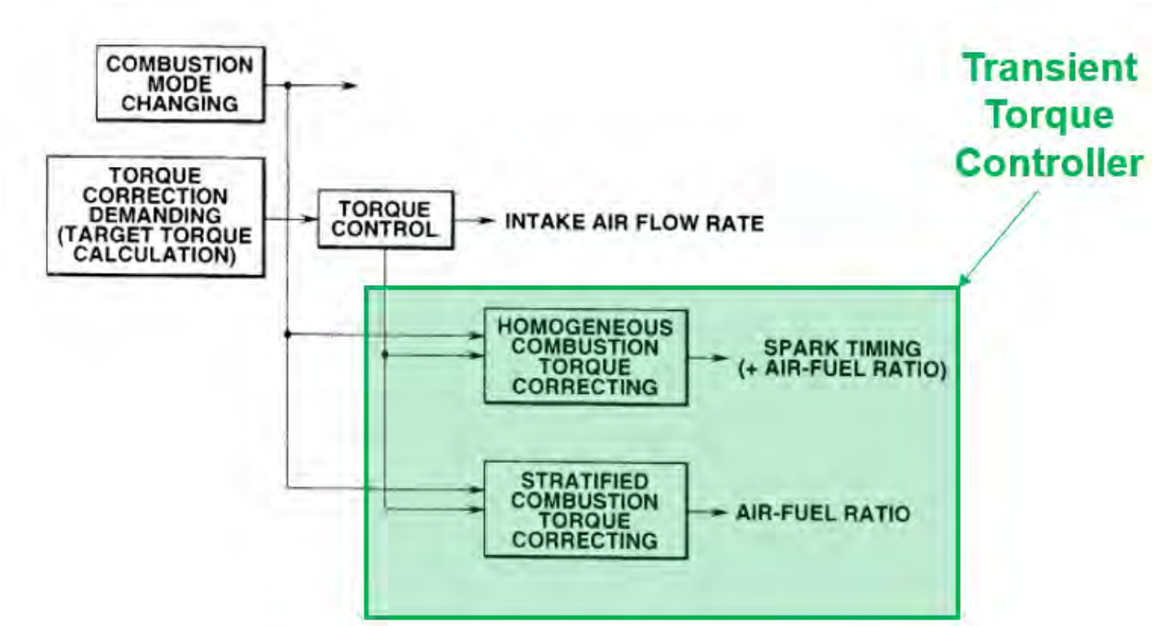
Additionally, a POSA would have understood that Scherer's technique for adjusting ignition timing and fuel injection based on the filtered torque signal is analogous to Suzuki's homogeneous and stratified torque correction sections. EX1003, ¶¶98-99, 133; EX1007, 4:20-5:9, 5:16-55; EX1012, 372-73, 376-78, 383. Accordingly, combining Scherer's high-pass filter 4 with Suzuki's control unit 20 that adjusts ignition timing in homogeneous mode and injected fuel quantity in stratified mode would have simply been applying a known technique to a known device to yield the predictable result of more quickly correcting

dynamic torque changes. EX1003, ¶¶98, 99, 133. Therefore, a POSA would have had a reasonable expectation of success in combining Suzuki and Scherer. *Id*.

Thus, Suzuki (and Cullen) in view of Scherer renders obvious [1.E]. *Id.*, ¶134.

7. [1.F] "a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal"

Suzuki discloses a transient torque controller as claimed. EX1003, ¶135. As shown below in Figure 1B, Suzuki discloses that the torque correction section includes "a homogenous combustion torque correcting section [that] **corrects at least the spark timing** in order to make a torque correction **with a fast response** … during homogenous combustion" and a "stratified combustion torque correcting section [that] **corrects at least the air-fuel ratio** to make torque correction during stratified combustion." EX1005, 3:10-22. Moreover, Suzuki's homogeneous and stratified torque correction sections are configured to adjust torque output during transient engine operations: "[Suzuki's engine control apparatus] widens the range (**dynamic range**) over which torque can be controlled…." *Id.*, 1:44-63, 3:10-22; EX1003, ¶135.



EX1005, FIG. 1B (annotated).

Suzuki further discloses that the homogenous combustion torque correcting section converts the torque correction factor processed from the torque shortage signal into a spark timing adjustment when the engine is set in a homogeneous mode (S38): "If the combustion mode is homogeneous combustion, then the program proceeds to step S38 wherein the torque correction factor PIPER is converted to a spark timing correction factor." EX1005, 7:51-59; EX1003, ¶136. As shown in FIG. 4, the torque correction factor is processed according to a spark timing calculating routine that determines spark timing ("spark adjustment signal") from a characteristic map, which is based on a function of engine speed and one of target torque or fuel quantity (S12 and S13). *Id*., 5:41-6:9, 8:1-2 ("The steps S31 to S37, S38, S39, S12 and S13 perform a homogeneous combustion torque correcting

function."). Thus, Suzuki's homogenous combustion torque correcting section "outputs…a spark adjustment signal," as recited in claim 1. EX1003, ¶136.

Suzuki also discloses that the stratified combustion torque correction section uses the torque correction factor processed from the torque shortage signal to calculate a fuel adjustment when the engine is set in a stratified mode (step S40). EX1005, 7:60-8:4 ("[T]he steps S31 to S37, S40 and S22 to S25 perform a stratified combustion torque correcting function."). As shown in Figure 5, the torque correction factor is processed according to a fuel delivery requirement calculating routine that determines the fuel injector's injection pulse ("fuel adjustment signal") by an equation using the measured air/fuel ratio, the measured airflow, and the engine speed as inputs. *Id*., 6:10-57. Thus, Suzuki's stratified combustion torque correction section "outputs a fuel adjustment signal," as recited in claim 1. EX1003, ¶137.

A POSA would have understood that Suzuki's homogeneous and stratified torque correction sections collectively compose a "transient torque controller," as recited in claim 1.[3] EX1003, ¶138. These correction sections are a controller

[3] Notably, a POSA would have understood that different software or instruction modules of a control unit constitute different controllers, as the term "controller" is used in the '565 patent. EX1003, ¶138. Neither the claims nor the '565 patent specification specify that the recited controllers, "torque demand

because they control torque output by generating spark timing adjustment and fuel adjustment signals. EX1003, ¶138; EX1005, 3:5-22. Indeed, Suzuki's torque correction sections operate in the same manner as the transient torque controller 21 disclosed by the '565 patent, which likewise generates a spark adjustment signal when the engine 100 is set in the homogenous mode and a fuel adjustment signal

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controller" and "transient torque controller," are separate physical structures. EX1003, ¶138. Indeed, in a district court complaint, the Patent Owner alleges that the software embedded within an engine control module constitutes a "controller," as recited in the '565 patent. EX1029, 34 ("[T]he transient torque controller (software within the ECM) receives as an input the filtered difference signal (described above) and outputs a fuel adjustment signal (to the ECM) and spark adjustment signal (used for engine control intervention)."). EX1029, 34. Thus, a POSA would have understood that different modules of Suzuki's control unit 20 are each a controller as that term is used in the '565 patent. Even assuming that the '565 patent required separate physical controllers, implementing Suzuki's homogeneous and stratified torque correction sections ("transient torque controller") as one physical controller and the torque correction demanding section ("torque demand controller") as a separate physical controller would have been an obvious design choice to a POSA. EX1003, ¶138.

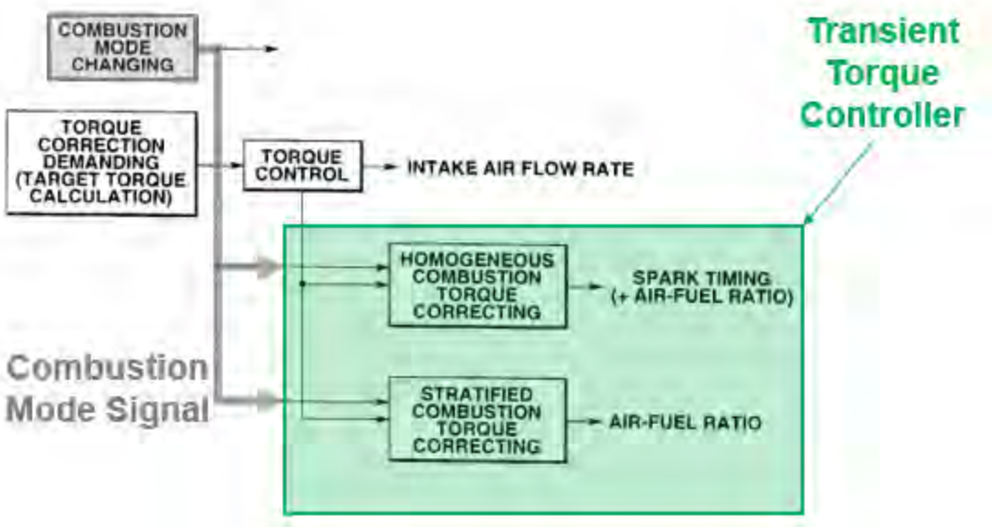
when the engine 100 is set in the stratified mode. EX1001, 3:34-50; EX1003, ¶138. Thus, Suzuki discloses a "transient torque controller," as recited in claim 1.

Thus, Suzuki discloses [1.F]. EX1003, ¶139.

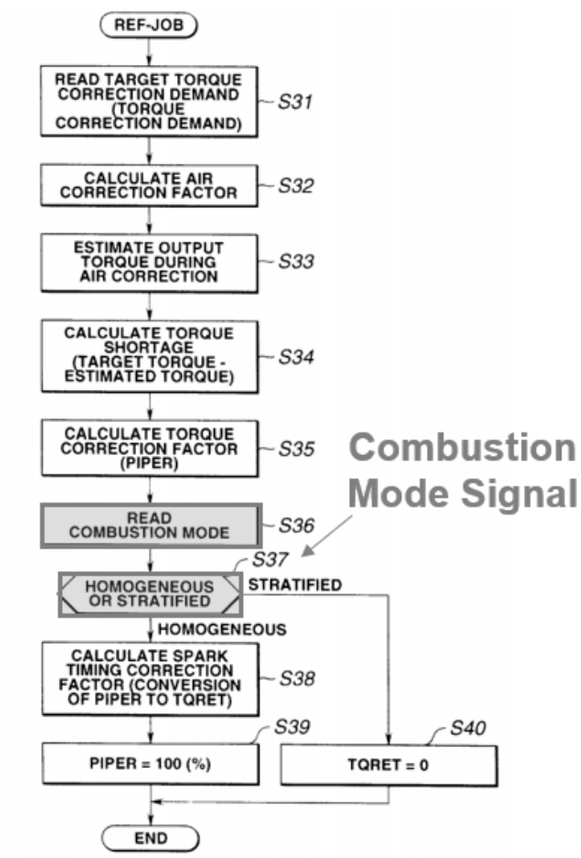
D. Suzuki, Cullen, and Scherer render obvious claim 4.

1. [4.A] "The device of claim 1, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode"

Suzuki discloses a DISI engine and a transient torque controller that receives a combustion mode signal, as claimed. EX1003, ¶140. Suzuki discloses a "controller for a direct-injection spark-ignition type engine." EX1005, 3:6-7. The controller includes "a combustion mode changing section for making a combustion mode change between homogenous combustion and stratified combustion." *Id.*, 3:7-10. As shown below in Figures 1B and 6, Suzuki's homogeneous and stratified torque correction sections (collectively, "transient torque controller") receive a signal from the combustion mode changing section to determine whether the engine is operating in the homogeneous or stratified mode. *Id.*, 7:45-8:4; EX1003, ¶140.



EX1005, FIG. 1B (annotated).



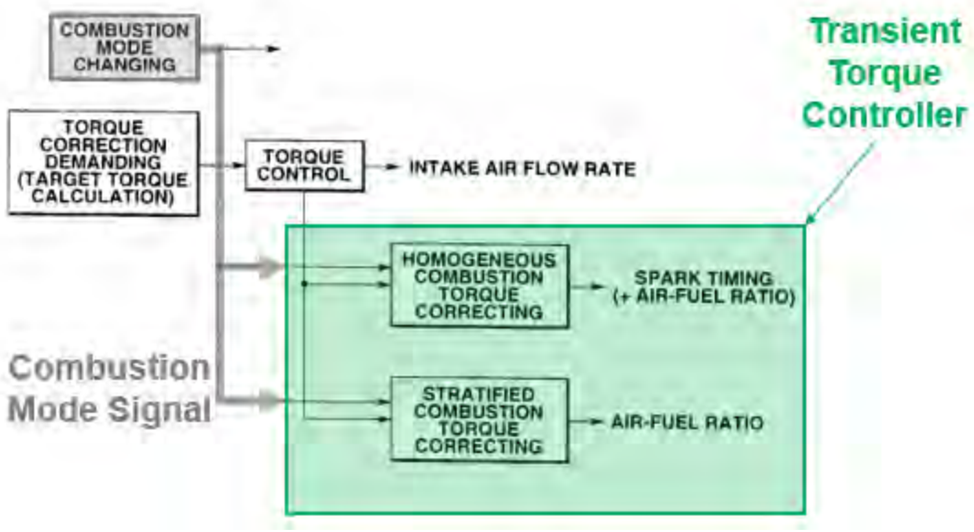
EX1005, FIG. 6 (annotated).

Suzuki's direct-injection spark-ignition engine is a "direct injection spark ignition engine," as recited in claim 4. EX1003, ¶141. And Suzuki's combustion mode changing section generates a "combustion mode signal" received by the homogeneous and stratified torque correction sections ("transient torque controller"), as recited in claim 4. This signal indicates whether the engine is operating in a stratified or a combustion mode. EX1005, 3:7-10; EX1003, ¶141.

Thus, Suzuki discloses [4.A]. EX1003, ¶142.

2. [4.B] "wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode"

Suzuki discloses a transient torque controller arranged to control the fuel adjustment signal as claimed. EX1003, ¶143. Again, Suzuki's stratified torque correction section composes, in part, the "transient torque controller" recited in claim 4. *See supra* Section VII.C.7; EX1003, ¶143.



EX1005, FIG. 1B (annotated).

Suzuki discloses that the "stratified combustion torque correcting section **corrects at least the air-fuel ratio** to make torque correction **during stratified combustion**." EX1005, 3:10-22.

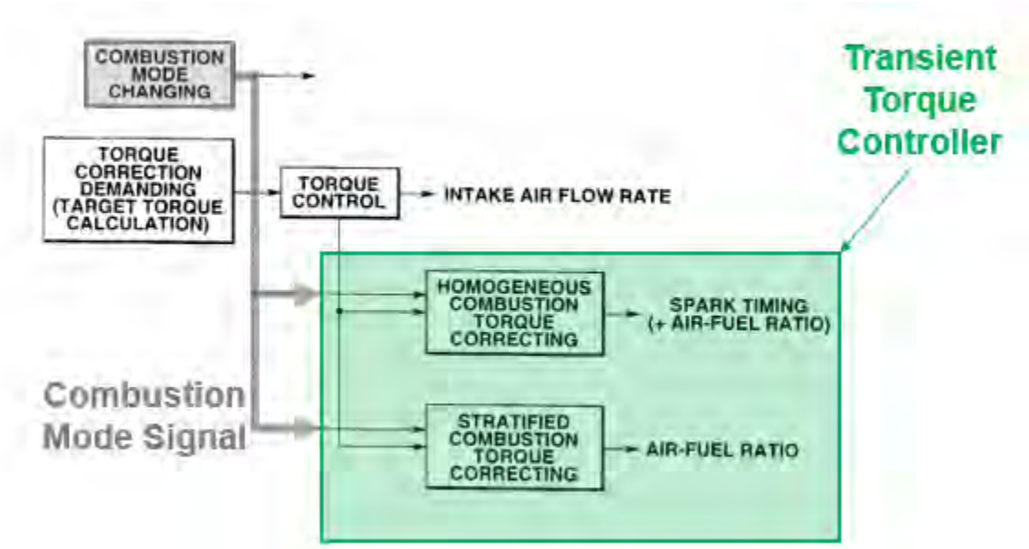
To correct the air-fuel ratio, Suzuki's stratified combustion torque correction section adjusts the injection pulse signal ("fuel adjustment signal") transmitted to the fuel injectors 5 based on the fuel delivery calculation routine shown in Figure 5. *Id.*, 6:50-57, 7:60-8:4 ("[T]he steps S31 to S37, S40 [of Figure 6] and S22 to S25 [of Figure 5] perform a stratified combustion torque correcting function."). Specifically, Suzuki's control unit adjusts the pulse width of the fuel injection pulse signal to correspond to a fuel delivery requirement T_i that is derived ultimately from the torque shortage signal ("the difference signal") generated in step S34 of Figure 6. *Id.*, 6:21-57, 7:35-44. Accordingly, in the stratified

combustion mode, Suzuki's stratified torque correction section controls the fuel adjustment signal. EX1003, ¶144. Indeed, Suzuki's stratified torque correction section operates in the same manner as the transient torque controller 21 disclosed by the '565 patent, which generates a fuel adjustment signal when the engine 100 is set in the stratified mode. EX1001, 3:35-50; EX1003, ¶144.

Thus, Suzuki discloses [4.B]. EX1003, ¶145.

3. [4.C] "wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode"

Suzuki discloses a transient torque controller arranged to control the spark adjustment signal as claimed. EX1003, ¶146.



EX1005, FIG. 1B (annotated).

Again, Suzuki's homogeneous torque correction section composes, in part, the "transient torque controller" recited in claim 4. *See supra* Section VII.C.6; EX1003, ¶147. And Suzuki discloses that the "homogenous combustion torque correcting section corrects at least the **spark timing** in order to make a torque correction with a fast response…**during homogenous combustion**." EX1005, 3:10-22.

To correct spark timing, Suzuki's homogeneous combustion torque correction section modifies the timing of a command signal ("spark adjustment signal") transmitted to spark plug 6 based on the spark timing calculation routine shown in FIG. 4. *Id.*, 6:7-9, 7:60-8:4 ("The steps S31 to S37, S38, S39 [of Figure 6], S12 and S13 [of Figure 4] perform a homogeneous combustion torque correcting function."). Specifically, Suzuki's control unit retards or advances the timing of the spark plug command signal based on a torque correction factor that is derived directly from the torque shortage signal ("the difference signal") generated in step S34 of Figure 6. *Id.*, 5:59-65, 7:35-59. Accordingly, in the homogeneous combustion mode, Suzuki's homogeneous torque correction section controls the spark adjustment signal. EX1003, ¶147. Indeed, Suzuki's homogeneous torque correction section operates in the same manner as the transient torque controller 21 disclosed by the '565 patent, which generates a spark adjustment signal when the engine 100 is set in the homogenous mode. EX1001, 3:34-50; EX1003, ¶147.

Thus, Suzuki discloses [4.C]. EX1003, ¶148.

E. Suzuki, Cullen, and Scherer render obvious claim 7.

1. [7.P] "A method for controlling a torque output of an engine, the method comprising:"

Claim 7 recites a method analogous to the apparatus of claim 1. [7.P] is similar to [1.P], which is disclosed by Suzuki. *See supra* Section VII.C.1; EX1003, ¶149. Particularly, Suzuki discloses a "torque correcting routine," as shown in Suzuki's Figure 6. EX1005, 7:10-13. Accordingly, Suzuki discloses [7.P] for at least the same reasons as [1.P]. EX1003, ¶149.

2. [7.A] "estimating a current torque signal from a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal"

[7.A] is similar to [1.C], which is rendered obvious by Suzuki and Cullen. *See supra* Section VII.C.4; EX1003, ¶¶91-93, 118-120, 150. For example, Suzuki discloses "[i]n step S33, the output torque during intake air correction is estimated." EX1005, 7:33-34. While Suzuki does not expressly disclose receiving a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal to estimate the torque output, Cullen discloses this limitation. EX1003, ¶150. Particularly, Cullen discloses a torque calculation procedure that estimates the torque (i.e., "IND_TQ") by inputting a current spark angle ("SPK"), a current air/fuel ratio ("A/F"), and an estimated air charge ("AIRCHG"). EX1006, 4:5-14, 5:34-50. And it would have been obvious to a

POSA to combine the teachings of Suzuki and Cullen to ensure that the estimated torque is calculated accurately, as described for [1.C]. EX1003, ¶150. Accordingly, Suzuki and Cullen render obvious [7.A] for at least the same reasons as [1.C]. *Id*.

3. [7.B] "comparing the estimated current torque signal with a desired torque signal to output a difference signal"

[7.B] is similar to [1.D], which is disclosed by Suzuki. *See supra* Section VII.C.5; EX1003, ¶151. For example, Suzuki discloses that "[i]n step S34, the estimated torque is subtracted from the target torque … to calculate the torque shortage due to the delay involved with changing the amount of intake air." EX1005, 7:35-39. A POSA would have understood that Suzuki's step of subtracting the estimated torque from target torque is the "comparing" step recited in claim 7. EX1003, ¶151. Accordingly, Suzuki discloses [7.B] for at least the same reasons as [1.D]. EX1003, ¶151.

4. [7.C] "filtering out a plurality of low frequency components from the difference signal"

[7.C] is similar to [1.E], which is rendered obvious by Suzuki (and Cullen) in view of Scherer. *See supra* Section VII.C.6; EX1003, ¶¶98-103, 131-134, 152. For example, a POSA would have understood that Suzuki suggests a high-pass filter receiving the torque shortage signals to generate the correction factor signals shown in Figures 12-15. EX1003, ¶152. And Scherer explicitly discloses a "high

pass filter 4 filter[ing] the dynamic desired engine torque part (M_d)…from the desired engine torque (M_{des}) supplied to it, and in turn provid[ing] the dynamic desired engine torque (M_d).” EX1007, 4:40-45. Scherer’s high-pass filter 4 performs the “filtering” recited in claim 7. EX1003, ¶152. And it would have been obvious to a POSA to combine Scherer’s use of a high-pass filter 4 with Suzuki’s torque correction routine so that Scherer’s control unit 20 corrects dynamic changes in torque demand in a quicker response time, as explained for [1.E]. *Id*. Accordingly, [7.C] would have been obvious for at least the same reasons as [1.E]. *Id*.

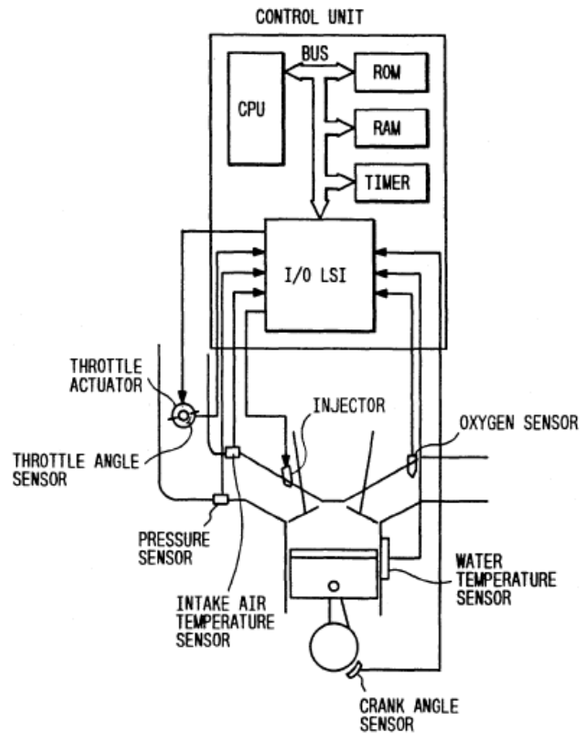
5. [7.D] “controlling a fuel adjustment signal and a spark adjustment signal in dependence upon a filtered difference signal”

[7.D] is similar to [1.F], which is disclosed by Suzuki. *See supra* Section VII.C.7; EX1003, ¶153. For example, Suzuki discloses “a homogenous combustion torque correcting section **corrects at least the spark timing**…during homogenous combustion” and a “stratified combustion torque correcting section **corrects at least the air-fuel ratio**…during stratified combustion.” EX1005, 3:10-22. Suzuki’s spark timing adjustments during the homogenous combustion mode and fuel quantity adjustments during stratified mode constitutes the “controlling” recited in claim 7. EX1003, ¶153. Accordingly, Suzuki discloses [7.D] for at least the same reasons as [1.F]. *Id*.

VIII. Ground 2: The combination of Suzuki, Cullen, Scherer, and Takahashi renders obvious claims 2, 3, 5, and 6.

A. Rationale for Combining Suzuki, Cullen, Scherer, and Takahashi

As an initial matter, Suzuki, Cullen, Scherer, and Takahashi are from the same field of endeavor—engine control systems. EX1003, ¶154. Similar to Suzuki, Cullen, and Scherer, Takahashi is directed to using a target torque value as input for controlling engine parameters, such as fuel quantity and air/fuel ratio. *Id.*, ¶155. Like Suzuki, Cullen, and Scherer, Takahashi's "invention is related to the method and system for simultaneous control of the throttle valve and fuel injection to ensure that the torque and air fuel ratio of the automobile engine will reach target values." EX1008, 1:6-9. Moreover, Takahashi's electronic control module (ECM) 11 has a control unit, a throttle position sensor, an engine speed sensor, an exhaust oxygen sensor, an engine water temperature sensor, and an airflow meter. EX1005, 4:17-40, FIG. 2; EX1008, 3:8-16, FIGS. 1 and 13.



EX1008, FIG. 13.

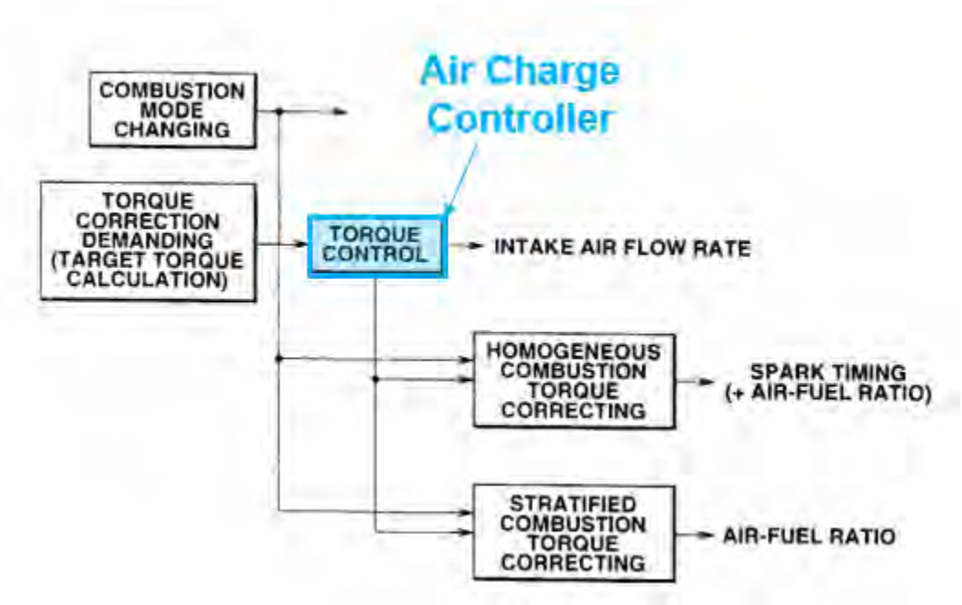
These components are similar to the components used in the control systems of Suzuki, Cullen, and Scherer. EX1003, ¶156. For example, Suzuki discloses a control unit 20 linked to crankshaft angle sensors 21-22, an airflow meter 23, a throttle valve sensor 25, and an O_2 sensor 27. EX1005, 4:6-40. Cullen discloses an engine control module 12 that receives a spark timing input 13, an air/fuel ratio input 16, an engine rpm input 17, and an engine air charge input 18. EX1006, 5:57-6:2. And Scherer discloses an engine control device linked to a sensor system for detecting air flow rate, engine speed, and engine load. EX1007, 3:59-67, 4:8-38.

Combining the teachings of Takahashi, Suzuki, Cullen, and Scherer would have simply involved modifying the engine controller (e.g., programming stored instructions in the microcomputer of Suzuki's control unit 20) to perform the steps taught in the references—a basic task for a POSA. EX1003, ¶157. A POSA would have been motivated to combine the teachings of Suzuki, Cullen, Scherer, and Takahashi for at least the reasons discussed below and would have had a reasonable expectation of success in doing so. *Id.*

The motivation to combine of Suzuki, Cullen, and Scherer is discussed above in Section VII.B. EX1003, ¶158. That motivation applies here for claims 2, 3, 5, and 6. *Id*. For example, a POSA would have been motivated to combine Cullen's routine for estimating torque output with Suzuki's control unit 20 to estimate engine output torque more accurately, thereby allowing Suzuki's control unit 20 to converge torque output to the desired torque output more precisely. *Id.*; EX1006, 2:21-42; *see supra* Section VII.B.1. And a POSA would have been motivated to combine Scherer's high-pass filter 4 with Suzuki's control unit 20 to allow Suzuki's torque correction section to correct the transient torque demand in a faster response time. EX1003, ¶158; EX1007, 4:40-45, 5:10-15, *see supra* Section VII.B.2.

A POSA would have also been motivated to combine the teachings of Takahashi with the Suzuki-Cullen-Scherer combination. EX1003, ¶159. Suzuki's

control unit 20 includes a torque control section shown in Figure 1B ("air charge controller") for controlling the throttle valve to adjust the cylinder air charge. EX1005, 3:12-15, 4:33-38; EX1003, ¶159.



EX1005, FIG. 1B (annotated).

While Suzuki discloses an air charge controller, Suzuki does not expressly disclose that the air charge controller produces an estimated air charge signal and receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal. But these features are explicitly disclosed in Takahashi. EX1003, ¶160. EX1008, 3:13-27, 10:27-66, FIGS. 14 and 15.

Takahashi discloses specific implementation details of an air charge controller outputting an estimated air charge signal and receiving as inputs an air

charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal. EX1003, ¶161. Particularly, Takahashi discloses a control unit having a throttle controller 144 ("air charge controller") that receives the demand air charge Q_{map0} ("air charge demand signal") from a target-air-mass-flow-rate deciding block 11 and estimates the current air mass flow rate Q_{map} ("estimated air charge signal") using a status-estimating block 142. EX1008, 10:43-60, FIG. 14. The status-estimating block 142 receives a current throttle angle signal θ_{th} from a throttle angle sensor ("throttle position signal"), an intake manifold pressure signal P_m from a pressure sensor ("manifold pressure signal"), an engine speed signal N from the crank angle sensor ("engine speed signal"), and an intake air temperature signal from the intake air temperature sensor ("air charge temperature signal"). *Id.*

A POSA would have understood that the throttle angle signal θ_{th}, intake manifold pressure signal P_m, engine speed signal N, intake air temperature signal, and demand air charge Q_{map0} inputted into the combination of Takahashi's throttle controller 144 and status-estimating block 142 are the inputs recited in claims 2 and 5. EX1003, ¶161. And based on these inputs, Takahashi's status-estimating block 142 calculates the estimated air charge, which the control unit uses to adjust both the throttle valve position and the fuel injection quantity. *Id.* Takahashi further discloses that the air-mass-flow-rate deciding block 11 receives a target

torque signal T_o ("desired torque signal"), a target air/fuel ratio signal A/F_o ("desired air/fuel"), and a spark advance signal θ_{adv} ("desired spark angle signal") to determine the target mass flow rate Q_{map0} ("air charge demand signal"). EX1008, 3:28-51; EX1003, ¶161.

Because Suzuki is silent on this implementation detail of the air charge controller, a POSA would have sought out these details provided by Takahashi's analogous control unit. EX1003, ¶162. Combining the teachings of Suzuki and Takahashi would have yielded predictable benefits and results—for example, precisely controlling the air mass flow rate at the inlet port of the engine cylinder. EX1008, 2:18-24 ("Since [using] a status estimating model…ensures a high precision estimation of the airflow status inside the intake manifold, the present invention further provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque at the target value."). A POSA would have understood that combining Takahashi's status-estimating block technique with Suzuki's torque control section would have estimated the air mass entering the engine cylinder more accurately, thereby allowing Suzuki's control unit 20 to converge torque output to the desired torque output more precisely. *Id.*; EX1003, ¶162. Furthermore, a POSA would have understood that incorporating Takahashi's target-air-mass-flow-rate deciding block 11 into Suzuki's torque correction section to output the demand air charge signal

would have allowed Suzuki's torque control section to control cylinder air charge more precisely, ultimately allowing engine torque output to achieve the target torque. EX1003, ¶162; EX1008, 1:49-57, 3:24-51. Accordingly, combining Takahashi's known status-estimating block technique and target air-mass-flow-rate deciding block 11 with Suzuki's known torque control section would have merely been applying a known technique in a similar, known device in the same way. *KSR*, 550 U.S. at 416; EX1003, ¶162.

Moreover, a POSA would have had a reasonable expectation of success in combining Suzuki, as modified by Cullen and Scherer, with Takahashi. EX1003, ¶163. Indeed, a POSA would have recognized that Takahashi's status-estimating block would have been easily applied to Suzuki's torque control section to output the estimate air charge signal based on the detected engine speed, throttle position, manifold pressure, and air charge temperature. *Id.*, ¶163.

A POSA would have also understood how to combine the teachings of Takahashi with Suzuki, as modified by Cullen and Scherer. *Id*. A POSA would have simply modified the software instructions stored in Suzuki's microcomputer such that the torque control section receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and generates an estimated air charge signal, as disclosed in Takahashi. EX1003, ¶163; EX1019, 102, 223. Considering the

similarities in Suzuki's and Takahashi's control systems, any necessary coding modifications to implement Takahashi's teachings into Suzuki's system would have been trivial and well within the skill of a POSA. EX1003, ¶163.

In sum, Suzuki's control unit 20, Cullen's technique for estimating torque output, Scherer's high-pass filter, and Takahashi's technique for generating an estimated air charge signal were known elements that a POSA would have been motivated to combine in known ways to provide the predictable benefits disclosed in the references for providing precise and rapid correction of engine torque demand. *KSR*, 550 U.S. at 419-421; EX1003, ¶164.

Accordingly, it would have been obvious to combine the teachings of Suzuki, Cullen, Scherer, and Takahashi. EX1003, ¶165.

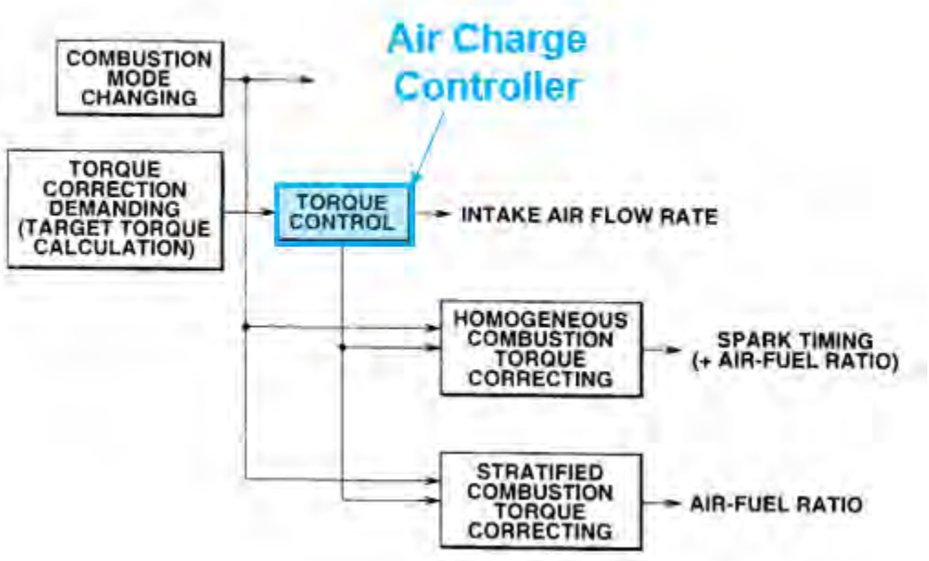
B. Suzuki, Cullen, Scherer, and Takahashi render obvious claims 2 and 5.

Claims 2 and 5 depend from claims 1 and 4, respectively, and recite "wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal."[4] EX1001, 4:22-26, 4:44-48.

[4] To a POSA, the plain and ordinary meaning of the term "air charge" is the quantity of air mass that is drawn into the engine cylinder. EX1003, ¶67; EX1011,

Suzuki in combination with Cullen, Scherer, and Takahashi renders obvious this limitation of claims 2 and 5. EX1003, ¶¶166-167.

As shown below in Figure 1B, Suzuki discloses that the torque correction section includes a torque control section (blue) that controls a throttle valve to adjust "the amount of air permitted to enter the engine in order to control the torque." EX1003, ¶168; EX1005, 3:12-15.



EX1005, FIG. 1B (annotated).

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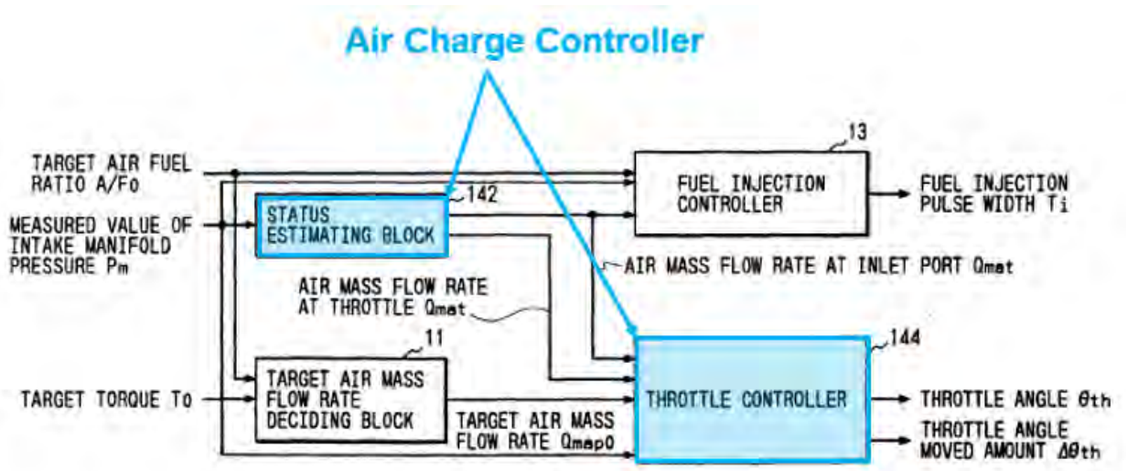
176. Notably, there is no feasible way to directly measure air charge. EX1003, ¶67; EX1011, 176. Rather, air charge is estimated from the mass flow rate entering through engine intake. EX1011, 176-77; *see also* EX1014, 294-296.

A POSA would have understood that Suzuki's torque control section is an "air charge controller," as recited in claims 2 and 5.[5] EX1003, ¶169. Suzuki's torque control section adjusts the air charge inputted into the engine cylinders via actuating the throttle valve. EX1005, 3:27-28 ("Air intake is controlled by an electronic controlled throttle valve 4. The degree of opening of the electronic controlled throttle valve 4 is controlled by, for example, a step motor operable in response to a signal from a control unit 20."), 4:32-37, 8:43-47; EX1003, ¶169. And Suzuki's torque control section operates in the same manner as the air charge controller 29 disclosed by the '565 patent, which transmits a signal indicating the desired throttle position to the throttle 9. EX1001, 3:19-22; EX1003, ¶169.

Suzuki does not expressly disclose that the torque control section produces an estimated air charge signal and receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal. However, Takahashi explicitly discloses these features. EX1008, 3:13-27, 10:27-66, FIGS. 14, 15; EX1003, ¶170.

[5] Again, a POSA would have understood that different software or instruction modules of a control unit constitute different controllers, as the term "controller" is used in the '565 patent. *See supra* n.3. Accordingly, a POSA would have understood that different modules of Suzuki's control unit 20 are each a controller as that term is used in the '565 patent. EX1003, ¶170, n.5.

Takahashi discloses a control unit that controls torque output based on receiving inputs from a throttle angle sensor, an intake pressure sensor, an intake air temperature sensor, a crank angle sensor, an engine coolant sensor, and an exhaust oxygen sensor. EX1008, 3:10-13, FIG. 13. As shown below in Figure 14, the control unit includes a throttle controller 144 that calculates a desired throttle position for the throttle valve to set the airflow into the engine cylinder at a desired air charge value, ultimately allowing the engine to achieve a target torque value. ; EX1003, ¶171; EX1008, 3:20-27, 6:10-12, 7:50-58.



EX1008, FIG. 14 (annotated).

The throttle controller 144 determines the desired throttle position as a function of a target air mass flow rate Q_{map0} ("air charge demand signal") and an

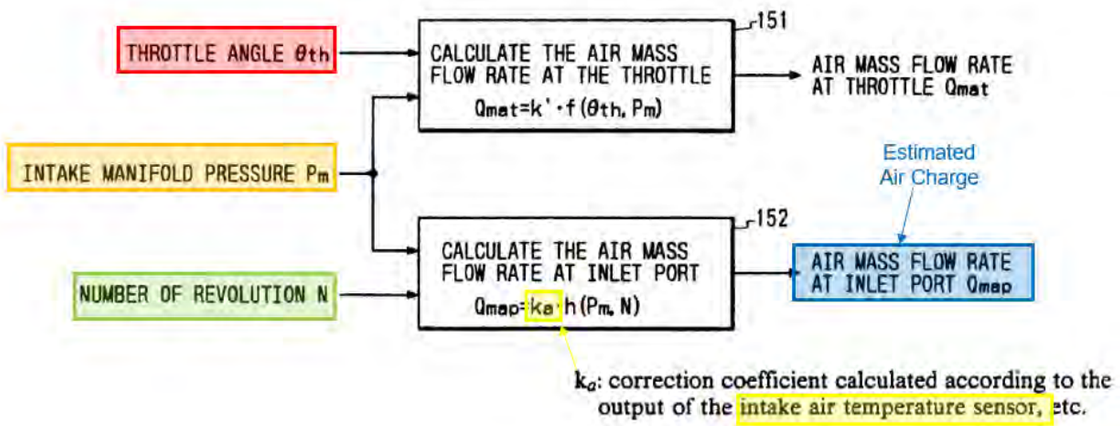
estimated air mass flow rate at the inlet port Q_{map}[6] ("estimated air charge signal"). EX1008, 10:42-47, FIG. 14; EX1003, ¶172. The throttle controller 144 receives the demand air charge Q_{map0} from a target air-mass-flow-rate deciding block 11 and estimates the current air mass flow rate Q_{map} using a status-estimating block 142. EX1008, 10:42-60, FIG. 14; EX1003, ¶172.

As shown below in Figure 15, the status-estimating block 142 receives a current throttle angle signal θ_{th} (red, "throttle position signal"), an intake manifold pressure signal P_m (orange, "manifold pressure signal"), and a number of revolutions *N* (green, "engine speed signal").[7] EX1008, 10:54-66; EX1003, ¶173. The status-estimating block 142 estimates the air charge value based on intake

[6] In Takahashi, there is a discrepancy between the reference symbols in the specification and the reference symbols in the figures regarding the "air mass flow rate at the inlet port." In the specification and FIG. 2, Takahashi refers to the "air mass flow rate at the inlet port" using the reference symbol Q_{map}. EX1008, 10:54-60. However, in FIG. 14, the "air mass flow rate at the inlet port" is represented by the reference symbol Q_{mat}. EX1003, ¶172.

[7] The measured parameter number of revolutions *N* disclosed in Takahashi represents engine speed. EX1008, 3:36 ("N: Engine speed (number of revolutions)"); EX1003, ¶173.

pressure P_m, engine speed N, and a correction coefficient k_a determined from current intake temperature sensor (yellow). EX1008, 10:54-66; EX1003, ¶173. The estimated air charge value is used to adjust both the throttle valve position and the fuel injection quantity, thereby controlling the engine torque output. EX1008, 3:24-27, 5:53-67, 10:21-27; EX1003, ¶173.



EX1008, FIG. 15 (annotated).

Takahashi discloses an air charge controller as recited in claims 2 and 5. EX1003, ¶174. Takahashi's throttle controller 144 and status-estimating block 142 collectively compose an "air charge controller," as recited in claims 2 and 5. Takahashi's status-estimating block 142 and throttle controller 144 operate in the same manner as the air charge controller 29 disclosed by the '565 patent, which receives an air charge demand signal and signals from throttle position sensor 6, engine speed sensor 3, manifold pressure sensor 110, and temperature meter 5. EX1003, ¶174; EX1001, 3:13-22. And Takahashi's throttle controller 144 and

status-estimating block 142 receive as inputs an air charge demand signal (Takahashi's target air mass flow rate Q_{map0}), a throttle position signal (Takahashi's throttle angle signal θ_{th}), an engine speed signal (Takahashi's number of revolutions N), a manifold pressure signal (i.e., Takahashi's intake manifold pressure P_m), and an air charge temperature signal (Takahashi's intake air temperature). EX1003, ¶175. Takahashi's status-estimating block 142 produces an estimated air charge signal (Takahashi's air mass flow rate at inlet port Q_{map}), which is ultimately used to adjust both the throttle angle position and fuel quantity. *Id*. Accordingly, Takahashi discloses an air charge controller that produces an estimated air charge signal and that receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal, as recited in claims 2 and 5. *Id*.

In view of Takahashi, it would have been obvious for a POSA to modify Suzuki's torque control section to receive as signal inputs an air charge demand, a throttle position, an engine speed, a manifold pressure, and an air charge temperature so that Suzuki's control unit 20 estimates the cylinder air charge more accurately. EX1003, ¶¶162, 176; EX1008, 1:43-65, 2:18-24, 10:21-27. Indeed, Takahashi expressly discloses that this configuration "provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque at the target value."

EX1008, 2:18-24. This modification would have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. EX1003, ¶176; *KSR*, 550 U.S. at 416. Accordingly, a POSA would have been motivated to combine the teachings of Takahashi with Suzuki (and Cullen and Scherer) so that the control unit converges the engine output torque to the demand torque more precisely. EX1008, 2:18-24; EX1003, ¶176.

Likewise, a POSA would have been able to easily implement Takahashi's teaching by modifying the software instructions stored in Suzuki's microcomputer such that the torque control section receives signals indicating air charge demand, throttle position, engine speed, manifold pressure, and air charge temperature to produce an estimated air charge signal. EX1003, ¶¶163, 177. Indeed, a POSA would have recognized to combine Takahashi's status-estimating block technique with Suzuki's torque control section to output the estimate air charge signal. EX1003, ¶¶162-163, 177. Accordingly, a POSA would have had a reasonable expectation of success in combining Suzuki and Takahashi. *Id.*

Thus, Suzuki, in combination with Cullen, Scherer, and Takahashi, renders obvious claims 2 and 5. *Id.*, ¶¶164, 178.

C. Suzuki, Cullen, Scherer, and Takahashi render obvious claims 3 and 6.

Claims 3 and 6 depend from claims 2 and 5, respectively, and each recite "wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel ratio."

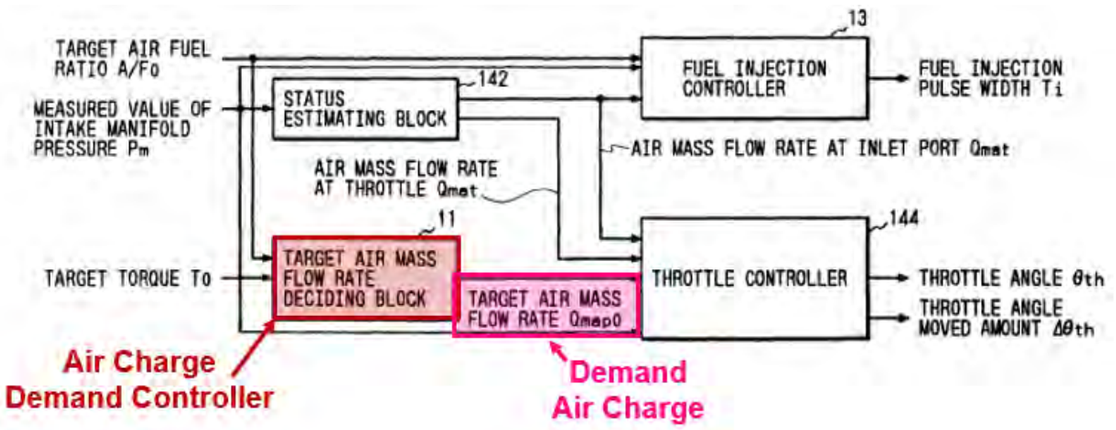
The Suzuki-Cullen-Scherer-Takahashi combination renders obvious claims 3 and 6. EX1003, ¶¶179-180. As described above, Takahashi discloses that the throttle controller 144 (which composes the recited air charge controller) receives the demand air charge Q_{map0} from a target air-mass-flow-rate deciding block 11. EX1008, 3:28-29, 10:42-50, FIG. 14. As shown below in Figure 14 and Expression 1 recited in column 3 of the specification, Takahashi further discloses that the air-mass-flow-rate deciding block 11 receives a target torque signal T_o (green, "desired torque signal"), a target air/fuel ratio signal A/F_o (blue, "desired air/fuel"), and a spark advance signal θ_{adv} (purple, "desired spark angle signal") to determine the target mass flow rate Q_{map0} (pink, "air charge demand signal"). EX1008, 3:28-51; EX1003, ¶180.

Air Charge Demand

$$Q_{map0} = \frac{N \cdot T_0}{K \cdot F_1(A/F_0) \cdot F_2(N) \cdot F_3(\theta_{adv})} \quad \text{(Expression 1)}$$

where,
T_0: Target torque
N: Engine speed (number of revolutions)
A/F_0: Target air fuel ratio
θ_{adv}: Spark advance
K: Constant
F_1, F_2, F_3, : Specified function

EX1008, 3:30-41 (annotated).



EX1008, FIG. 14 (annotated).

Takahashi's target air-mass-flow-rate deciding block 11 is an "air charge demand controller," as recited in claims 3 and 6. EX1003, ¶181. The target air-mass-flow-rate deciding block 11 determines a demand air charge value for the throttle controller 144 based on receiving a desired torque signal, a desired spark angle signal, and a desired air/fuel ratio. *Id*. Indeed, Takahashi's target air-mass-

flow-rate deciding block 11 operates in the same manner as the air charge demand controller 27 disclosed by the '565 patent, which receives a desired torque signal, a desired spark angle signal, and a desired air/fuel ratio and outputs a demand air charge signal to the air charge controller 29. EX1003, ¶181; EX1001, 3:6-12.

It would have been obvious for a POSA to incorporate Takahashi's target air-mass-flow-rate deciding block 11 into Suzuki's torque correction section to output the demand air charge signal to Suzuki's torque control section. EX1003, ¶¶162, 182; EX1008, 1:43-65, 2:17-23, 10:21-27. Indeed, Takahashi expressly discloses that determining the target air mass flow rate based on the target torque, target air/fuel ratio, and spark advance provides precise control of cylinder air charge, ultimately allowing engine torque output to achieve the target torque. EX1008, 1:49-57, 2:17-23, 3:24-51 ("Since it uses a status estimating model which ensures a high precision estimation of the air flow status inside the intake manifold, the present invention…provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque."). Such modification would have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. EX1003, ¶¶162, 182. Accordingly, a POSA would have been motivated to combine the teachings of Takahashi with Suzuki, Cullen, and Scherer so that Suzuki's control

unit converges the engine output torque at the demand torque value with more precision. EX1008, 2:17-23; EX1003, ¶182.

Likewise, a POSA would have been able to easily implement Takahashi's teaching by modifying the software instructions stored in the microcomputer of Suzuki's control unit 20 such that the demand air charge value is calculated according to Takahashi's Expression 1 equation. EX1003, ¶¶163, 183; EX1008, 3:30-41. Indeed, a POSA would have recognized that the target air mass flow rate technique in Takahashi could be applied to Suzuki's torque control section to provide a demand air charge signal that would achieve the demand torque. EX1003, ¶¶163, 183. Accordingly, a POSA would have had a reasonable expectation of success in combining Suzuki and Takahashi. *Id*.

Thus, Suzuki, Cullen, Scherer, and Takahashi render obvious claims 3 and 6. *Id.*, ¶184.

IX. Conclusion

For the reasons above, *inter partes* review and cancellation of claims 1-7 of U.S. Patent No. 6,581,565 is requested.

Respectfully submitted,

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CERTIFICATE OF COMPLIANCE WITH TYPE-VOLUME LIMITATION, TYPEFACE REQUIREMENTS, AND TYPE STYLE REQUIREMENTS

1. This Petition complies with the type-volume limitation of 14,000 words, comprising 13,864 words, excluding the parts exempted by 37 C.F.R. § 42.24(a).

2. This Petition complies with the general format requirements of 37 C.F.R. § 42.6(a) and has been prepared using Microsoft® Word 2010 in 14 point Times New Roman.

Respectfully submitted,

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CERTIFICATION OF SERVICE (37 C.F.R. §§ 42.6(e), 42.105(a))

The undersigned hereby certifies that on January 31, 2020 true and correct copies of the foregoing **PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 6,581,565**, Petitioner's Power of Attorney, and all associated exhibits were served in their entireties on the following parties via FedEx Express® or Express Mail:

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(12) **United States Patent**
Heslop et al.

(10) **Patent No.: US 6,581,565 B2**
(45) **Date of Patent: Jun. 24, 2003**

(54) **ENGINE TORQUE CONTROLLER**

(75) Inventors: **Garon Nigel Heslop**, Billericay (GB); **Jon Dixon**, Maldon (GB); **Richard Stephen Blachford**, Cambridge (GB)

(73) Assignee: **Visteon Global Technologies, Inc.**, Dearborn, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/191,641**

(22) Filed: **Jul. 9, 2002**

(65) **Prior Publication Data**

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(30) **Foreign Application Priority Data**

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(51) **Int. Cl.**[7] **F02D 41/14**; F02B 17/00

(52) **U.S. Cl.** **123/295**; 123/406.23; 123/406.47; 123/478

(58) **Field of Search** 123/295, 350, 123/352, 399, 406.23, 406.47, 406.55, 478, 480, 488

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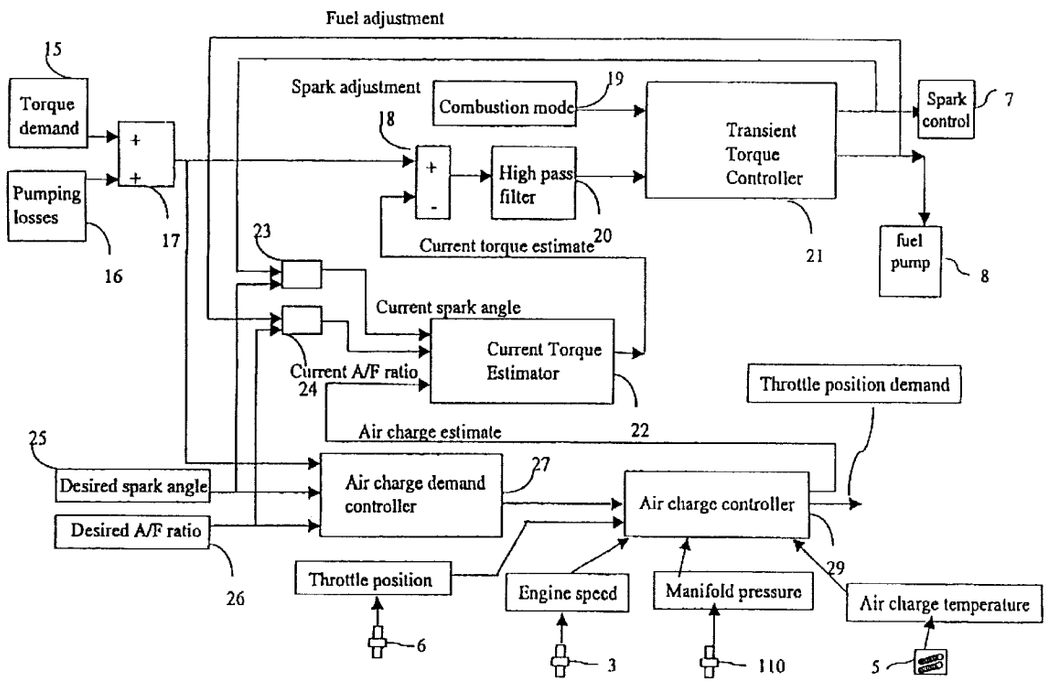
* cited by examiner

Primary Examiner—Tony M. Argenbright
(74) *Attorney, Agent, or Firm*—Brinks Hofer Gilson & Lione

(57) **ABSTRACT**

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines. The invention provides a torque controller and a method of controlling torque for an engine in which torque is controlled in dependence upon a filtered difference signal where the filtered difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque.

7 Claims, 3 Drawing Sheets



VW EX1001
U.S. Patent No. 6,581,565

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

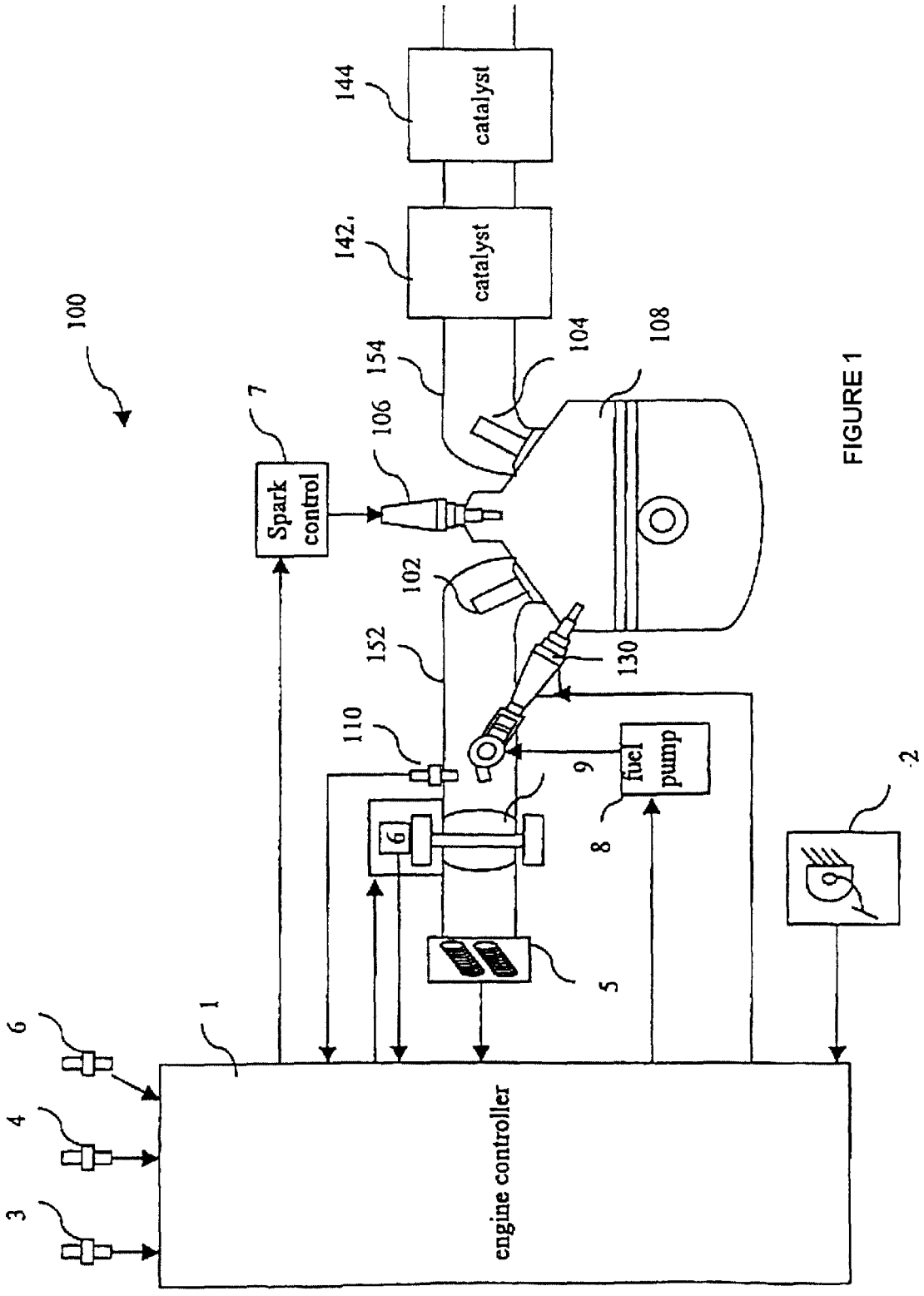

100
144
catalyst
142
catalyst
154
104
108
7
Spark control
106
102
152
130
110
9
fuel pump
8
6
2
5
1
6
4
3
engine controller

FIGURE 1

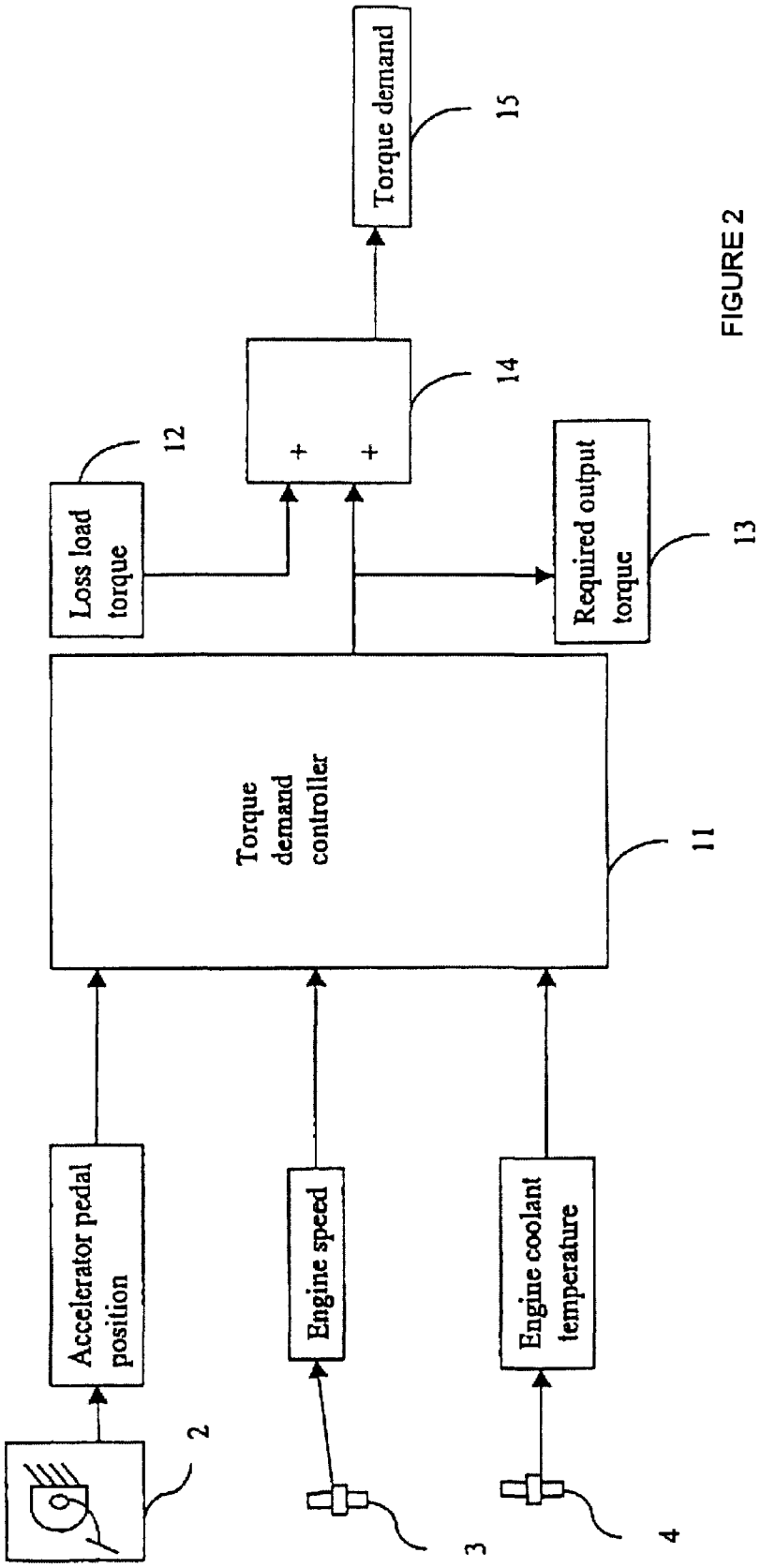

Torque demand
15
14
+
+
12
Loss load torque
Required output torque
13
Torque demand controller
11
Accelerator pedal position
Engine speed
Engine coolant temperature
2
3
4

FIGURE 2

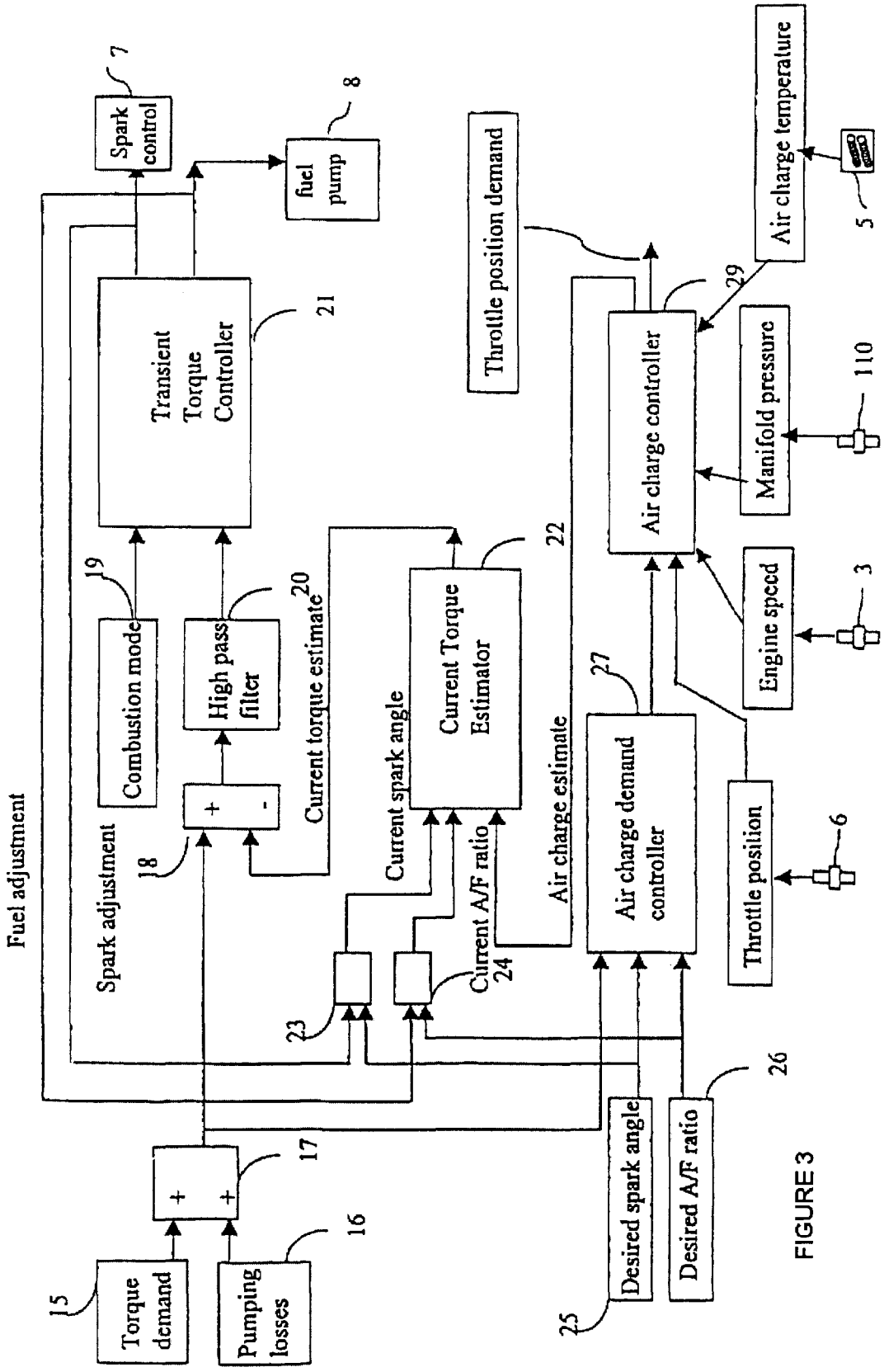

Fuel adjustment
Spark adjustment
Spark control
7
fuel pump
8
Transient Torque Controller
21
Combustion mode
19
High pass filter
20
Current torque estimate
18
+
-
Current spark angle
Current Torque Estimator
22
Current A/F ratio
24
Air charge estimate
23
Throttle position demand
Air charge controller
29
Air charge temperature
5
Manifold pressure
110
Engine speed
3
27
Air charge demand controller
Throttle position
6
Torque demand
15
Pumping losses
16
17
Desired spark angle
25
Desired A/F ratio
26

FIGURE 3

ENGINE TORQUE CONTROLLER

TECHNICAL FIELD

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines.

BACKGROUND

An engine torque controller is comprised of a torque demand controller and a torque producer. The torque demand controller determines a required target torque, in accordance with an accelerator pedal position, current engine speed, external loads and other factors. This determined torque is then used by the torque producer to produce the desired torque by controlling the spark angle and the air/fuel ratio.

Direct Injection Spark Ignition (DISI) engines inject fuel directly into cylinders where it is ignited by a spark from a spark plug. DISI engines operate in a stratified mode or a homogenous mode. When a DISI engine is in the stratified mode, the combustion chambers contain stratified layers having different air/fuel mixtures. The strata closest to the spark plug contains a stoichiometric mixture, which is a mixture in which the exact amount of air to combust the amount of fuel is present, i.e. when the combustion leaves no excess oxygen or unburned fuel. Subsequent strata contain progressively leaner mixtures. Operation in a stratified mode occurs at lower speeds and lower load conditions.

When the engine is in a homogenous mode, a homogenous mixture of air and fuel is introduced into the combustion chamber. Homogenous operation may be either lean of stoichiometry (i.e. higher air/fuel ratio), at stoichiometry, or rich of stoichiometry (i.e. lower air fuel ratio).

In engine torque controllers for DISI engines, when the engine is operating in stratified mode, spark angle has little influence on the torque produced. The torque producer modifies the air/fuel in order to control the torque produced. Conversely, when the engine is operating in homogenous mode, the air/fuel ratio is controlled tightly in order to maintain correct operation of the catalytic converter to reduce noxious emission. The torque producer modifies the timing of the spark ignition in order to control the torque produced.

A problem occurs in either of these modes of operation when there is a steady state error between the torque demanded and the estimate of the torque produced. In the stratified mode if a fuel adjustment occurs due to such a steady state error then the air/fuel ratio will not be ideal and fuel economy will suffer and performance of the catalytic converter will deteriorate. In the homogenous mode, if the timing of the spark ignition is altered due to such a steady state torque error then the fuel economy will once again suffer and the engine is more likely to stall when a load is imposed. Therefore, there is a need for a method of correction for a steady state error between the torque demanded and an estimate of the torque produced.

SUMMARY

In a preferred embodiment, the engine is a direct injection spark ignition engine and the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode. If the signal indicates that the engine is operating in the stratified mode then the fuel and spark controller is arranged to control the fuel adjustment signal. If the signal indicates that the engine is operating in the homogeneous mode then the fuel and spark controller is arranged to control the spark adjustment signal.

Preferably, the controller also has an air charge controller arranged to receive an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal. Preferably, there is also an air charge demand controller arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

According to another aspect of the invention, there is provided a method of controlling torque for an engine. The method includes estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal, comparing the estimated current torque signal with a desired torque signal to provide a difference signal, and filtering low frequency components from the difference signal. Finally, controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

These and other aspects and advantages of the present invention will become apparent upon reading the following detailed description of the invention in combination with the accompanying figures.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a block diagram illustrating part of an engine and an engine controller, in accordance with the present invention;

FIG. **2** is a block diagram of a torque demand controller, in accordance with the present invention; and

FIG. **3** is a block diagram of a torque producer, in accordance with the present invention.

DETAILED DESCRIPTION

FIG. **1** illustrates an embodiment of a direct injection spark ignition engine **100** which has an engine controller **1**. The engine controller **1** receives signals from an accelerator pedal and sensor assembly **2**, an engine speed sensor **3**, an engine temperature sensor **4**, an air charge temperature sensor **5**, a manifold absolute pressure sensor **110** and a throttle position indicator **6**.

A fuel injector **130** injects fuel directly into a combustion chamber **108**. The injected fuel mixes with an air charge which enters through an air intake valve **102** via an air intake manifold **152**. The air charge is controlled by a throttle **9** and the fuel injected is controlled by a fuel pump **8**. A spark control unit **7** controls a spark plug **106**, to generate a spark for ignition of the air/fuel mixture. Exhaust gases from the resulting combustion exit via an exhaust valve **104** into an exhaust manifold **154**. The exhaust manifold **154** has a three way catalytic converter **142** and a Nox trap/catalyst **144**.

FIG. **2** illustrates an embodiment of a torque demand controller **11** that is part of the engine controller **1**. The torque demand controller **11** calculates a required output torque signal **13**, based on an accelerator pedal position signal received from the accelerator pedal and sensor assembly **2**, an engine speed signal received from the engine speed sensor **3** and an engine temperature signal received from the engine temperature sensor **4**. A loss load torque signal **12**, which represents losses due to losses in the engine and powertrain system, is added to the required output torque signal **13** by an adder **14** to generate a torque demand signal **15**.

Referring now to FIG. **3**, an adder **17** receives as inputs the torque demand signal **15** and a pumping losses signal **16**, which represents losses due to the inherent losses in the engine cycle (i.e. due to the energy required to draw air in and to push out exhaust gases). The adder **17** outputs a desired torque signal.

An air charge demand controller **27** receives as inputs the desired torque signal, a desired spark angle signal **25** and a desired air fuel ratio signal **26**. The desired spark angle signal **25** and the desired air fuel ratio signal **26** are calculated elsewhere in the engine controller **1** and depend upon signals such as engine speed, engine load and engine temperature.

The air charge demand controller **27** generates an air charge demand signal that is received by an air charge controller **29**. The air charge controller **29** also receives as inputs a signal indicating throttle position that is received from the throttle position indicator **6** (FIG. **1**), the engine speed sensor **3**, the manifold absolute pressure sensor **110** and the air charge temperature meter **5**. The air charge controller **29** generates a signal indicating desired throttle position that is sent to throttle **9** (FIG. **1**) and a signal representing an estimate of the air charge.

The estimated air charge may be different from the air charge demanded by the air charge demand controller **27** due to delays in the engine **100**, such as the time taken for the throttle **9** to move, the time taken for the pressure in the air intake manifold **152** to rise or fall, or any errors in position of the throttle. The air charge estimate signal is sent to a current torque estimator **22**.

The current torque estimator **22** uses the air charge estimate signal, together with a signal representing the current spark angle and a signal representing the current air/fuel ratio to generate a signal representing an estimate of the current torque.

The estimate of the current torque is compared to the desired torque signal by a comparator **18** to generate an error signal which is then filtered by a high pass filter **20**. The resulting filtered error signal is used by a transient torque controller **21** to generate signals for temporarily adjusting the torque produced by the engine **100**.

A combustion mode signal **19**, which is produced elsewhere in the engine controller **1**, indicates whether the engine **100** is operating in a stratified mode or in a homogenous mode. If the engine **100** is operating in the stratified mode then a fuel adjustment signal is generated and sent to the fuel pump **8** in order to adjust the amount of fuel which is injected into the combustion chamber **108** by the fuel injector **130**. If the engine **100** is operating in the homogenous mode then a spark adjustment signal is generated and sent to the spark control unit **7** to adjust the timing of the ignition spark generated by the spark plug **106**.

The signal representing the current spark angle is calculated by a calculator **23** using the desired spark angle and any spark adjustment signal received from the transient torque controller **21**. The signal representing the current air fuel ratio is calculated by a calculator **24** using the desired air fuel ratio and any fuel adjustment signal received from the transient torque controller **21**. When the engine **100** is operating in stratified mode the current spark angle will be equal to the desired spark angle **25**. When the engine **100** is operating in homogenous mode the current air/fuel ratio will be equal to the desired air fuel ratio **26**.

As any person skilled in the art of systems and methods of controlling the torque output of an engine will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the invention without departing from the scope of this invention defined in the following claims.

What is claimed is:

1. A device for controlling a torque output of an engine, the device comprising:

a torque demand controller for generating a torque demand signal; and

a torque producer which receives the torque demand signal, the torque producer includes:

an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal;

a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal;

a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent; and

a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal.

2. The device in claim **1**, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

3. The device in claim **2**, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel.

4. The device of claim **1**, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode, and

wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode, and

wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode.

5. The device in claim **4**, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

6. The device in claim **5**, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel.

7. A method for controlling a torque output of an engine, the method comprising:

estimating a current torque signal from a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;

comparing the estimated current torque signal with a desired torque signal to output a difference signal;

filtering out a plurality of low frequency components from the difference signal; and

controlling a fuel adjustment signal and a spark adjustment signal in dependence upon a filtered difference signal.

* * * * *

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

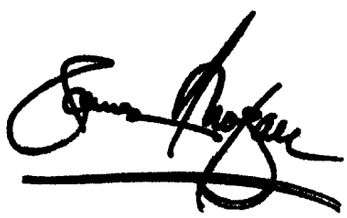
PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4,
Lines 30 and 53, after "air/fuel" insert -- ratio -- before "." (period).

Signed and Sealed this

Twenty-eighth Day of October, 2003



JAMES E. ROGAN
Director of the United States Patent and Trademark Office

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
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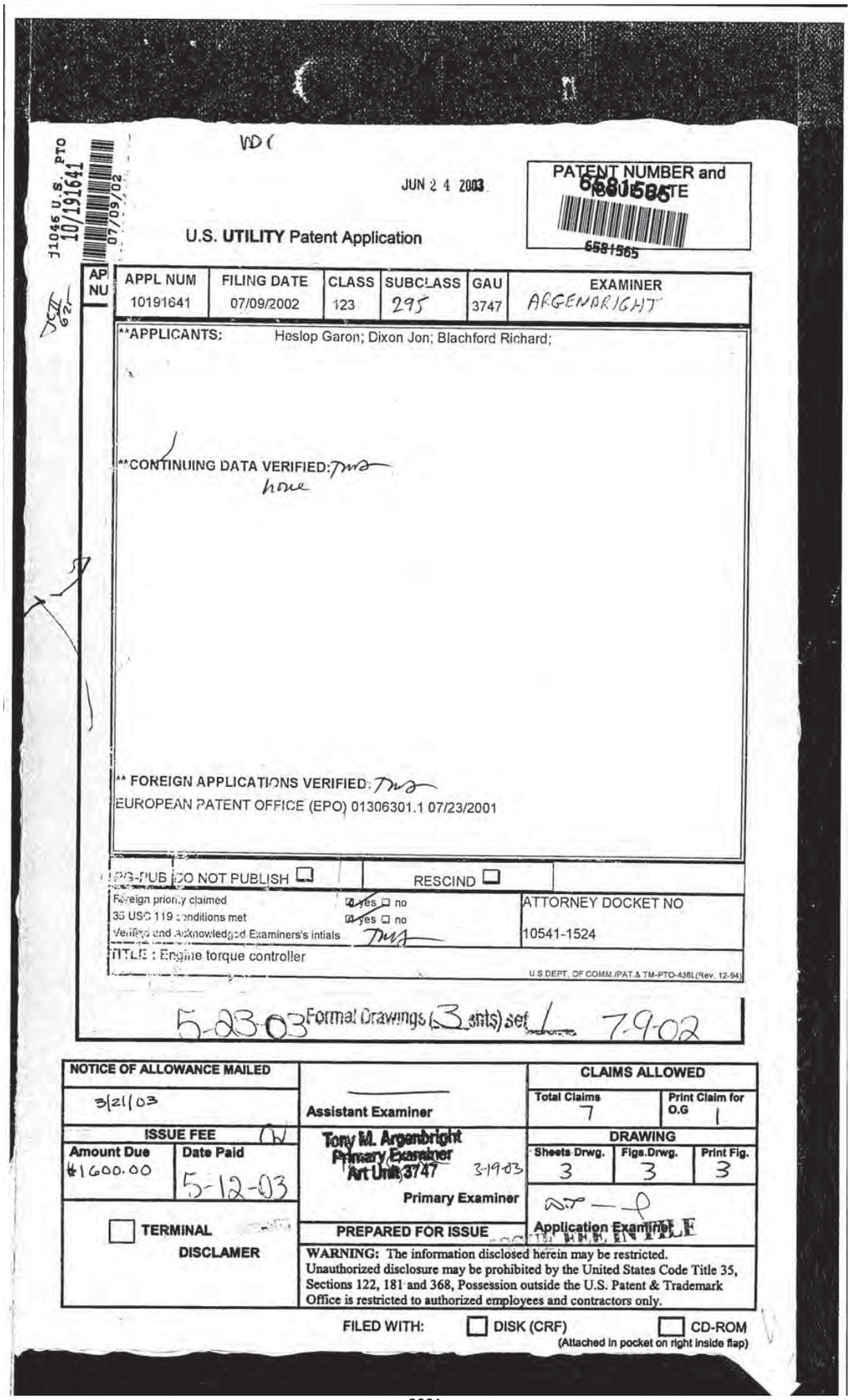
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Signed and Sealed this

Twenty-eighth Day of October, 2003



JAMES E. ROGAN
Director of the United States Patent and Trademark Office



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JUN 2 4 2003

PATENT NUMBER and DATE
6581565

U.S. UTILITY Patent Application

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APPL NUM	FILING DATE	CLASS	SUBCLASS	GAU	EXAMINER
10191641	07/09/2002	123	295	3747	ARGENBRIGHT

**APPLICANTS: Heslop Garon; Dixon Jon; Blachford Richard;

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TITLE : Engine torque controller

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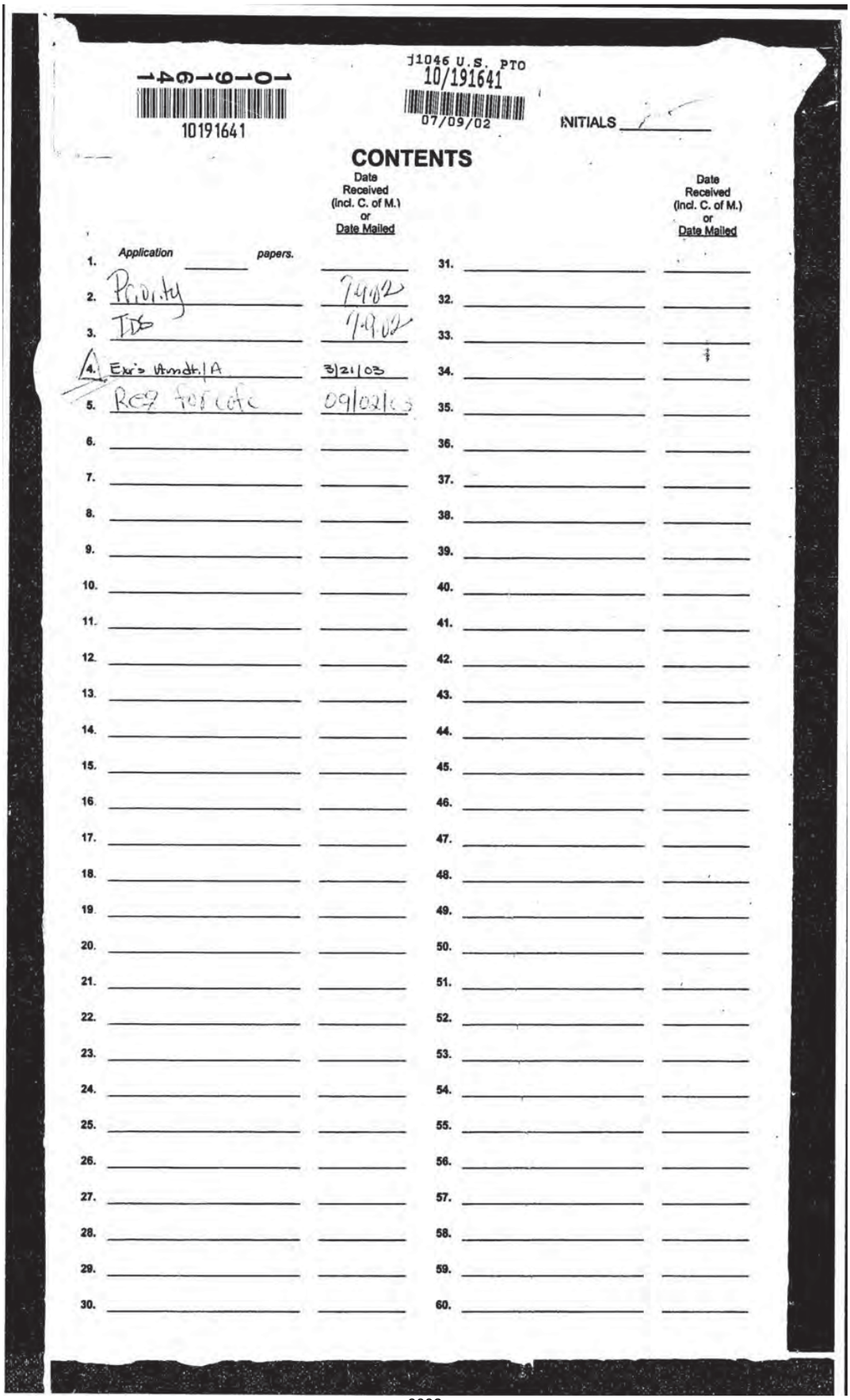
NOTICE OF ALLOWANCE MAILED		CLAIMS ALLOWED	
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ISSUE FEE	Tony M. Argenbright Primary Examiner Art Unit 3747 3-19-03	DRAWING	
Amount Due $1600.00 / Date Paid 5-12-03	Primary Examiner	Sheets Drwg. 3 / Figs.Drwg. 3 / Print Fig. 3	
☐ TERMINAL DISCLAMER	PREPARED FOR ISSUE	Application Examiner	

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FILED WITH: ☐ DISK (CRF) ☐ CD-ROM (Attached in pocket on right inside flap)

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U.S. Patent No. 6,581,565

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565



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INITIALS

CONTENTS

		Date Received (Incl. C. of M.) or Date Mailed			Date Received (Incl. C. of M.) or Date Mailed
1.	Application papers.		31.		
2.	Priority	7/9/02	32.		
3.	IDS	7/9/02	33.		
4.	Ex's Amdt. A	3/21/03	34.		
5.	RCE for cofc	09/02/03	35.		
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PATENT APPLICATION SERIAL NO. _____

U.S. DEPARTMENT OF COMMERCE
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07-10-02 10/191641.020902
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"Express Mail" mailing label number EV 107432431 US
Date of Deposit July 9, 2002

Case No. 10541-1524

PATENT APPLICATION TRANSMITTAL LETTER

To the Commissioner for Patents:

Transmitted herewith for filing is the patent application of: Garon Nigel Heslop; Jon Dixon; and Richard Stephen Blachford for : ENGINE TORQUE CONTROLLER. Enclosed are:

07/09/02 10/191641 U.S. PTO 11046

- ☒ 3 sheet(s) of drawings, 12 pages of application (including title page), and the following Appendices : ____.
- ☒ Declaration.
- ☒ Power of Attorney.
- ☐ Verified statement to establish small entity status under 37 CFR §§ 1.9 and 1.27.
- ☒ Assignment transmittal letter and Assignment of the invention to : Visteon Global Technologies, Inc..
- ☒ Certified Copy of European Priority Document; Information Disclosure Statement, Form PTO 1449 with references; Two Return Postcards.

Claims as Filed	Col. 1	Col. 2	Small Entity			Other Than Small Entity	
For	No. Filed	No. Extra	Rate	Fee	or	Rate	Fee
Basic Fee				$ 370	or		$ 740
Total Claims	7-20		x$9=	$	or	x$18=	$0
Indep. Claims	2-3		x$42=	$	or	x$84=	$0
Multiple Dependent Claims Present			+$140=	$	or	+$280=	$0
*If the difference in col. 1 is less than zero, enter "0" in col. 2.			Total	$	or	Total	$740.00

- ☒ Please charge my Deposit Account No. 06-1500 in the amount of $: 740.00. A duplicate copy of this sheet is enclosed.
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  - ☐ Any filing fees under 37 CFR § 1.16 for presentation of extra claims.
  - ☐ Any patent application processing fees under 37 CFR § 1.17.
  - ☐ The issue fee set in 37 CFR § 1.18 at or before mailing of the Notice of Allowance, pursuant to 37 CFR § 1.311(b).

July 9, 2002
Date

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IN THE UNITED STATES PATENT AND TRADEMARK OFFICE
APPLICATION FOR UNITED STATES LETTERS PATENT

INVENTORS: GARON NIGEL HESLOP
JON DIXON
RICHARD STEPHEN BLACHFORD

TITLE: **ENGINE TORQUE CONTROLLER**

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PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Attorney Docket No.: 10541-1524
Visteon Disclosure No.: V200-0895

ENGINE TORQUE CONTROLLER

TECHNICAL FIELD

[0001] This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines.

BACKGROUND

[0002] An engine torque controller is comprised of a torque demand controller and a torque producer. The torque demand controller determines a required target torque, in accordance with an accelerator pedal position, current engine speed, external loads and other factors. This determined torque is then used by the torque producer to produce the desired torque by controlling the spark angle and the air/fuel ratio.

[0003] Direct Injection Spark Ignition (DISI) engines inject fuel directly into cylinders where it is ignited by a spark from a spark plug. DISI engines operate in a stratified mode or a homogenous mode. When a DISI engine is in the stratified mode, the combustion chambers contain stratified layers having different air/fuel mixtures. The strata closest to the spark plug contains a stoichiometric mixture, which is a mixture in which the exact amount of air to combust the amount of fuel is present, i.e. when the combustion leaves no excess oxygen or unburned fuel. Subsequent strata contain progressively leaner mixtures. Operation in a stratified mode occurs at lower speeds and lower load conditions.

[0004] When the engine is in a homogenous mode, a homogenous mixture of air and fuel is introduced into the combustion chamber. Homogenous operation may

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be either lean of stoichiometry (i.e. higher air/fuel ratio), at stoichiometry, or rich of stoichiometry (i.e. lower air fuel ratio).

[0005] In engine torque controllers for DISI engines, when the engine is operating in stratified mode, spark angle has little influence on the torque produced. The torque producer modifies the air/fuel in order to control the torque produced. Conversely, when the engine is operating in homogenous mode, the air/fuel ratio is controlled tightly in order to maintain correct operation of the catalytic converter to reduce noxious emission. The torque producer modifies the timing of the spark ignition in order to control the torque produced.

[0006] A problem occurs in either of these modes of operation when there is a steady state error between the torque demanded and the estimate of the torque produced. In the stratified mode if a fuel adjustment occurs due to such a steady state error then the air/fuel ratio will not be ideal and fuel economy will suffer and performance of the catalytic converter will deteriorate. In the homogenous mode, if the timing of the spark ignition is altered due to such a steady state torque error then the fuel economy will once again suffer and the engine is more likely to stall when a load is imposed. Therefore, there is a need for a method of correction for a steady state error between the torque demanded and an estimate of the torque produced.

SUMMARY

[0007] In a preferred embodiment, the engine is a direct injection spark ignition engine and the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode. If the signal indicates that the engine is operating in

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the stratified mode then the fuel and spark controller is arranged to control the fuel adjustment signal. If the signal indicates that the engine is operating in the homogeneous mode then the fuel and spark controller is arranged to control the spark adjustment signal.

[0008] Preferably, the controller also has an air charge controller arranged to receive an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal. Preferably, there is also an air charge demand controller arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

[0009] According to another aspect of the invention, there is provided a method of controlling torque for an engine. The method includes estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal, comparing the estimated current torque signal with a desired torque signal to provide a difference signal, and filtering low frequency components from the difference signal. Finally, controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

[0010] These and other aspects and advantages of the present invention will become apparent upon reading the following detailed description of the invention in combination with the accompanying figures.

BRIEF DESCRIPTION OF THE FIGURES

[0011] FIGURE 1 is a block diagram illustrating part of an engine and an engine controller, in accordance with the present invention;

[0012] FIGURE 2 is a block diagram of a torque demand controller, in accordance with the present invention; and

[0013] FIGURE 3 is a block diagram of a torque producer, in accordance with the present invention.

DETAILED DESCRIPTION

[0014] Figure 1 illustrates an embodiment of a direct injection spark ignition engine 100 which has an engine controller 1. The engine controller 1 receives signals from an accelerator pedal and sensor assembly 2, an engine speed sensor 3, an engine temperature sensor 4, an air charge temperature sensor 5, a manifold absolute pressure sensor 110 and a throttle position indicator 6.

[0015] A fuel injector 130 injects fuel directly into a combustion chamber 108. The injected fuel mixes with an air charge which enters through an air intake valve 102 via an air intake manifold 152. The air charge is controlled by a throttle 9 and the fuel injected is controlled by a fuel pump 8. A spark control unit 7 controls a spark plug 106, to generate a spark for ignition of the air/fuel mixture. Exhaust gases from the resulting combustion exit via an exhaust valve 104 into an exhaust manifold 154. The exhaust manifold 154 has a three way catalytic converter 142 and a Nox trap/catalyst 144.

[0016] Figure 2 illustrates an embodiment of a torque demand controller 11 that is part of the engine controller 1. The torque demand controller 11 calculates a required output torque signal 13, based on an accelerator pedal position signal

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received from the accelerator pedal and sensor assembly 2, an engine speed signal received from the engine speed sensor 3 and an engine temperature signal received from the engine temperature sensor 4. A loss load torque signal 12, which represents losses due to losses in the engine and powertrain system, is added to the required output torque signal 13 by an adder 14 to generate a torque demand signal 15.

[0017] Referring now to Figure 3, an adder 17 receives as inputs the torque demand signal 15 and a pumping losses signal 16, which represents losses due to the inherent losses in the engine cycle (i.e. due to the energy required to draw air in and to push out exhaust gases). The adder 17 outputs a desired torque signal.

[0018] An air charge demand controller 27 receives as inputs the desired torque signal, a desired spark angle signal 25 and a desired air fuel ratio signal 26. The desired spark angle signal 25 and the desired air fuel ratio signal 26 are calculated elsewhere in the engine controller 1 and depend upon signals such as engine speed, engine load and engine temperature.

[0019] The air charge demand controller 27 generates an air charge demand signal that is received by an air charge controller 29. The air charge controller 29 also receives as inputs a signal indicating throttle position that is received from the throttle position indicator 6 (Figure 1), the engine speed sensor 3, the manifold absolute pressure sensor 110 and the air charge temperature meter 5. The air charge controller 29 generates a signal indicating desired throttle position that is sent to throttle 9 (Figure 1) and a signal representing an estimate of the air charge.

[0020] The estimated air charge may be different from the air charge demanded by the air charge demand controller 27 due to delays in the engine 100,

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such as the time taken for the throttle 9 to move, the time taken for the pressure in the air intake manifold 152 to rise or fall, or any errors in position of the throttle. The air charge estimate signal is sent to a current torque estimator 22.

[0021] The current torque estimator 22 uses the air charge estimate signal, together with a signal representing the current spark angle and a signal representing the current air/fuel ratio to generate a signal representing an estimate of the current torque.

[0022] The estimate of the current torque is compared to the desired torque signal by a comparator 18 to generate an error signal which is then filtered by a high pass filter 20. The resulting filtered error signal is used by a transient torque controller 21 to generate signals for temporarily adjusting the torque produced by the engine 100.

[0023] A combustion mode signal 19, which is produced elsewhere in the engine controller 1, indicates whether the engine 100 is operating in a stratified mode or in a homogenous mode. If the engine 100 is operating in the stratified mode then a fuel adjustment signal is generated and sent to the fuel pump 8 in order to adjust the amount of fuel which is injected into the combustion chamber 108 by the fuel injector 130. If the engine 100 is operating in the homogenous mode then a spark adjustment signal is generated and sent to the spark control unit 7 to adjust the timing of the ignition spark generated by the spark plug 106.

[0024] The signal representing the current spark angle is calculated by a calculator 23 using the desired spark angle and any spark adjustment signal received from the transient torque controller 21. The signal representing the current air fuel ratio is calculated by a calculator 24 using the desired air fuel ratio and any

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fuel adjustment signal received from the transient torque controller 21. When the engine 100 is operating in stratified mode the current spark angle will be equal to the desired spark angle 25. When the engine 100 is operating in homogenous mode the current air/fuel ratio will be equal to the desired air fuel ratio 26.

[0025] As any person skilled in the art of systems and methods of controlling the torque output of an engine will recognize from the previous detailed description and from the figures and claims, modifications and changes can be made to the preferred embodiments of the invention without departing from the scope of this invention defined in the following claims.

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CLAIMS

1. A device for controlling a torque output of an engine, the device comprising:

a torque demand controller for generating a torque demand signal; and

a torque producer which receives the torque demand signal, the torque producer includes:

an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal;

a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal;

a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent; and

a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal.

2. The device in claim 1, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

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3. The device in claim 2, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel ratio.

4. The device of claim 1, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode, and

wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode, and

wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode.

5. The device in claim 4, wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal.

6. The device in claim 5, wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel.

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7. A method for controlling a torque output of an engine, the method comprising:

estimating a current torque signal from a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;

comparing the estimated current torque signal with a desired torque signal to output a difference signal;

filtering out a plurality of low frequency components from the difference signal; and

controlling a fuel adjustment signal and a spark adjustment signal in dependence upon a filtered difference signal.

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Attorney Docket No.: 10541-1524
Visteon Disclosure No.: V200-0895

ABSTRACT

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines. The invention provides a torque controller and a method of controlling torque for an engine in which torque is controlled in dependence upon a filtered difference signal where the filtered difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque.

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Attorney Docket No.: 10541-1524
Visteon Case No.: V200-0895

DECLARATION AND POWER OF ATTORNEY ORIGINAL APPLICATION

As a below named inventor, I hereby declare:

My residence, post office address and citizenship are as stated below next to my name;

I believe I am the original, first and sole inventor or an original, first and joint inventor of the subject matter that is claimed and for which a patent is sought on the invention entitled:

ENGINE TORQUE CONTROLLER

the specification of which (check one)

_X_ is attached hereto.

____ was filed on _____ as United States Application Serial No. _____ and was amended on _____ (if applicable).

I acknowledge my duty to disclose to the United States Patent and Trademark Office all information that I know to be material to the patentability of this application as defined in Title 37 C.F.R. § 1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, Section 119(a)-(d) or Section 365(b) of any foreign application(s) for patent or inventor's certificate, or Section 365(a) of any PCT International application which designated at least one country other than the United States, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate or PCT International application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application(s):			Priority Not Claimed
01306301.1 (Number)	Europe (Country)	23 July 2001 (Filing Date)	☐
_____ (Number)	_____ (Country)	_____ (Filing Date)	☐
_____ (Number)	_____ (Country)	_____ (Filing Date)	☐

I hereby claim the benefit under 35 U.S. C. Section 119(e) of any United States provisional application(s) listed below:

_____ (Application Serial No.)	_____ (Filing Date)
_____ (Application Serial No.)	_____ (Filing Date)
_____ (Application Serial No.)	_____ (Filing Date)

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US PATENT NO. 6,581,565

I hereby claim the benefit under 35 U.S.C. Section 120 of any United States applications(s), or Section 365(c) of any PCT International Application designating the United States, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT International application in the manner provided by the first paragraph of 35 U.S.C. Section 112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, C.F.R., Section 1.56 which became available between the filing date of the prior application and the national or PCT International filing date of this application.

(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)
(Application Serial No.)	(Filing Date)	(Status: patented, pending, abandoned)

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

POWER OF ATTORNEY: As a named inventor, I hereby appoint the attorneys, agents, and each shareholder, attorney of counsel, associate, and employee of Brinks Hofer Gilson & Lione, who is a registered Patent Attorney or registered Patent Agent, and who is associated with the customer number printed below, my attorney with full power of substitution and revocation to prosecute this application and transact all business in the United States Patent and Trademark Office connected therewith and to act on my behalf before the competent International Authorities in connection with any and all international applications filed by me.

29074

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PATENT TRADEMARK OFFICE

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Fourth inventor's signature	Date
Residence	
Citizenship	
Post Office Address	

Full name of fifth inventor, if any	
Fifth inventor's signature	Date
Residence	
Citizenship	
Post Office Address	

Full name of sixth inventor, if any	
Sixth inventor's signature	Date
Residence	
Citizenship	
Post Office Address	

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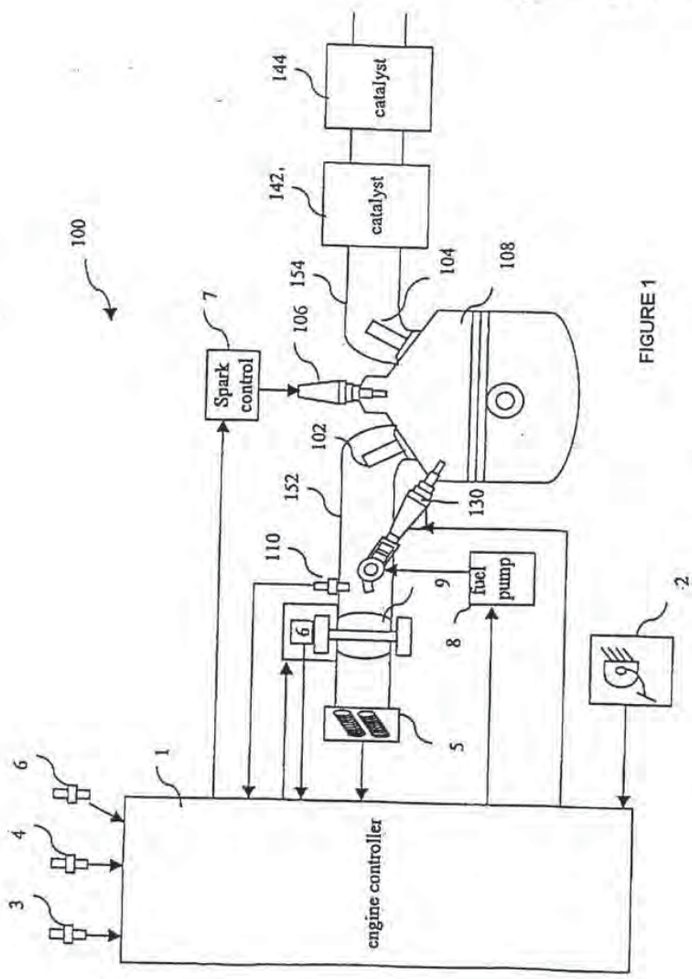


FIGURE 1

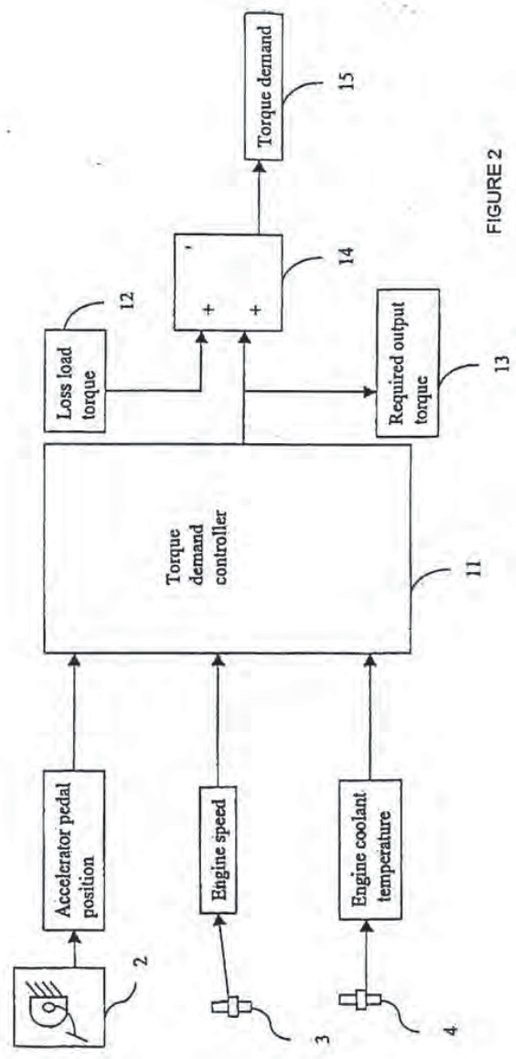

Torque demand
15
14
+
+
12
Loss load torque
Required output torque
13
Torque demand controller
11
Accelerator pedal position
Engine speed
Engine coolant temperature
2
3
4

FIGURE 2

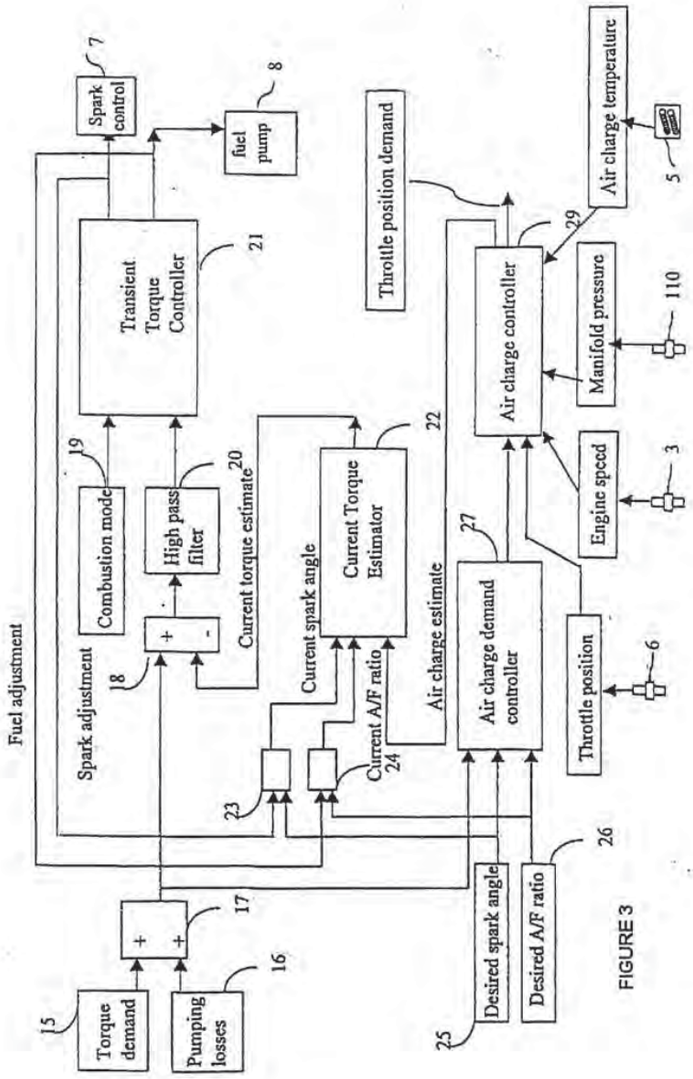

Fuel adjustment
Spark adjustment
Torque demand
Pumping losses
Combustion mode
High pass filter
Current torque estimate
Transient Torque Controller
Spark control
fuel pump
Current spark angle
Current A/F ratio
Current Torque Estimator
Air charge estimate
Throttle position demand
Air charge controller
Air charge demand controller
Desired spark angle
Desired A/F ratio
Throttle position
Engine speed
Manifold pressure
Air charge temperature
15
16
17
18
19
20
21
22
23
24
25
26
27
29
3
5
6
7
8
110

FIGURE 3

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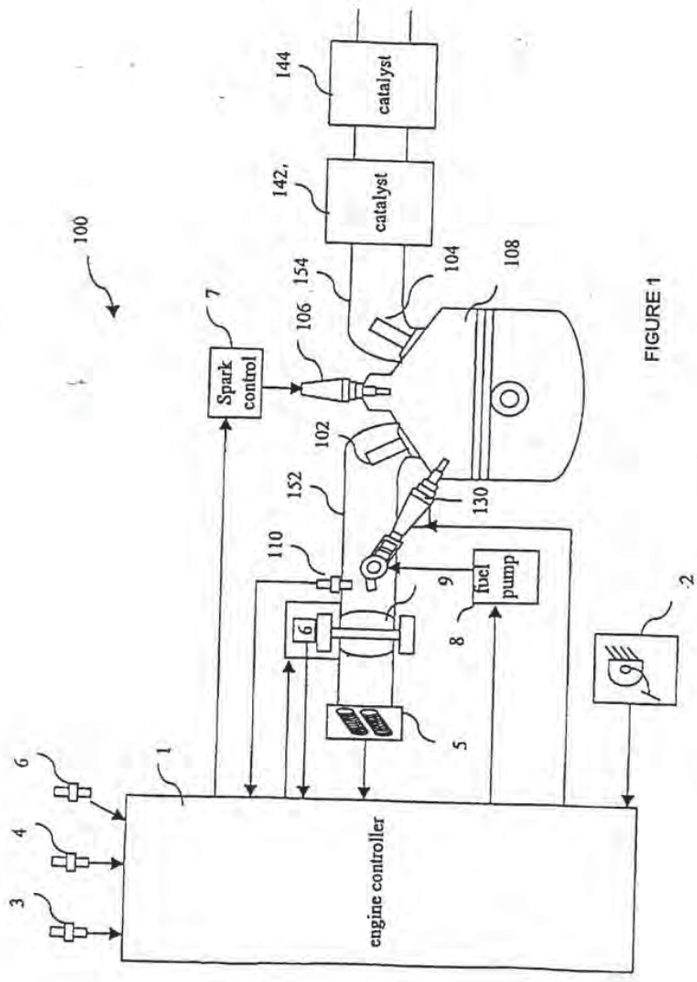


FIGURE 1

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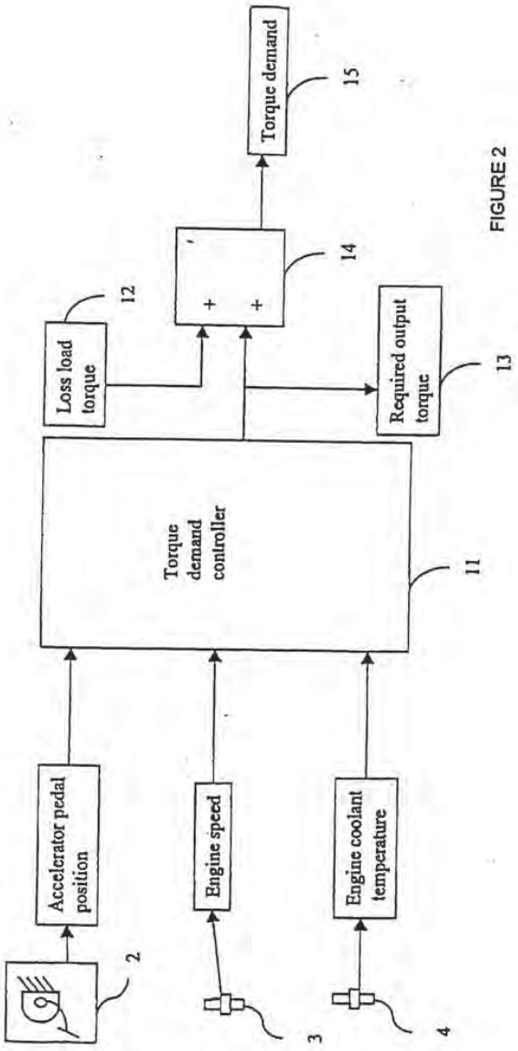


FIGURE 2

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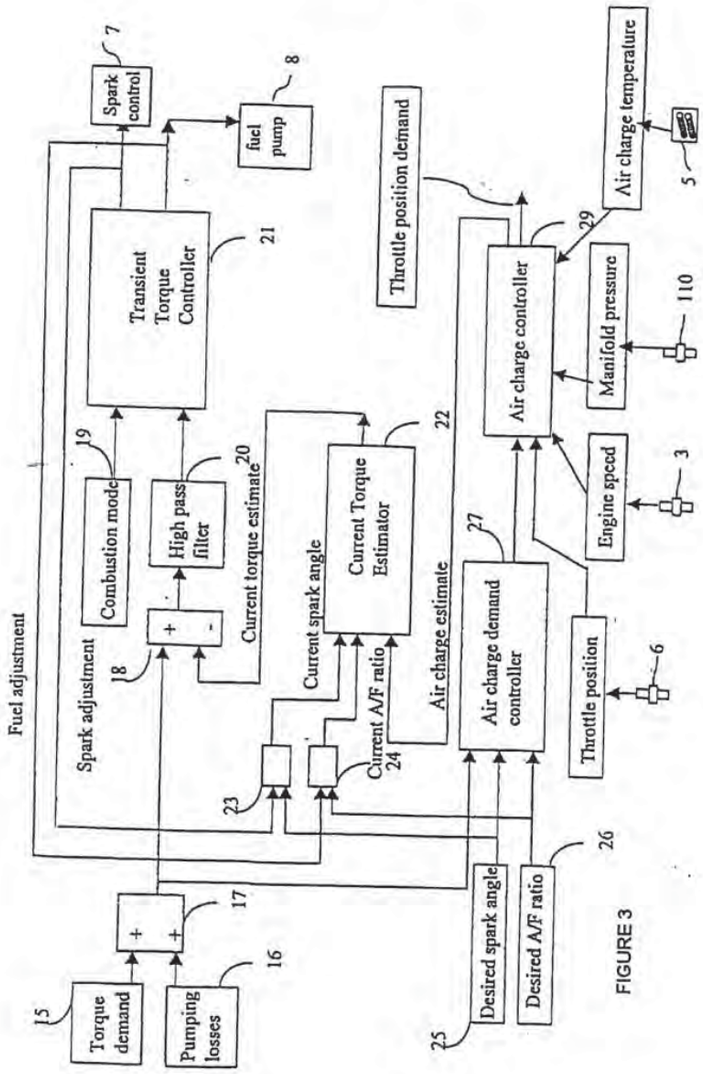


FIGURE 3

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#2

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11046 U.S. PTO
10/191641
07/09/02

Bescheinigung | Certificate | Attestation

Die angehefteten Unterlagen stimmen mit der ursprünglich eingereichten Fassung der auf dem nächsten Blatt bezeichneten europäischen Patentanmeldung überein.

The attached documents are exact copies of the European patent application described on the following page, as originally filed.

Les documents fixés à cette attestation sont conformes à la version initialement déposée de la demande de brevet européen spécifiée à la page suivante.

Patentanmeldung Nr. | Patent application No. | Demande de brevet n°

01306301.1

Der Präsident des Europäischen Patentamts;
Im Auftrag

For the President of the European Patent Office

Le Président de l'Office européen des brevets
p.o.

R C van Dijk

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THE HAGUE, 10/05/02
LA HAYE, LE

EPA/EPO/OEB Form 1014 - 02.91

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Blatt 2 der Bescheinigung
Sheet 2 of the certificate
Page 2 de l'attestation

Anmeldung Nr.: Application no.: Demande n°: 01306301.1

Anmeldetag: Date of filing: Date de dépôt: 23/07/01

Anmelder: Applicant(s): Demandeur(s):
Visteon Global Technologies, Inc.
Dearborn, Michigan 48126-2490
UNITED STATES OF AMERICA

Bezeichnung der Erfindung: Title of the invention: Titre de l'invention:
Engine torque controller

In Anspruch genommene Priorität(en) / Priority(ies) claimed / Priorité(s) revendiquée(s)

Staat: State: Pays:	Tag: Date: Date:	Aktenzeichen: File no. Numéro de dépôt:

Internationale Patentklassifikation: International Patent classification: Classification internationale des brevets:
F02D41/30, F02D41/14

Am Anmeldetag benannte Vertragstaaten: Contracting states designated at date of filing: Etats contractants désignés lors du dépôt:
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ENGINE TORQUE CONTROLLER

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines.

An engine torque controller comprises a torque demand controller, and a torque producer. The torque demand controller determines a required target torque, in accordance with an accelerator pedal position, current engine speed, external loads and the like. This determined torque is then used by the torque producer to produce the desired torque by control of sparking angle and air/fuel ratio.

Direct Injection Spark Ignition (DISI) engines inject fuel directly into cylinders where it is ignited by a spark from a spark plug. DISI engines operate in a stratified mode or a homogenous mode. When a DISI engine is in the stratified mode, the combustion chambers contain stratified layers with different air/fuel mixtures. The strata closest to the spark plug contains a stoichiometric mixture, which is a mixture in which there is exactly the amount of air to combust the amount of fuel present, i.e. when combusted leaves no excess oxygen of unburned fuel. Subsequent strata contain progressively leaner mixtures. Operation in stratified mode occurs at lower speeds and lower load conditions.

When the engine is in the homogeneous mode, a homogeneous mixture of air and fuel is introduced into the combustion

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chamber. Homogeneous operation may be either lean of stoichiometry (i.e. higher air/fuel ratio), at stoichiometry, or rich of stoichiometry (i.e. lower air/fuel ratio).

In engine torque controllers for DISI engines, when the engine is operating in stratified mode, spark angle has little influence on the torque produced. The torque producer modifies the air/fuel ratio in order to control the torque produced. Conversely, when the engine is operating in homogenous mode the air/fuel ratio is controlled tightly, in order to maintain correct operation of a catalytic converter to reduces noxious emissions, and the torque producer modifies the timing of the spark ignition in order to control the torque produced.

A problem occurs in either of these modes of operation when there is a steady state error between the torque demanded and an estimate of the torque produced. In the stratified mode if a fuel adjustment occurs due to such a steady state error then the air/fuel ratio will not be ideal, and fuel economy will suffer and performance of the catalytic converters will deteriorate. In the homogenous mode if the timing of the spark ignition is altered due to such a steady state torque error, then fuel economy will suffer once again, and the engine is more likely to stall when a load is imposed.

This invention serves to alleviate the aforementioned problems.

According to the present invention there is provided a

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torque controller for an engine, the torque controller comprising a torque demand controller and a torque producer, in which the torque producer comprises

an estimator arranged to receive a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal; and arranged to output an estimated torque signal;

a comparator arranged to receive the estimated torque signal and the desired torque signal, and arranged to output a difference signal; and

a high pass filter arranged to receive the difference signal and output a filtered signal in which low frequency components are absent; and

a transient torque controller arranged to receive the filtered signal and to output a fuel adjustment signal and a spark adjustment signal in dependence thereon.

In a preferred embodiment, the engine is a direct injection spark ignition engine and the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode. If the signal indicates that the engine is operating in the stratified mode then the fuel and spark controller is arranged to control the fuel adjustment signal. If the signal indicates that the engine is operating in the homogeneous mode then the fuel and spark controller is arranged to control the spark adjustment signal.

Preferably the controller also has an air charge controller arranged to receive an air charge demand signal, a throttle

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position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal. Preferably there is also an air charge demand controller arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

According to a second aspect of the invention there is provided a method of controlling torque for an engine comprising the steps of

estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;

comparing the estimated current torque signal with a desired torque signal to provide a difference signal;

filtering low frequency components from the difference signal; and

controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

An embodiment of the invention will now be described, by way of example only, with reference to the accompanying drawings in which:

Figure 1 is a schematic diagram illustrating part of an engine and an engine controller;

Figure 2 is a schematic block diagram of a torque demand

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controller; and

Figure 3 is a schematic block diagram of a torque producer.

Figure 1 illustrates an embodiment of a direct injection spark ignition engine 100 which has an engine controller 1. The engine controller 1 receives signals from an accelerator pedal and sensor assembly 2, an engine speed sensor 3, an engine temperature sensor 4, an air charge temperature sensor 5, a manifold absolute pressure sensor 110 and a throttle position indicator 6.

A fuel injector 130 injects fuel directly into a combustion chamber 108. The injected fuel mixes with an air charge which enters through an air intake valve 102 via an air intake manifold 152. The air charge is controlled by a throttle 9 and the fuel injected is controlled by a fuel pump 8. A spark control unit 7 controls a spark plug 106, to generate a spark for ignition of the air/fuel mixture. Exhaust gases from the resulting combustion exit via an exhaust valve 104 into an exhaust manifold 154. The exhaust manifold 154 has a three way catalytic converter 142 and a Nox trap/catalyst 144.

Figure 2 illustrates schematically a torque demand controller 11 which is part of the engine controller 1. The torque demand controller 11 calculates a required output torque signal 13, based on an accelerator pedal position signal received from the accelerator pedal and sensor assembly 2, an engine speed signal received from the engine speed sensor 3 and an engine temperature signal received from the engine temperature sensor 4. A loss load torque

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signal 12, which represents losses due to losses in the engine and power train system, is added to the required output torque signal 13, at an adder 14 to generate a torque demand signal 15.

Referring now to Figure 3, the torque demand signal 15 is added to a pumping losses signal 16, which represents losses due to the inherhent losses in the engine cycle (i.e. due to the energy required to draw air in and to push out exhaoust gases) at an adder 17 to generate a desired torque signal.

An air charge demand controller 27 is arranged to receive the desired torque signal, together with a desired spark angle signal 25 and a desired air fuel ratio signal 26. The desired spark angle signal 25 and the desired air fuel ratio signal 26 are calculated elsewhere in the engine controller 1, and depend upon signals such as engine speed, engine load and engine temperature.

The air charge demand controller 27 generates an air charge demand signal, which is received by an air charge controller 29, together with a signal indicating throttle position which is received from the throttle position indicator 6 (figure 1). The air charge controller 29 generates a signal indicating desired throttle position, which is sent to the throttle 9 (figure 1).

The air charge controller 29 also receives signals from the engine speed sensor 3, the manifold absolute pressure sensor 110 and the air charge temperature meter 5. The air charge controller uses these received signals to generate a

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signal representing an estimate of the air charge. This estimated air charge may be different to the air charge demanded by the air charge demand controller 27 due to delays in the engine 100, such as the time taken for the throttle 9 to move, or the time taken for the pressure in the air intake manifold 152 to rise or fall, or any errors in position of the throttle. The air charge estimate signal is sent to a current torque estimator 22.

The current torque estimator 22 uses the air charge estimate signal, together with a signal representing the current spark angle and a signal representing the current air/fuel ratio to generate a signal representing an estimate of the current torque.

The estimate of the current torque is compared to the desired torque signal by a comparator 18 to generate an error signal which is then filtered by a high pass filter 20. The resulting filtered error signal is used by a transient torque controller 21 to generate signals for temporarily adjusting the torque produced by the engine 100.

A combustion mode signal 19, which is produced elsewhere in the engine controller 1, indicates whether the engine 100 is operating in stratified mode or in homogenous mode. If the engine 100 is operating in stratified mode then a fuel adjustment signal is generated and sent to the fuel pump 8 in order to adjust the amount of fuel which is injected into the combustion chamber 108 by the fuel injector 130. If the engine 100 is operating in the homogenous mode then a spark adjustment signal is generated and sent to the

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spark control unit 7 to adjust the timing of the ignition spark generated by the spark plug 106.

The signal representing the current spark angle is calculated by a calculator 23 using the desired spark angle and any spark adjustment signal received from the transient torque controller 21. The signal representing the current air fuel ratio is calculated by a calculator 24 using the desired air fuel ratio and any fuel adjustment signal received from the transient torque controller 21. When the engine 100 is operating in stratified mode the current spark angle will be equal to the desired spark angle 25. When the engine 100 is operating in homogenous mode the current air/fuel ratio will be equal to the desired air fuel ratio 26.

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CLAIMS

1. A torque controller for an engine, the torque controller comprising a torque demand controller (1) and a torque producer, in which the torque producer comprises

an estimator (22) arranged to receive a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal; and arranged to output an estimated torque signal;

a comparator (18) arranged to receive the estimated torque signal and a desired torque signal, and arranged to output a difference signal; and

a high pass filter (20) arranged to receive the difference signal and output a filtered signal in which low frequency components are absent; and

a transient torque controller (21) arranged to receive the filtered signal and to output a fuel adjustment signal and a spark adjustment signal in dependence thereon.

2. A torque controller according to claim 1, in which

the engine is a direct injection spark ignition engine;

the transient torque controller (21) is arranged to receive a combustion mode signal (19) indicating whether the engine is operating in a stratified mode or a homogeneous mode;

the transient torque controller (21) is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode ; and

the transient torque controller is arranged to control

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the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode.

3. A torque controller according to claim 1 or claim 2, further comprising an air charge controller (29) arranged to receive an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal and arranged to output the estimated air charge signal.

4. A torque controller according to claim 4 further comprising an air charge demand controller (20) arranged to receive the desired torque signal, a desired spark angle signal and a desired air/fuel ratio signal and to output the air charge demand signal.

5. A method of controlling torque for an engine comprising the steps of

estimating a current torque signal in dependence upon a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;

comparing the estimated current torque signal with a desired torque signal to provide a difference signal;

filtering low frequency components from the difference signal; and

controlling a fuel adjustment signal and a spark adjustment signal in dependence upon the filtered difference signal.

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ABSTRACT

Engine Torque Controller

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines. The invention provides a torque controller and a method of controlling torque for an engine, in which torque is controlled in dependence upon a filtered difference signal where the filtered difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque.

Figure 3

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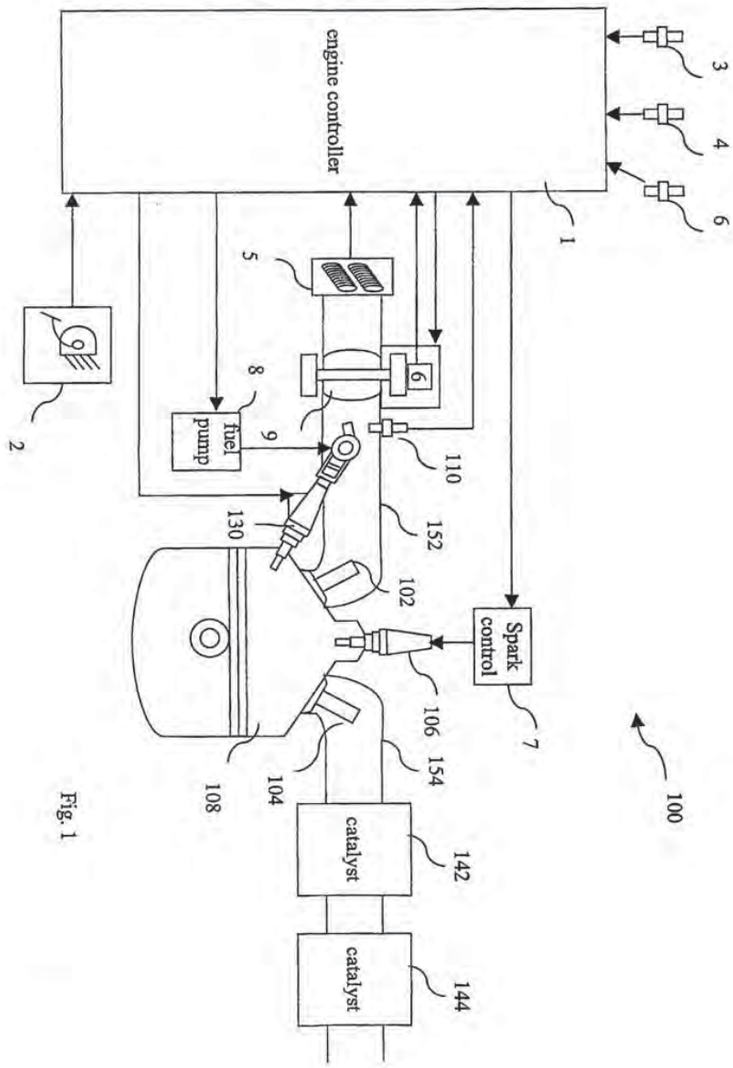


Fig. 1

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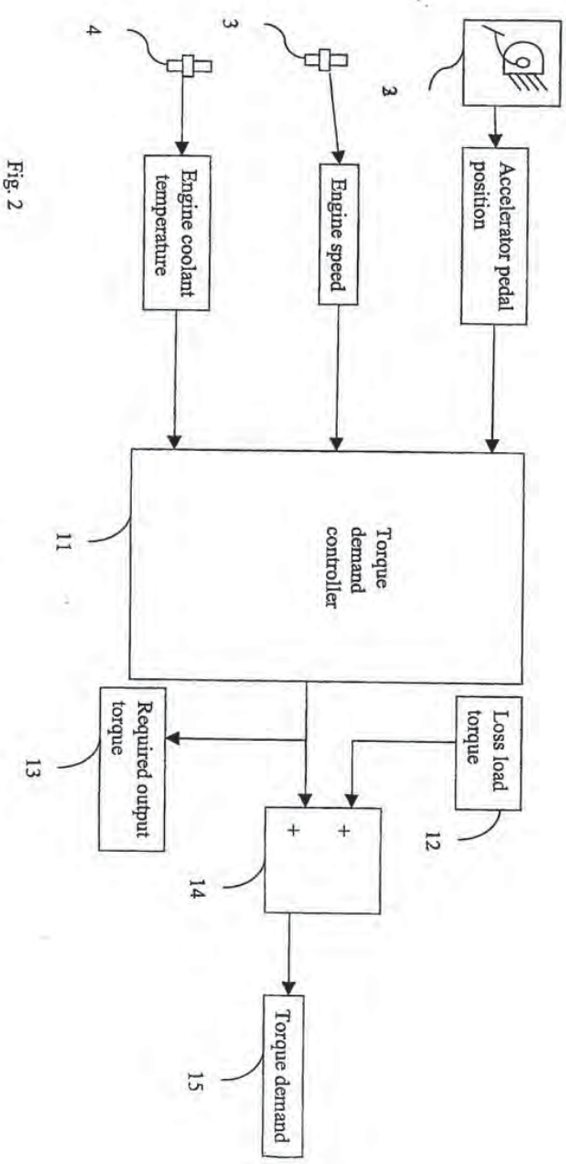


Fig. 2

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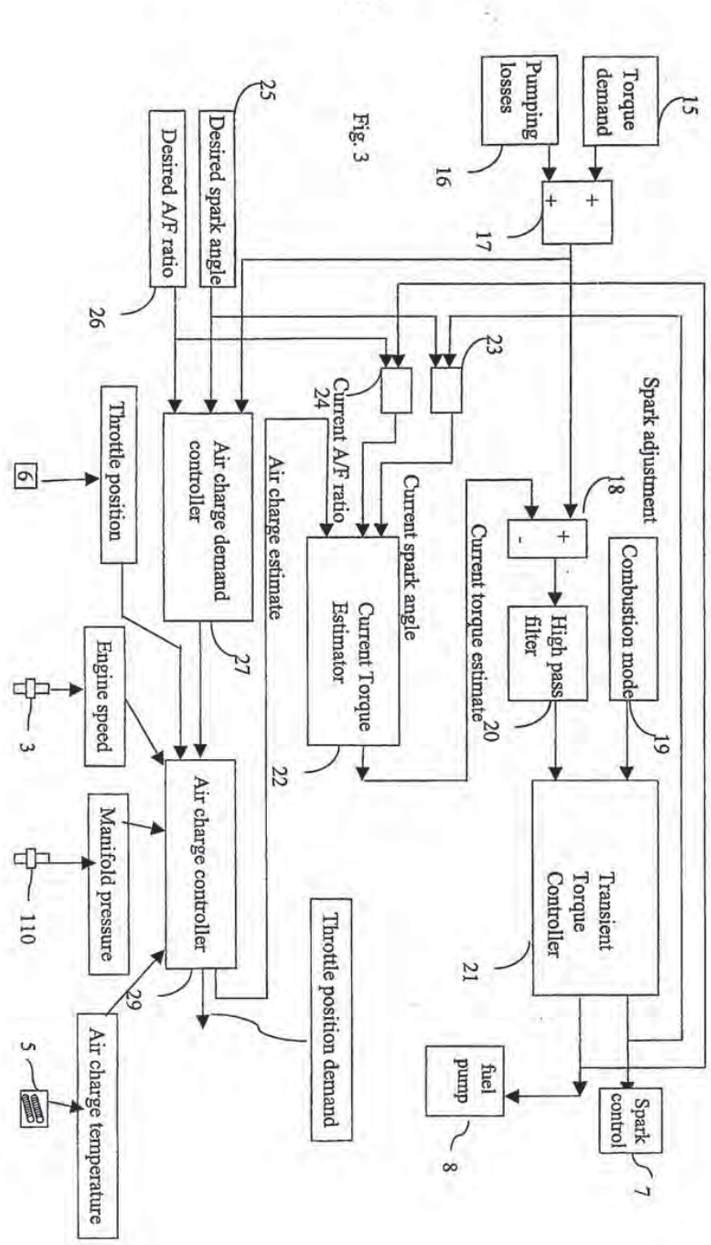


Fig. 3

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#3/IDS 8/16/02

PATENT
Attorney Docket No.: 10541-1524

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

Group Art Unit: Unknown

Examiner: Unknown

Inventors: Heslop et al.

Serial No: Unknown

Filed: Concurrent Herewith

For: ENGINE TORQUE CONTROLLER

INFORMATION DISCLOSURE STATEMENT



Commissioner for Patents
Washington, DC 20231

Sir:

Under the duties of disclosure, candor, and good faith of 37 CFR §1.56, the Applicant hereby submits the references listed on the attached PTO-1449 form for consideration by the Examiner. In the opinion of the Applicant, the pending claims are patentably distinct from the listed references. Furthermore, the filing of this information disclosure statement shall not be construed to be an admission that the information cited in the statement is material to patentability (37 C.F.R §1.97(h)).

Under 37 CFR §1.97(b)(1), no fee should be required. If a fee is required, however, please charge any such fee pursuant to 37 CFR §1.16 or §1.17 to deposit account no. 06-1500.

Respectfully submitted,

Date: July 9, 2002

By: _____
Raymond J. Vivacqua
Reg. No. 45,369
Attorney for Applicant

BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610
(734) 302-6000

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

10/191641 ALLGN BRIGHT

European Patent Office

EUROPEAN SEARCH REPORT

Application Number
EP 01 30 6301

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int.Cl.7)
X	US 6 237 563 B1 (TREINIES STEFAN ET AL) 29 May 2001 (2001-05-29) * column 1, line 66 - column 2, line 47 * * figures 2,3 *	1,5	F02D41/30 F02D41/14
A	DE 42 32 974 A (BOSCH GMBH ROBERT) 7 April 1994 (1994-04-07) * column 2, line 34 - line 50 *	1,5	
A	US 5 954 026 A (STOSS PETER ET AL) 21 September 1999 (1999-09-21) * column 2, line 41 - line 56 * * figure 1 *	1,5	
A	US 6 047 681 A (HEMBERGER HANS-HUBERT ET AL) 11 April 2000 (2000-04-11) * figures 1,2 *	1,5	

TECHNICAL FIELDS SEARCHED (Int.Cl.7)
F02D

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	14 January 2002	De Vita, D

CATEGORY OF CITED DOCUMENTS
X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons

& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

FORM PTO-1449	SERIAL NO.	CASE NO. 10541-1524
LIST OF PATENTS AND PUBLICATIONS FOR APPLICANT'S INFORMATION DISCLOSURE STATEMENT	FILING DATE	GROUP ART UNIT 3747
(use several sheets if necessary)	APPLICANT(S): Heslop et al.	

REFERENCE DESIGNATION **U.S. PATENT DOCUMENTS**

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	NAME	CLASS/ SUBCLASS	FILING DATE
~~—~~	~~A1~~	~~6,237,563~~	~~05/29/2001~~	~~Froehlich et al.~~ on 892	~~—~~	
DWS	A2	6,047,681	04/11/2000	Scherer et al.	123/406.46	
DWS	A3	5,954,026	09/21/1999	Stoss et al.	123/406.24	
	A4					
	A5					
	A6					
	A7					
	A8					
	A9					
	A10					
	A11					
	A12					
	A13					



FOREIGN PATENT DOCUMENTS

EXAMINER INITIAL		DOCUMENT NUMBER	DATE	COUNTRY	CLASS/ SUBCLASS	TRANSLATION YES	TRANSLATION NO
DWS	A14	DE 42 32 974 A1	~~07/04~~/1994 04/07	Germany	—		X
	A15						
	A16						
	A17						
	A18						

EXAMINER INITIAL	OTHER ART (Including Author, Title, Date, Pertinent Pages, etc.)
	A19
	A20
	A21
	A22
	A23
	A24

EXAMINER	DATE CONSIDERED
Argenbright	3-19-03

EXAMINER: Initial if reference considered, whether or not citation is in conformance with MPEP 609; Draw line through citation if not in conformance and not considered. Include copy of this form with next communication to applicant.

Rev. Dec.-99
F:\COMMON\rvivacqu\client matters\10541 (VISTEON)\1500\1524\PTO 1449.dot

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Notice of Allowability	Application No.	Applicant(s)	
	10/191,641	HESLOP ET AL.	
	Examiner	Art Unit	
	T. M. Argenbright	3747	

-- The MAILING DATE of this communication appears on the cover sheet with the correspondence address--

All claims being allowable, PROSECUTION ON THE MERITS IS (OR REMAINS) CLOSED in this application. If not included herewith (or previously mailed), a Notice of Allowance (PTOL-85) or other appropriate communication will be mailed in due course. **THIS NOTICE OF ALLOWABILITY IS NOT A GRANT OF PATENT RIGHTS.** This application is subject to withdrawal from issue at the initiative of the Office or upon petition by the applicant. See 37 CFR 1.313 and MPEP 1308.

1. ☐ This communication is responsive to _____.
2. ☒ The allowed claim(s) is/are *1-7*.
3. ☒ The drawings filed on *09 July 2002* are accepted by the Examiner.
4. ☒ Acknowledgment is made of a claim for foreign priority under 35 U.S.C. § 119(a)-(d) or (f).
   a) ☒ All b) ☐ Some* c) ☐ None of the:
      1. ☒ Certified copies of the priority documents have been received.
      2. ☐ Certified copies of the priority documents have been received in Application No. _____.
      3. ☐ Copies of the certified copies of the priority documents have been received in this national stage application from the International Bureau (PCT Rule 17.2(a)).

   * Certified copies not received: _____.
5. ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. § 119(e) (to a provisional application).
   (a) ☐ The translation of the foreign language provisional application has been received.
6. ☐ Acknowledgment is made of a claim for domestic priority under 35 U.S.C. §§ 120 and/or 121.

Applicant has THREE MONTHS FROM THE "MAILING DATE" of this communication to file a reply complying with the requirements noted below. Failure to timely comply will result in ABANDONMENT of this application. **THIS THREE-MONTH PERIOD IS NOT EXTENDABLE.**

7. ☐ A SUBSTITUTE OATH OR DECLARATION must be submitted. Note the attached EXAMINER'S AMENDMENT or NOTICE OF INFORMAL PATENT APPLICATION (PTO-152) which gives reason(s) why the oath or declaration is deficient.

8. ☐ CORRECTED DRAWINGS must be submitted.
   (a) ☐ including changes required by the Notice of Draftsperson's Patent Drawing Review (PTO-948) attached
      1) ☐ hereto or 2) ☐ to Paper No. ____.
   (b) ☐ including changes required by the proposed drawing correction filed _____, which has been approved by the Examiner.
   (c) ☐ including changes required by the attached Examiner's Amendment / Comment or in the Office action of Paper No. _____.

   Identifying indicia such as the application number (see 37 CFR 1.84(c)) should be written on the drawings in the top margin (not the back) of each sheet. The drawings should be filed as a separate paper with a transmittal letter addressed to the Official Draftsperson.

9. ☐ DEPOSIT OF and/or INFORMATION about the deposit of BIOLOGICAL MATERIAL must be submitted. Note the attached Examiner's comment regarding REQUIREMENT FOR THE DEPOSIT OF BIOLOGICAL MATERIAL.

Attachment(s)

1☒ Notice of References Cited (PTO-892)
2☐ Notice of Informal Patent Application (PTO-152)
3☐ Notice of Draftperson's Patent Drawing Review (PTO-948)
4☐ Interview Summary (PTO-413), Paper No.____.
5☒ Information Disclosure Statements (PTO-1449), Paper No. *3*.
6☒ Examiner's Amendment/Comment
7☐ Examiner's Comment Regarding Requirement for Deposit of Biological Material
8☐ Examiner's Statement of Reasons for Allowance
9☐ Other

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

EXAMINER'S AMENDMENT

An examiner's amendment to the record appears below. Should the changes and/or additions be unacceptable to applicant, an amendment may be filed as provided by 37 CFR 1.312. To ensure consideration of such an amendment, it MUST be submitted no later than the payment of the issue fee.

The application has been amended as follows:

In claims 3 and 6, last line, --ratio-- has been inserted after "air/fuel".

This application currently names joint inventors. In considering patentability of the claims under 35 U.S.C. 103(a), the examiner presumes that the subject matter of the various claims was commonly owned at the time any inventions covered therein were made absent any evidence to the contrary. Applicant is advised of the obligation under 37 CFR 1.56 to point out the inventor and invention dates of each claim that was not commonly owned at the time a later invention was made in order for the examiner to consider the applicability of 35 U.S.C. 103(c) and potential 35 U.S.C. 102(e), (f) or (g) prior art under 35 U.S.C. 103(a).

Any inquiry concerning this communication or earlier communications from the examiner should be directed to T. M. Argenbright whose telephone number is 703-308-1955. The examiner can normally be reached 6:30am-3:00pm M-Th and 6:30am-2:00pm alt. Fridays.

If attempts to reach the examiner by telephone are unsuccessful, the examiner's supervisor, Henry C. Yuen can be reached on 703-308-1946. The fax phone numbers for the organization where this application or proceeding is assigned are 703-872-9302 for regular communications and 703-872-9303 for After Final communications.

Any inquiry of a general nature or relating to the status of this application or proceeding should be directed to the receptionist whose telephone number is 703-308-0861.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

T. M. Argenbright
Primary Examiner
Art Unit 3747

March 19, 2003

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Notice of References Cited	Application/Control No. 10/191,641	Applicant(s)/Patent Under Reexamination HESLOP ET AL.	
	Examiner T. M. Argenbright	Art Unit 3747	Page 1 of 1

U.S. PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Name	Classification
*	A	US-6237563	05-2001	FROEHLICH ET AL	123/350
*	B	US-6227163	05-2001	ENOKI ET AL	123/295
*	C	US-6219611	04-2001	RUSSELL	123/399x
*	D	US-5638788	06-1997	SANVIDO ET AL	123/339.2
	E	US-			
	F	US-			
	G	US-			
	H	US-			
	I	US-			
	J	US-			
	K	US-			
	L	US-			
	M	US-			

FOREIGN PATENT DOCUMENTS

*		Document Number Country Code-Number-Kind Code	Date MM-YYYY	Country	Name	Classification
	N					
	O					
	P					
	Q					
	R					
	S					
	T					

NON-PATENT DOCUMENTS

*		Include as applicable: Author, Title Date, Publisher, Edition or Volume, Pertinent Pages)
	U	
	V	
	W	
	X	

*A copy of this reference is not being furnished with this Office action. (See MPEP § 707.05(a).)
Dates in MM-YYYY format are publication dates. Classifications may be US or foreign.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231
www.uspto.gov

NOTICE OF ALLOWANCE AND FEE(S) DUE

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

EXAMINER	
ARGENBRIGHT, TONY MICHAEL	
ART UNIT	CLASS-SUBCLASS
3747	123-295000

DATE MAILED: 03/21/2003

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

TITLE OF INVENTION: ENGINE TORQUE CONTROLLER

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1300	$300	$1600	06/23/2003

THE APPLICATION IDENTIFIED ABOVE HAS BEEN EXAMINED AND IS ALLOWED FOR ISSUANCE AS A PATENT. PROSECUTION ON THE MERITS IS CLOSED. THIS NOTICE OF ALLOWANCE IS NOT A GRANT OF PATENT RIGHTS. THIS APPLICATION IS SUBJECT TO WITHDRAWAL FROM ISSUE AT THE INITIATIVE OF THE OFFICE OR UPON PETITION BY THE APPLICANT. SEE 37 CFR 1.313 AND MPEP 1308.

THE ISSUE FEE AND PUBLICATION FEE (IF REQUIRED) MUST BE PAID WITHIN THREE MONTHS FROM THE MAILING DATE OF THIS NOTICE OR THIS APPLICATION SHALL BE REGARDED AS ABANDONED. THIS STATUTORY PERIOD CANNOT BE EXTENDED. SEE 35 U.S.C. 151. THE ISSUE FEE DUE INDICATED ABOVE REFLECTS A CREDIT FOR ANY PREVIOUSLY PAID ISSUE FEE APPLIED IN THIS APPLICATION. THE PTOL-85B (OR AN EQUIVALENT) MUST BE RETURNED WITHIN THIS PERIOD EVEN IF NO FEE IS DUE OR THE APPLICATION WILL BE REGARDED AS ABANDONED.

HOW TO REPLY TO THIS NOTICE:

I. Review the SMALL ENTITY status shown above.

If the SMALL ENTITY is shown as YES, verify your current SMALL ENTITY status:
A. If the status is the same, pay the TOTAL FEE(S) DUE shown above.

B. If the status is changed, pay the PUBLICATION FEE (if required) and twice the amount of the ISSUE FEE shown above and notify the United States Patent and Trademark Office of the change in status, or

If the SMALL ENTITY is shown as NO:

A. Pay TOTAL FEE(S) DUE shown above, or

B. If applicant claimed SMALL ENTITY status before, or is now claiming SMALL ENTITY status, check the box below and enclose the PUBLICATION FEE and 1/2 the ISSUE FEE shown above.

☐ Applicant claims SMALL ENTITY status. See 37 CFR 1.27.

II. PART B - FEE(S) TRANSMITTAL should be completed and returned to the United States Patent and Trademark Office (USPTO) with your ISSUE FEE and PUBLICATION FEE (if required). Even if the fee(s) have already been paid, Part B - Fee(s) Transmittal should be completed and returned. If you are charging the fee(s) to your deposit account, section "4b" of Part B - Fee(s) Transmittal should be completed and an extra copy of the form should be submitted.

III. All communications regarding this application must give the application number. Please direct all communications prior to issuance to Box ISSUE FEE unless advised to the contrary.

IMPORTANT REMINDER: Utility patents issuing on applications filed on or after Dec. 12, 1980 may require payment of maintenance fees. It is patentee's responsibility to ensure timely payment of maintenance fees when due.

PTOL-85 (REV. 04-02) Approved for use through 01/31/2004.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

PART B - FEE(S) TRANSMITTAL

Complete and send this form, together with applicable fee(s), to: Mail **Box ISSUE FEE**
Commissioner for Patents
Washington, D.C. 20231
Fax (703)746-4000

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission
I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Box Issue Fee address above, or being facsimile transmitted to the USPTO, on the date indicated below.

(Depositor's name)
(Signature)
(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

TITLE OF INVENTION: ENGINE TORQUE CONTROLLER

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1300	$300	$1600	06/23/2003

EXAMINER	ART UNIT	CLASS-SUBCLASS
ARGENBRIGHT, TONY MICHAEL	3747	123-295000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

❑ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

❑ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 _____
2 _____
3 _____

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE (B) RESIDENCE: (CITY and STATE OR COUNTRY)

Please check the appropriate assignee category or categories (will not be printed on the patent) ❑ individual ❑ corporation or other private group entity ❑ government

4a. The following fee(s) are enclosed:

❑ Issue Fee
❑ Publication Fee
❑ Advance Order - # of Copies _____

4b. Payment of Fee(s):

❑ A check in the amount of the fee(s) is enclosed.
❑ Payment by credit card. Form PTO-2038 is attached.
❑ The Commissioner is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number _____ (enclose an extra copy of this form).

Commissioner for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature) (Date)

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Washington, DC 20231.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMIT THIS FORM WITH FEE(S)

PTOL-85 (REV. 04-02) Approved for use through 01/31/2004. OMB 0651-0033 U.S. Patent and Trademark Office; U.S. DEPARTMENT OF COMMERCE

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

EXAMINER	
ARGENBRIGHT, TONY MICHAEL	
ART UNIT	**PAPER NUMBER**
3747	

DATE MAILED: 03/21/2003

Determination of Patent Term Adjustment under 35 U.S.C. 154 (b)
(application filed on or after May 29, 2000)

The patent term adjustment to date is 0 days. If the issue fee is paid on the date that is three months after the mailing date of this notice and the patent issues on the Tuesday before the date that is 28 weeks (six and a half months) after the mailing date of this notice, the term adjustment will be 0 days.

If a continued prosecution application (CPA) was filed in the above-identified application, the filing date that determines patent term adjustment is the filing date of the most recent CPA.

Applicant will be able to obtain more detailed information by accessing the Patent Application Information Retrieval (PAIR) system. (http://pair.uspto.gov)

Any questions regarding the patent term extension or adjustment determination should be directed to the Office of Patent Legal Administration at (703)305-1383.

PTOL-85 (REV. 04-02) Approved for use through 01/31/2004.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

UNITED STATES PATENT AND TRADEMARK OFFICE

UNITED STATES DEPARTMENT OF COMMERCE
United States Patent and Trademark Office
Address: COMMISSIONER OF PATENTS AND TRADEMARKS
Washington, D.C. 20231
www.uspto.gov

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Heslop	10541-1524	4815

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610
UNITED STATES

EXAMINER	
ARGENBRIGHT, TONY MICHAEL	
ART UNIT	**PAPER NUMBER**
3747	

DATE MAILED: 03/21/2003

Notice of Fee Increase on January 1, 2003

If a reply to a "Notice of Allowance and Fee(s) Due" is filed in the Office on or after January 1, 2003, then the amount due will be higher than that set forth in the "Notice of Allowance and Fee(s) Due" since there will be an increase in fees effective on January 1, 2003. See Revision of Patent and Trademark Fees for Fiscal Year 2003; Final Rule, 67 Fed. Reg. 70847, 70849 (November 27, 2002).

The current fee schedule is accessible from: http://www.uspto.gov/main/howtofees.htm.

If the issue fee paid is the amount shown on the "Notice of Allowance and Fee(s) Due," but not the correct amount in view of the fee increase, a "Notice to Pay Balance of Issue Fee" will be mailed to applicant. In order to avoid processing delays associated with mailing of a "Notice to Pay Balance of Issue Fee," if the response to the Notice of Allowance and Fee(s) due form is to be filed on or after January 1, 2003 (or mailed with a certificate of mailing on or after January 1, 2003), the issue fee paid should be the fee that is required at the time the fee is paid. If the issue fee was previously paid, and the response to the "Notice of Allowance and Fee(s) Due" includes a request to apply a previously-paid issue fee to the issue fee now due, then the difference between the issue fee amount at the time the response is filed and the previously paid issue fee should be paid. See Manual of Patent Examining Procedure, Section 1308.01 (Eighth Edition, August 2001).

Questions relating to issue and publication fee payments should be directed to the Customer Service Center of the Office of Patent Publication at (703) 305-8283.

PTOL-85 (REV. 04-02) Approved for use through 01/31/2004.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

P C9C

Certificate
SEP 0 8 2003
of Correction
m
#5

I hereby certify that this correspondence is being deposited with the United States Postal Service, with sufficient postage, as first class mail in an envelope addressed to the Commissioner for Patents, P.O. Box 1450, Alexandria, VA 22313-1450, on

8/28/03
(Date of Deposit)

OIPE JC1 SEP 0 2 2003 PATENT & TRADEMARK OFFICE

Raymond J. Vivacqua - Reg. No. 45,369
Name of applicant, assignee, or Registered Representative

Signature

8/28/03
Date of Signature

Our File No. 10541/1524

IN THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re Application of:	
Garon N. Heslop et al.	Examiner: Tony M. Argenbright
Patent No.: 6,581,565 B2	
Issue Date: June 24, 2003	Group Art Unit: 3747
Serial No.: 10/191,641	
Filing Date: July 9, 2002	
For: ENGINE TORQUE CONTROLLER	

REQUEST FOR CERTIFICATE OF CORRECTION

Commissioner for Patents
P.O. Box 1450
Alexandria, VA 22313-1450

Attn: Certificate of Corrections Branch

Sir:

Please issue a Certificate of Correction for the above-identified patent to correct the errors listed on the accompanying PTO Form 1050. This request is being made pursuant to 35 U.S.C. § 254, since the errors comprise minor or typographical errors by the Patent and Trademark Office.

SEP 0 9 2003

The Commissioner is hereby authorized to charge any fees required to Deposit Account No. 06-1500 (Visteon Global Technologies, Inc.). A duplicate copy of this sheet is enclosed.

Respectfully submitted,



Raymond A. Vivacqua
Registration No. 45,369
Attorney for Applicants

BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, Illinois 60610
(312) 321-4200

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Staple Here Only !

PRINTER'S TRIM LINE

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al. Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

~~In the Claims~~

Col. 4 30
~~In claim 3~~, line ~~4~~, after "air/fuel" insert --ratio-- before "." (period).

Col 4 53
~~In claim 6~~, line ~~4~~, after "air/fuel" insert --ratio-- before "." (period).

MAILING ADDRESS OF SENDER:
Raymond J. Vivacqua
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, Illinois 60610

PATENT NO. 6,581,565 B2

No. of add'l copies @ 50¢ per page

SEP 09 2003

FORM PTO 1050 (Rev. 2-93)

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UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al. Page 1 of 1

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

In the Claims

In claim 3, line 4, after "air/fuel" insert --ratio-- before "." (period).

In claim 6, line 4, after "air/fuel" insert --ratio-- before "." (period).

6,581,565 B2

PATENT NO.

No. of add'l copies @ 50¢ per page

MAILING ADDRESS OF SENDER:
Raymond J. Vivacqua
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, Illinois 60610

SEP 09 2003

FORM PTO 1050 (Rev. 2-93)

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 6,581,565 B2
DATED : June 24, 2003
INVENTOR(S) : Garon N. Heslop et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 4,
Lines 30 and 53, after "air/fuel" insert -- ratio -- before "." (period).

Signed and Sealed this

Twenty-eighth Day of October, 2003



JAMES E. ROGAN
Director of the United States Patent and Trademark Office

HM-

PART B - FEE(S) TRANSMITTAL

OIPE MAY 12 2003 PATENT & TRADEMARK OFFICE

V B/H

Complete and send this form, together with applicable fee(s), to: Mail Box ISSUE FEE
Commissioner for Patents
Washington, D.C. 20231
Fax (703)746-4000

INSTRUCTIONS: This form should be used for transmitting the ISSUE FEE and PUBLICATION FEE (if required). Blocks 1 through 4 should be completed where appropriate. All further correspondence including the Patent, advance orders and notification of maintenance fees will be mailed to the current correspondence address as indicated unless corrected below or directed otherwise in Block 1, by (a) specifying a new correspondence address; and/or (b) indicating a separate "FEE ADDRESS" for maintenance fee notifications.

CURRENT CORRESPONDENCE ADDRESS (Note: Legibly mark-up with any corrections or use Block 1)

7590 03/21/2003

Steven L. Oberholtzer
BRINKS HOFER GILSON & LIONE
P.O. Box 10395
Chicago, IL 60610

Note: A certificate of mailing can only be used for domestic mailings of the Fee(s) Transmittal. This certificate cannot be used for any other accompanying papers. Each additional paper, such as an assignment or formal drawing, must have its own certificate of mailing or transmission.

Certificate of Mailing or Transmission

I hereby certify that this Fee(s) Transmittal is being deposited with the United States Postal Service with sufficient postage for first class mail in an envelope addressed to the Box Issue Fee address above, or being facsimile transmitted to the USPTO, on the date indicated below.

Raymond J. Vivacqua	(Depositor's name)
	(Signature)
5/9/03	(Date)

APPLICATION NO.	FILING DATE	FIRST NAMED INVENTOR	ATTORNEY DOCKET NO.	CONFIRMATION NO.
10/191,641	07/09/2002	Garon Nigel Haslop	10541-1524	4815

TITLE OF INVENTION: ENGINE TORQUE CONTROLLER

APPLN. TYPE	SMALL ENTITY	ISSUE FEE	PUBLICATION FEE	TOTAL FEE(S) DUE	DATE DUE
nonprovisional	NO	$1300	$300	$1600	06/23/2003

EXAMINER	ART UNIT	CLASS-SUBCLASS
ARGENBRIGHT, TONY MICHAEL	3747	123-295000

1. Change of correspondence address or indication of "Fee Address" (37 CFR 1.363).

☐ Change of correspondence address (or Change of Correspondence Address form PTO/SB/122) attached.

☐ "Fee Address" indication (or "Fee Address" Indication form PTO/SB/47; Rev 03-02 or more recent) attached. **Use of a Customer Number is required.**

2. For printing on the patent front page, list (1) the names of up to 3 registered patent attorneys or agents OR, alternatively, (2) the name of a single firm (having as a member a registered attorney or agent) and the names of up to 2 registered patent attorneys or agents. If no name is listed, no name will be printed.

1 Brinks Hofer Gilson & Lione
2
3

3. ASSIGNEE NAME AND RESIDENCE DATA TO BE PRINTED ON THE PATENT (print or type)

PLEASE NOTE: Unless an assignee is identified below, no assignee data will appear on the patent. Inclusion of assignee data is only appropriate when an assignment has been previously submitted to the USPTO or is being submitted under separate cover. Completion of this form is NOT a substitute for filing an assignment.

(A) NAME OF ASSIGNEE: Visteon Global Technologies, Inc.

(B) RESIDENCE: (CITY and STATE OR COUNTRY): Dearborn, Michigan

Please check the appropriate assignee category or categories (will not be printed on the patent) ☐ individual ☒ corporation or other private group entity ☐ government

4a. The following fee(s) are enclosed:

☒ Issue Fee

☒ Publication Fee

☐ Advance Order - # of Copies _____

4b. Payment of Fee(s):

☐ A check in the amount of the fee(s) is enclosed.

☐ Payment by credit card. Form PTO-2038 is attached.

☒ The Commissioner is hereby authorized by charge the required fee(s), or credit any overpayment, to Deposit Account Number 06-1500 (enclose an extra copy of this form).

Commissioner for Patents is requested to apply the Issue Fee and Publication Fee (if any) or to re-apply any previously paid issue fee to the application identified above.

(Authorized Signature) _____ (Date) 5/9/03

NOTE: The Issue Fee and Publication Fee (if required) will not be accepted from anyone other than the applicant; a registered attorney or agent; or the assignee or other party in interest as shown by the records of the United States Patent and Trademark Office.

05/13/2003 BSAYASI2 00000106 061500 10191641

01 FC:1501 1300.00 CH
02 FC:1504 300.00 CH

This collection of information is required by 37 CFR 1.311. The information is required to obtain or retain a benefit by the public which is to file (and by the USPTO to process) an application. Confidentiality is governed by 35 U.S.C. 122 and 37 CFR 1.14. This collection is estimated to take 12 minutes to complete, including gathering, preparing, and submitting the completed application form to the USPTO. Time will vary depending upon the individual case. Any comments on the amount of time you require to complete this form and/or suggestions for reducing this burden, should be sent to the Chief Information Officer, U.S. Patent and Trademark Office, U.S. Department of Commerce, Washington, D.C. 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Commissioner for Patents, Washington, DC 20231.

Under the Paperwork Reduction Act of 1995, no persons are required to respond to a collection of information unless it displays a valid OMB control number.

TRANSMIT THIS FORM WITH FEE(S)

504528678 08/31/2017

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT4575384

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT

CONVEYING PARTY DATA

Name	Execution Date
MOBILE AUTOMOTIVE TECHNOLOGIES, LLC	08/28/2017

RECEIVING PARTY DATA

Name:	MICHIGAN MOTOR TECHNOLOGIES LLC
Street Address:	2360 ORCHARD LAKE ROAD SUITE 100
City:	SYLVAN LAKE
State/Country:	MICHIGAN
Postal Code:	48320

PROPERTY NUMBERS Total: 42

Property Type	Number
Patent Number:	6345604
Patent Number:	6347680
Patent Number:	6379281
Patent Number:	6443128
Patent Number:	6510839
Patent Number:	6557540
Patent Number:	6561166
Patent Number:	6571157
Patent Number:	6581565
Patent Number:	6581574
Patent Number:	6588260
Patent Number:	6598581
Patent Number:	6607302
Patent Number:	6609497
Patent Number:	6612287
Patent Number:	6619106
Patent Number:	6644115
Patent Number:	6736122
Patent Number:	6741441
Patent Number:	6752741

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Property Type	Number
Patent Number:	6757149
Patent Number:	6758885
Patent Number:	6763804
Patent Number:	6766788
Patent Number:	6817592
Patent Number:	6847882
Patent Number:	6856209
Patent Number:	6874362
Patent Number:	6976477
Patent Number:	6988031
Patent Number:	7089894
Patent Number:	7116081
Patent Number:	7124963
Patent Number:	7137577
Patent Number:	7143501
Patent Number:	7168637
Patent Number:	7191755
Patent Number:	7198207
Patent Number:	7293554
Patent Number:	7487761
Patent Number:	7712451
Patent Number:	7982358

CORRESPONDENCE DATA

Fax Number: (302)449-9010

Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.

Phone: 3024499010
Email: mmcclain@devlinlawfirm.com
Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/TIMOTHY DEVLIN/
DATE SIGNED:	08/31/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 2
source=michmotorassn#page1.tif

source=michmotorassn#page2.tif

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

EXHIBIT B

U.S. PATENT ASSIGNMENT

WHEREAS, Mobile Automotive Technologies, LLC, an Alabama limited liability company ("Assignor"), is the owner of (i) United States Patent and Patent Applications listed in Schedule A and the following (ii) through (iv) to the extent Assignor owns, controls or has the right to license or enforce them at any time: (ii) any patents or patent applications that claim priority directly or indirectly from any of the foregoing patent(s) in subsection (i), or from which priority is directly or indirectly claimed by any such patent(s) in subsection (i), or that have common priority with any such patent(s) in subsection (i); (iii) any foreign counterparts, foreign related patents, continuations, divisionals, continuations-in-part, extensions, substitutions, reissues, renewals and all results of oppositions, reexaminations, supplemental examinations, requests for continued examination and other review procedures of any of the foregoing in subsections (i) and (ii); and (iv) all patents issuing on patent applications covered by any of the foregoing subsections (i) through (iii) (together the "Assigned Patents").

WHEREAS, Michigan Motor Technologies LLC ("Assignee") is desirous of acquiring title in and to the Assigned Patents.

WHEREAS, Assignor is the owner of any and all right, title, and interest in and to the Assigned Patents.

WHEREAS, Assignor desires to sell, assign, and transfer all its right, title, and interest in the Assigned Patents to Assignee, and Assignee desires to obtain all such right, title, and interest in the Assigned Patents from Assignor.

NOW, THEREFORE, in consideration of good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, Assignor hereby sells, assigns, transfers and conveys unto Assignee, its permitted successors and assigns, all of Assignor's right, title, and interest in and to the Assigned Patents, together with all claims, demands, or causes of action that Assignor has or might have by reason of any infringement of the Assigned Patents prior to the effective date of this assignment, including the right to sue and collect damages for all past, present and future infringement and all lost profits resulting therefrom.

IN WITNESS WHEREOF, this Agreement has been executed by duly authorized representatives of the Parties on the dates below.

Signature

Name John Mobile Automotive Technology LLC

Date: 8/25/17

Signature

Name KEVIN C BRADY MICHIGAN MOTOR TECHNOLOGY LLC

Date: 8/28/17

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

SCHEDULE A

Patents:

US6345604
US6347680
US6379281
US6443128
US6510839
US6557540
US6561166
US6571157
US6581565
US6581574
US6588260
US6598581
US6607302
US6609497
US6612287
US6619106
US6644115
US6736122
US6741441
US6752741
US6757149
US6758885
US6763804
US6766788
US6817592
US6847882
US6856209
US6874362
US6976477
US6988031
US7089894
US7116081
US7124963
US7137577
US7143501
US7168637
US7191755
US7198207
US7293554
US7487761
US7712451
US7982358
DE103 44 494.7-34
GB2385013
GB2422688
JP4235485
DE103 22 529.3

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

504528526 08/31/2017

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT4575232

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT

CONVEYING PARTY DATA

Name	Execution Date
GODO KAISHA IP BRIDGE	09/02/2016

RECEIVING PARTY DATA

Name:	MOBILE AUTOMOTIVE TECHNOLOGIES, LLC
Street Address:	951 GOVERNMENT STREET, SUITE B
City:	MOBILE
State/Country:	ALABAMA
Postal Code:	36604

PROPERTY NUMBERS Total: 42

Property Type	Number
Patent Number:	6345604
Patent Number:	6347680
Patent Number:	6379281
Patent Number:	6443128
Patent Number:	6510839
Patent Number:	6557540
Patent Number:	6561166
Patent Number:	6571157
Patent Number:	6581565
Patent Number:	6581574
Patent Number:	6588260
Patent Number:	6598581
Patent Number:	6607302
Patent Number:	6609497
Patent Number:	6612287
Patent Number:	6619106
Patent Number:	6644115
Patent Number:	6736122
Patent Number:	6741441
Patent Number:	6752741

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Property Type	Number
Patent Number:	6757149
Patent Number:	6758885
Patent Number:	6763804
Patent Number:	6766788
Patent Number:	6817592
Patent Number:	6847882
Patent Number:	6856209
Patent Number:	6874362
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Patent Number:	7089894
Patent Number:	7116081
Patent Number:	7124963
Patent Number:	7137577
Patent Number:	7143501
Patent Number:	7168637
Patent Number:	7191755
Patent Number:	7198207
Patent Number:	7293554
Patent Number:	7487761
Patent Number:	7712451
Patent Number:	7982358

CORRESPONDENCE DATA

Fax Number: (302)449-9010

Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.

Phone: 3024499010
Email: mmcclain@devlinlawfirm.com
Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/TIMOTHY DEVLIN/
DATE SIGNED:	08/31/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 3
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source=MobileAutoSignedPAA#page3.tif

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

EXHIBIT B

U.S. PATENT ASSIGNMENT

WHEREAS, Godo Kaisha IP Bridge 1 ("Assignor"), is the owner of (i) United States Patent and Patent Applications listed in Schedule A and the following (ii) through (iv) to the extent Assignor owns, controls or has the right to license or enforce them at any time: (ii) any patents or patent applications that claim priority directly or indirectly from any of the foregoing patent(s) in subsection (i), or from which priority is directly or indirectly claimed by any such patent(s) in subsection (i), or that have common priority with any such patent(s) in subsection (i); (iii) any foreign counterparts, foreign related patents, continuations, divisionals, continuations-in-part, extensions, substitutions, reissues, renewals and all results of oppositions, reexaminations, supplemental examinations, requests for continued examination and other review procedures of any of the foregoing in subsections (i) and (ii); and (iv) all patents issuing on patent applications covered by any of the foregoing subsections (i) through (iii) (together the "Assigned Patents").

WHEREAS, Mobile Automotive Technologies, LLC, an Alabama limited liability company ("Assignee") is desirous of acquiring title in and to the Assigned Patents.

WHEREAS, Assignor is the owner of any and all right, title, and interest in and to the Assigned Patents.

WHEREAS, Assignor desires to sell, assign, and transfer all its right, title, and interest in the Assigned Patents to Assignee, and Assignee desires to obtain all such right, title, and interest in the Assigned Patents from Assignor.

NOW, THEREFORE, in consideration of good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, Assignor hereby sells, assigns, transfers and conveys unto Assignee, its permitted successors and assigns, all of Assignor's right, title, and interest in and to the Assigned Patents, together with all claims, demands, or causes of action that Assignor has or might have by reason of any infringement of the Assigned Patents prior to the effective date of this assignment, including the right to sue and collect damages for all past, present and future infringement and all lost profits resulting therefrom.

IN WITNESS WHEREOF, this Agreement has been executed by duly authorized representatives of the Parties on the dates below.

Signature

Hideyuki Ogata
Name

Date: Sept. 2, 2016

Signature

KEVIN C. BRADY
Name

Date: AUG 27, 2016

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

SCHEDULE A

Patents:

US6345604
US6347680
US6379281
US6443128
US6510839
US6557540
US6561166
US6571157
US6581565
US6581574
US6588260
US6598581
US6607302
US6609497
US6612287
US6619106
US6644115
US6736122
US6741441
US6752741
US6757149
US6758885
US6763804
US6766788
US6817592
US6847882
US6856209
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US7137577
US7143501
US7168637
US7191755
US7198207

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

US7293554
US7487761
US7712451
US7982358

DE103 44 494.7-34
GB2385013
GB2422688
JP4235485

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

504528590 08/31/2017

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT4575296

SUBMISSION TYPE:	NEW ASSIGNMENT
NATURE OF CONVEYANCE:	ASSIGNMENT

CONVEYING PARTY DATA

Name	Execution Date
GODO KAISHA IP BRIDGE	11/02/2016

RECEIVING PARTY DATA

Name:	MOBILE AUTOMOTIVE TECHNOLOGIES, LLC
Street Address:	951 GOVERNMENT STREET, SUITE B
City:	MOBILE
State/Country:	ALABAMA
Postal Code:	36604

PROPERTY NUMBERS Total: 42

Property Type	Number
Patent Number:	6345604
Patent Number:	6347680
Patent Number:	6379281
Patent Number:	6443128
Patent Number:	6510839
Patent Number:	6557540
Patent Number:	6561166
Patent Number:	6571157
Patent Number:	6581565
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Patent Number:	6607302
Patent Number:	6609497
Patent Number:	6612287
Patent Number:	6619106
Patent Number:	6644115
Patent Number:	6736122
Patent Number:	6741441
Patent Number:	6752741

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Property Type	Number
Patent Number:	6757149
Patent Number:	6758885
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Patent Number:	6847882
Patent Number:	6856209
Patent Number:	6874362
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Patent Number:	7191755
Patent Number:	7198207
Patent Number:	7293554
Patent Number:	7487761
Patent Number:	7712451
Patent Number:	7982358

CORRESPONDENCE DATA

Fax Number: (302)449-9010

Correspondence will be sent to the e-mail address first; if that is unsuccessful, it will be sent using a fax number, if provided; if that is unsuccessful, it will be sent via US Mail.

Phone: 3024499010
Email: mmcclain@devlinlawfirm.com
Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/TIMOTHY DEVLIN/
DATE SIGNED:	08/31/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 3
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PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

504584165 10/06/2017

PATENT ASSIGNMENT COVER SHEET

Electronic Version v1.1
Stylesheet Version v1.2

EPAS ID: PAT4630877

SUBMISSION TYPE:	RESUBMISSION
NATURE OF CONVEYANCE:	ASSIGNMENT
RESUBMIT DOCUMENT ID:	504528590

CONVEYING PARTY DATA

Name	Execution Date
GODO KAISHA IP BRIDGE	11/02/2016

RECEIVING PARTY DATA

Name:	MOBILE AUTOMOTIVE TECHNOLOGIES, LLC
Street Address:	951 GOVERNMENT STREET, SUITE B
City:	MOBILE
State/Country:	ALABAMA
Postal Code:	36604

PROPERTY NUMBERS Total: 42

Property Type	Number
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Patent Number:	6347680
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Patent Number:	6612287
Patent Number:	6619106
Patent Number:	6644115
Patent Number:	6736122
Patent Number:	6741441

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

Property Type	Number
Patent Number:	6752741
Patent Number:	6757149
Patent Number:	6758885
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Patent Number:	6766788
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Patent Number:	6847882
Patent Number:	6856209
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Patent Number:	7089894
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Patent Number:	7124963
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Patent Number:	7143501
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Patent Number:	7191755
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Patent Number:	7487761
Patent Number:	7712451
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Correspondent Name: TIMOTHY DEVLIN
Address Line 1: 1306 N. BROOM STREET
Address Line 2: 1ST FLOOR
Address Line 4: WILMINGTON, DELAWARE 19806

NAME OF SUBMITTER:	TIMOTHY DEVLIN
SIGNATURE:	/Timothy Devlin/
DATE SIGNED:	10/06/2017
	This document serves as an Oath/Declaration (37 CFR 1.63).

Total Attachments: 6

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source=Full page photo 2#page1.tif
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source=MobileAutoSignedPAA#page2.tif
source=MobileAutoSignedPAA#page3.tif

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

AMENDMENT NO. 1 TO THE PATENT ASSIGNMENT AGREEMENT

This Amendment No. 1 (the "**Amendment**"), dated as of the latest execution date below, is entered into by Mobile Automotive Technologies, LLC, an Alabama limited liability company and Godo Kaisha IP Bridge 1, with its principal offices at c/o Sakura Sogo Jimusho, 1-11 Kanda Jimbocho, Chiyoda-ku, Tokyo 102-0083, Japan, and amends the Patent Assignment Agreement entered into by the parties, executed on September 2, 2016 (the "**PTA**"). Capitalized terms not defined herein are defined in the PTA.

The parties agree to retroactively amend the PTA as follows:

1. Exhibit A to the PTA is hereby retroactively amended and restated in its entirety in the form of Exhibit A attached hereto.

2. The parties intend and agree that this Amendment shall be effective as of the Effective Date of the PTA with the same force and effect as if executed on that date. Except as expressly amended by this Amendment, all other terms, conditions and provisions of the PTA shall apply.

IN WITNESS WHEREOF, the parties have executed this Amendment through their duly authorized representatives.

Mobile Automotive Technologies, LLC

By: _____

Name: Kevin C. Brady

Title: Managing Member

Date: 10-21-2016

Godo Kaisha IP Bridge 1

By: _____

Name: Hideyuki Ogata

Title: Executive Manager

Date: 11-2-2016

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

EXHIBIT A

Patents:

1 US6345604
2 US6347680
3 US6379281
4 US6443128
5 US6510839
6 US6557540
7 US6561166
8 US6571157
9 US6581565
10 US6581574
11 US6588260
12 US6598581
13 US6607302
14 US6609497
15 US6612287
16 US6619106
17 US6644115
18 US6736122
19 US6741441
20 US6752741
21 US6757149
22 US6758885
23 US6763804
24 US6766788
25 US6817592
26 US6847882
27 US6856209
28 US6874362
29 US6976477
30 US6988031
31 US7089894
32 US7116081
33 US7124963
34 US7137577
35 US7143501
36 US7168637

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

37 US7191755
38 US7198207
39 US7293554
40 US7487761
41 US7712451
42 US7982358
43 DE103 44 494.7-34
44 GB2385013
45 GB2422688
46 JP4235485
47 DE103 22 529.3

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

EXHIBIT B

U.S. PATENT ASSIGNMENT

WHEREAS, Godo Kaisha IP Bridge 1 ("Assignor"), is the owner of (i) United States Patent and Patent Applications listed in Schedule A and the following (ii) through (iv) to the extent Assignor owns, controls or has the right to license or enforce them at any time: (ii) any patents or patent applications that claim priority directly or indirectly from any of the foregoing patent(s) in subsection (i), or from which priority is directly or indirectly claimed by any such patent(s) in subsection (i), or that have common priority with any such patent(s) in subsection (i); (iii) any foreign counterparts, foreign related patents, continuations, divisionals, continuations-in-part, extensions, substitutions, reissues, renewals and all results of oppositions, reexaminations, supplemental examinations, requests for continued examination and other review procedures of any of the foregoing in subsections (i) and (ii); and (iv) all patents issuing on patent applications covered by any of the foregoing subsections (i) through (iii) (together the "Assigned Patents").

WHEREAS, Mobile Automotive Technologies, LLC, an Alabama limited liability company ("Assignee") is desirous of acquiring title in and to the Assigned Patents.

WHEREAS, Assignor is the owner of any and all right, title, and interest in and to the Assigned Patents.

WHEREAS, Assignor desires to sell, assign, and transfer all its right, title, and interest in the Assigned Patents to Assignee, and Assignee desires to obtain all such right, title, and interest in the Assigned Patents from Assignor.

NOW, THEREFORE, in consideration of good and valuable consideration, the receipt and adequacy of which is hereby acknowledged, Assignor hereby sells, assigns, transfers and conveys unto Assignee, its permitted successors and assigns, all of Assignor's right, title, and interest in and to the Assigned Patents, together with all claims, demands, or causes of action that Assignor has or might have by reason of any infringement of the Assigned Patents prior to the effective date of this assignment, including the right to sue and collect damages for all past, present and future infringement and all lost profits resulting therefrom.

IN WITNESS WHEREOF, this Agreement has been executed by duly authorized representatives of the Parties on the dates below.

Signature

Hideyuki Ogata
Name

Date: Sept. 2, 2016

Signature

KEVIN C. BRADY
Name

Date: AUG 27, 2016

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

SCHEDULE A

Patents:

US6345604
US6347680
US6379281
US6443128
US6510839
US6557540
US6561166
US6571157
US6581565
US6581574
US6588260
US6598581
US6607302
US6609497
US6612287
US6619106
US6644115
US6736122
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US7124963
US7137577
US7143501
US7168637
US7191755
US7198207

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

US7293554
US7487761
US7712451
US7982358

DE103 44 494.7-34
GB2385013
GB2422688
JP4235485

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

PATENT APPLICATION FEE DETERMINATION RECORD
Effective October 1, 2001

Application or Docket Number: 10541-1524

CLAIMS AS FILED - PART I

	(Column 1)	(Column 2)
TOTAL CLAIMS	7	
FOR	NUMBER FILED	NUMBER EXTRA
TOTAL CHARGEABLE CLAIMS	7 minus 20=	*
INDEPENDENT CLAIMS	2 minus 3 =	*
MULTIPLE DEPENDENT CLAIM PRESENT		☐

* If the difference in column 1 is less than zero, enter "0" in column 2

SMALL ENTITY TYPE ☐		OR	OTHER THAN SMALL ENTITY	
RATE	FEE		RATE	FEE
BASIC FEE	370.00	OR	BASIC FEE	740.00
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL		OR	TOTAL	740

CLAIMS AS AMENDED - PART II

AMENDMENT A

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

SMALL ENTITY		OR	OTHER THAN SMALL ENTITY	
RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT B

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

AMENDMENT C

	(Column 1) CLAIMS REMAINING AFTER AMENDMENT		(Column 2) HIGHEST NUMBER PREVIOUSLY PAID FOR	(Column 3) PRESENT EXTRA
Total	*	Minus	**	=
Independent	*	Minus	***	=
FIRST PRESENTATION OF MULTIPLE DEPENDENT CLAIM				☐

RATE	ADDITIONAL FEE		RATE	ADDITIONAL FEE
X$ 9=		OR	X$18=	
X42=		OR	X84=	
+140=		OR	+280=	
TOTAL ADDIT. FEE		OR	TOTAL ADDIT. FEE	

* If the entry in column 1 is less than the entry in column 2, write "0" in column 3.
** If the "Highest Number Previously Paid For" IN THIS SPACE is less than 20, enter "20."
***If the "Highest Number Previously Paid For" IN THIS SPACE is less than 3, enter "3."
The "Highest Number Previously Paid For" (Total or Independent) is the highest number found in the appropriate box in column 1.

FORM PTO-875 (Rev. 8/01) *U.S. Government Printing Office: 2001 — 484-484/59268 Patent and Trademark Office, U.S. DEPARTMENT OF COMMERCE

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

SEARCH

Class	Sub.	Date	Exmr.
123	295 350 352 399 406.23 406.47 406.55 478 480 488	3-19-03	TMS

INTERFERENCE SEARCHED

Class	Sub.	Date	Exmr.
123	295 350 352 399 406.23 406.47 406.55 478 480 488	3-19-03	TMS

SEARCH NOTES

(List databases searched. Attach search strategy inside.)

	Date	Exmr.

ISSUE SLIP STAPLE AREA (for additional cross-references)

ISSUING CLASSIFICATION

ORIGINAL		CROSS REFERENCE(S)	
CLASS	SUBCLASS	CLASS	SUBCLASS (ONE SUBCLASS PER BLOCK)
123	295	123	406.23 406.47 478
INTERNATIONAL CLASSIFICATION			
F02D	41/14		
F02B	17/00		
	1		
	1		
	1		^ Continued on Issue Slip Inside File Jacket

INDEX OF CLAIMS

✓ ..... Rejected - (Through numeral) ... Canceled N ..... Non-elected A ..... Appeal
= ..... Allowed + ... Restricted I ..... Interference O ..... Objected

Claim Final	Claim Original	Date 3/19/03	Claim Final	Claim Original	Claim Final	Claim Original
1	1	=		51		101
2	2	=		52		102
3	3	=		53		103
4	4	=		54		104
5	5	=		55		105
6	6	=		56		106
7	7	=		57		107
	8			58		108
	9			59		109
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	48			98		148
	49			99		149
	50			100		150

If more than 150 claims or 9 actions staple additional sheet here

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

US006581565B2

(12) **United States Patent**
Heslop et al.

(10) **Patent No.: US 6,581,565 B2**
(45) **Date of Patent: Jun. 24, 2003**

(54) **ENGINE TORQUE CONTROLLER**

(75) Inventors: **Garon Nigel Heslop**, Billericay (GB); **Jon Dixon**, Maldon (GB); **Richard Stephen Blachford**, Cambridge (GB)

(73) Assignee: **Visteon Global Technologies, Inc.**, Dearborn, MI (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **10/191,641**

(22) Filed: **Jul. 9, 2002**

(65) **Prior Publication Data**

US 2003/0015169 A1 Jan. 23, 2003

(30) **Foreign Application Priority Data**

Jul. 23, 2001 (EP) 01306301

(51) **Int. Cl.**[7] **F02D 41/14**; F02B 17/00

(52) **U.S. Cl.** **123/295**; 123/406.23; 123/406.47; 123/478

(58) **Field of Search** 123/295, 350, 123/352, 399, 406.23, 406.47, 406.55, 478, 480, 488

(56) **References Cited**

U.S. PATENT DOCUMENTS

5,638,788	A *	6/1997	Sanvido et al.	123/339.2
5,954,026	A	9/1999	Stoss et al.	123/406.24
6,047,681	A	4/2000	Scherer et al.	123/406.46
6,219,611	B1 *	4/2001	Russell	123/399 X
6,227,163	B1 *	5/2001	Enoki et al.	123/295
6,237,563	B1 *	5/2001	Froehlich et al.	123/350

FOREIGN PATENT DOCUMENTS

DE	42 32 974	A1	4/1994

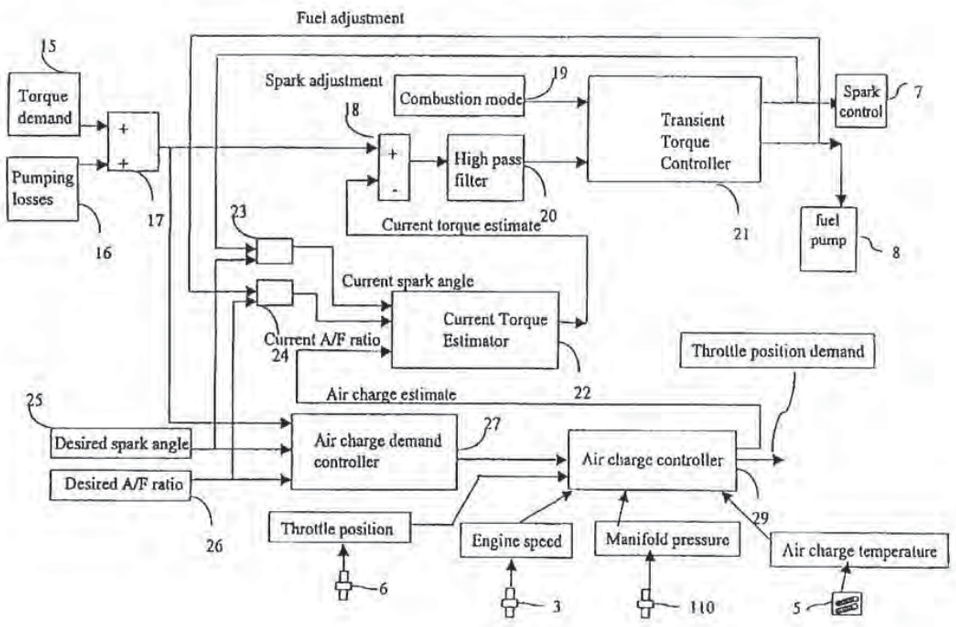
* cited by examiner

Primary Examiner—Tony M. Argenbright
(74) *Attorney, Agent, or Firm*—Brinks Hofer Gilson & Lione

(57) **ABSTRACT**

This invention relates to an engine torque controller for spark ignition internal combustion engines and more specifically for direct injection engines. The invention provides a torque controller and a method of controlling torque for an engine in which torque is controlled in dependence upon a filtered difference signal where the filtered difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque.

7 Claims, 3 Drawing Sheets



PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

UNITED STATES PATENT AND TRADEMARK OFFICE

BEFORE THE PATENT TRIAL AND APPEAL BOARD

VOLKSWAGEN GROUP OF AMERICA, INC.,
Petitioner

v.

MICHIGAN MOTOR TECHNOLOGIES, LLC,
Patent Owner

Case IPR2020-00444
Patent 6,581,565

DECLARATION OF C. ARTHUR MACCARLEY, PH.D., P.E. IN SUPPORT OF PETITION FOR *INTER PARTES* REVIEW OF U.S. PATENT NO. 6,581,565

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Patent Trial and Appeal Board
U.S. Patent & Trademark Office
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Alexandria, VA 22313-1450

VW EX1003
U.S. Patent No. 6,581,565

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PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

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1. Combining Suzuki and Cullen.....45

2. Combining Scherer with Suzuki and Cullen 49

B. Suzuki, Cullen, and Scherer render obvious claim 1. 55

1. [1.P] “A device for controlling a torque output of an engine, the device comprising:” 55

2. [1.A] “a torque demand controller for generating a torque demand signal; and;”.....57

3. [1.B] “a torque producer which receives the torque demand signal,”..59

4. [1.C] “the torque producer includes: an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal;”.....60

5. [1.D] “a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal;”.....64

6. [1.E] “a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent; and”.....66

7. [1.F] “a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal.” 73

C. Suzuki, Cullen, and Scherer render obvious claim 4. 77

1. [4.A] “The device of claim 1, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode”.....77

2. [4.B] “wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode, and”.....79

3. [4.C] “wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode.”.....81

D. Suzuki, Cullen, and Scherer render obvious claim 7. 82

1. [7.P] “A method for controlling a torque output of an engine, the method comprising:” 82

2. [7.A] “estimating a current torque signal from a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;” 83

3. [7.B] “comparing the estimated current torque signal with a desired torque signal to output a difference signal” 83

4. [7.C] “filtering out a plurality of low frequency components from the difference signal; and”.....84

5. [7.D] “controlling a fuel adjustment signal and a spark adjustment signal in dependence upon a filtered difference signal”.....85

XI. Ground 2: The combination of Suzuki, Cullen, Scherer, and Takahashi renders obvious claims 2, 3, 5, and 6. 85

A. Rationale for combining Suzuki, Cullen, Scherer, and Takahashi 85

B. Suzuki, Cullen, Scherer, and Takahashi render obvious claims 2 and 5. 92

C. Suzuki, Cullen, Scherer, and Takahashi render obvious claims 3 and 6. 99

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XIII. Conclusion 104

I. Introduction

I, C. Arthur MacCarley, Ph.D. PE., declare as follows:

1. I have been retained on behalf of Volkswagen Group of America, Inc. ("VWGoA") for the above-captioned *inter partes* review proceeding to provide my expert opinions and expert knowledge. I understand that this proceeding involves U.S. Patent No. 6,581,565 ("the '565 patent"), titled "Engine Torque Controller," and that the '565 patent is currently assigned to Michigan Motor Technologies LLC ("MMT"). I understand that the Petition submitted by VWGoA challenges claims 1–7 of the '565 patent.

2. The '565 patent describes a device and a method for controlling engine torque output in terms of fuel and spark adjustments that compensate for the difference between a demand torque and an estimated torque. I am familiar with the technology described in the '565 patent as of its earliest possible priority date, July 23, 2001.

3. I have been asked to provide my independent technical review, analysis, insights, and opinions regarding the '565 patent and the references that form the basis for the grounds of unpatentability set forth in the Petition for *inter partes* review of the '565 patent filed by VWGoA.

4. In preparing this Declaration, I have reviewed and am familiar with all the documents cited herein. I have reviewed and am familiar with the '565 patent

and its file history. I confirm that to the best of my knowledge, the accompanying exhibits are true and accurate copies of what they purport to be and that an expert in the field would reasonably rely on them to formulate opinions such as those set forth in this Declaration.

5. I am being compensated at my customary rate of $300 per hour for my work on this case. My compensation is not dependent upon my opinions, my testimony, or the outcome of this case.

II. Summary of Grounds

6. I understand that the Petition for *inter partes* review of the ’565 patent filed by VWGoA asserts the following grounds of unpatentability:

Ground	References	Basis	Claims Challenged
1	Suzuki, Cullen, Scherer	§103	1, 4, 7
2	Suzuki, Cullen, Scherer, Takahashi	§103	2, 3, 5, 6

III. Summary of Opinions

7. In my opinion, the challenged claims of the ’565 patent would have been obvious in view of the combinations of references that VWGoA asserts, as well as the state-of-the-art in automotive engine control on or before the year 2001, known to a person of ordinary skill in the art.

8. Independent claim 1 of the ’565 patent recites a device for controlling a torque output of an engine. EX1001, ’565 patent, 4:2-3. The claimed device includes a torque demand controller for generating a torque demand signal and a torque producer which receives the torque demand signal. *Id*., 4:5-8. The claimed torque producer includes an estimator that receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal. *Id*., 4:9-12. The claimed torque producer includes a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal. *Id*., 4:13-15. The claimed torque producer includes a high-pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent. *Id*., 4:16-18. The claimed torque producer includes a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal. *Id*., 4:19-22.

9. As discussed in this Declaration, all these recited elements—for example, a torque demand controller and a torque producer having an estimator, a comparator, a high-pass filter, and a transient torque controller—were basic, well-known components found in generic engine control systems as of July 23, 2001, the earliest possible priority date. And, as discussed in this Declaration, the claimed solution for compensating between estimated and demand torques during transient

engine operations was well known and had been solved by the prior art in exactly the same way as recited in claims 1-7 of the ’565 patent. Moreover, as further discussed in this Declaration, well before the ’565 patent’s July 23, 2001 earliest possible priority date, a person of ordinary skill in the art would have had a good reason to combine the asserted prior art references, and in so doing, they would have had a reasonable expectation of success.

10. Therefore, it is my opinion that the challenged claims would have been obvious in view of the disclosures in the asserted prior art references, as described in detail below.

IV. Qualifications

11. My experience and education are detailed in my curriculum vitae (“CV”), a copy of which is provided as EX1004. My CV also lists peer-reviewed publications on which I am the primary or a named author and identifies parties on behalf of whom I have previously provided expert testimony.

12. My research and development work since the late 1970s has focused on advanced control systems in automotive or transportation applications, including developing microprocessor-based engine control systems for regulating air intake, fuel injection, and ignition. As an academic for 31 years, my teaching specialization is control systems and electronics applicable to automotive and similar applications, as well as internal combustion engines and fuels. I have conducted research and

managed many projects that are highly relevant to the subject matter of the '565 patent, as detailed below.

13. I obtained my Bachelor of Science in Engineering (Energy and Kinetics specialization) and my Master of Science (Electrical Engineering) from the University of California, Los Angeles in 1976 and 1978, respectively. I then earned a Ph.D. in Electrical Engineering with a specialty in Computer-based Control Systems in 1987 from Purdue University, West Lafayette, Indiana.

14. Before pursuing my Ph.D., I was employed by the Digital Communications Laboratory of the Hughes Aircraft Corp between 1977 and 1979. Between 1979 and 1983, I was employed by the University of Denver Research Institute and by the American Bosch Division of United Technologies. My work at that time included the design and optimization of electronic diesel and SI engine fuel injection controls. This included responsibility for the development and validation of electronic engine control algorithms. I also designed, constructed, and tested electronic fuel injection and ignition control systems for hydrogen, methanol, and natural gas fueled engines under contract to the U.S. Department of Energy.

15. While earning my Ph.D. at Purdue University, I was the recipient of the David Ross Fellowship for Doctoral Study, and I focused my research on microprocessor-based control systems and indirect sensing methods for automotive fuel injection applications.

16. I am currently a Professor of Electrical and Computer Engineering at the California Polytechnic State University, San Luis Obispo (Cal Poly). I have been on the faculty since 1988, tenured since 1994. I have served as the Chair of the Electrical Engineering Department, the Director of the Computer Engineering Program, and as the interim Head of the BioResource and Agricultural Engineering Department. I am currently the Director of the Transportation Electronics Laboratory and have been since 1995. I have also served as a Guest Professor of Electrical Engineering at Olin College in Needham, Massachusetts in 2011, and I have taught Electrical and Mechanical Engineering in the International Summer School program at Munich University of Applied Science in Munich, Germany every year from 2014 to the present.

17. My university teaching and research specialties include digital control systems, microprocessor-embedded systems, automotive and transportation electronics, internal combustion engines, advanced sensors, and alternative engine fuels, all with applications in the field of automotive engineering

18. I am a Senior Member of the Society of Automotive Engineers (SAE), the Institute of Electrical and Electronic Engineers (IEEE), and Sigma Xi (Scientific Research Honor Society). I have been a Registered Professional Engineer in good standing in the state of Colorado continuously since 1981.

19. Based upon on my education, my professional experience from 1978 through the present, and my scholarly publications, I am an expert in the relevant field of the ’565 patent at issue here, and I have been an expert in this field since before the ’565 patent was filed with the United States Patent and Trademark Office (“USPTO”). I am intimately familiar with how a person of ordinary skill in the art (“POSA”) would have understood and used the terminology found in the ’565 patent at the time of its filing.

V. Materials Considered

20. In formulating my opinions, I have relied upon my training, knowledge, and experience that are relevant to the ’565 patent. Furthermore, I have specifically considered the following documents, in addition to any other documents cited in this Declaration:

Exhibit No.	Description
1001	U.S. Patent No. 6,581,565 B2 to Heslop *et al*. (“’565 Patent”)
1002	Prosecution File History of U.S. Patent No. 6,581,565 B2 (“’565 history”)
1004	Curriculum Vitae of C. Arthur MacCarley, Ph.D., P.E.
1005	U.S. Patent No. 6,006,717 A to Suzuki *et al.*, titled “Direct-Injection Spark-Ignition Type Engine Control Apparatus,” issued December 28, 1999 (“Suzuki”)
1006	U.S. Patent No. 5,241,855 A to Cullen *et al.*, titled “Method and Apparatus for Inferring Engine Torque,” issued September 7, 1993 (“Cullen”)
1007	U.S. Patent No. 6,07,681 A to Scherer *et al.*, titled “Process and Apparatus for Adjusting the Torque of an Internal-Combustion Engine,” issued April 11, 2000 (“Scherer”)

Exhibit No.	Description
1008	U.S. Patent No. 5,282,449 A to Takahashi *et al.*, titled "Method and System for Engine Control," issued February 1, 1994 ("Takahashi")
1009	"Bosch Fuel Injection Systems," F. Aird, Berkeley Publishing Group, 2001, ISBN 1-55788-365-3 ("Aird")
1010	U.S. Patent No. 6,209,519 B1 to Melchior *et al.*, titled "Method and Arrangement for Controlling the Quiet Running of an Internal Combustion Engine," issued April 3, 2001 ("Melchior")
1011	U.S. Patent No. 5,692,471 A to Zhang, titled "Method and Arrangement for Controlling a Vehicle," issued December 2, 1997 ("Zhang")
1012	"Bosch Automotive Handbook," Robert Bosch GmbH, 2000, ISBN 0-7680-0669-4 ("Bosch")
1013	*Intentionally Left Blank*
1014	John B. Heywood, Internal Combustion Engine Fundamentals, 1st Ed. McGraw-Hill, Inc., 1988. ("Heywood")
1015	Ronald K. Jurgen, "Automotive Electronics Handbook," McGraw-Hill, Inc., ISBN0-07-033189-8, c.1994 (selected portions) ("Jurgen")
1016	*Intentionally Left Blank*
1017	*Intentionally Left Blank*
1018	*Intentionally Left Blank*
1019	Understanding Automotive Electronics, Fifth Edition (1998), William B. Ribbens, Ph.D. ("Ribbens")
1020	*Intentionally Left Blank*
1021	*Intentionally Left Blank*
1022	*Intentionally Left Blank*
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1028	*Intentionally Left Blank*

1029	Amended Complaint for Patent Infringement, *Michigan Motor Technologies LLC v. Volkswagen AG*, Case No. 2:19-cv-10485 (E.D. Mich.), filed April 30, 2019

VI. Legal Standards

21. I have also relied upon various legal principles (as explained to me by Volkswagen's counsel) in formulating my opinions. My understanding of these principles is summarized below.

22. I have been told the following legal principles apply to analysis of patentability. I also have been told that, in an *inter partes* review proceeding, a patent claim may be deemed unpatentable if it is shown by a preponderance of evidence that the claim is anticipated by one prior art reference under 35 U.S.C. § 102 or rendered obvious by one or more prior art reference under 35 U.S.C. § 103.

23. I understand that documents and materials such as printed publications or patents that qualify as prior art can be used to render a patent claim as anticipated or as obvious.

24. I understand that once the claims of a patent have been properly construed, the second step in determining anticipation or obviousness of a patent claim requires a comparison of the properly construed claim language to the prior art on a limitation-by-limitation basis.

A. My Understanding of Claim Construction

25. I understand that during an *inter partes* review proceeding, claims are to be construed in light of the specification as would be read by a person of ordinary skill in the relevant art at the time of the purported priority date. I understand that claim terms are given their ordinary and customary meaning as would be understood by a person of ordinary skill in the relevant art in the context of the entire disclosure. A claim term, however, will not receive its ordinary meaning if the patentee acted as his own lexicographer and clearly set forth a definition of the claim term in the specification. In this case, the claim term will receive the definition set forth in the patent.

B. A Person of Ordinary Skill in the Art

26. I understand that a person of ordinary skill in the relevant art (herein "POSA") is presumed to be aware of all pertinent art, thinks along conventional wisdom in the art, and is a person of ordinary creativity—not an automaton.

27. I have been asked to consider the level of ordinary skill in the field that someone would have had at the time the alleged invention was made. In deciding the level of ordinary skill, I considered the following:

- the levels of education and experience of persons working in the field;
- the types of problems encountered in the field; and
- the sophistication of the technology.

28. I understand that the relevant time for considering whether a claim would have been obvious to a POSA is at the time of the alleged invention, which I have been told to assume for this case is July 23, 2001.

29. Regardless if I use "I" or "POSA" during my technical analysis below, all of my statements and opinions are to be understood to be based on how a POSA would have understood or read a document at the time of the alleged invention.

C. My Understanding of Obviousness

30. I understand that a patent claim is unpatentable if the claimed invention would have been obvious to a person of ordinary skill in the art at the time of the alleged invention. I understand that this means that even if all of the elements of the claim cannot be found in a single prior art reference that would anticipate the claim, the claim can still be unpatentable.

31. It is my understanding that, to obtain a patent, a claimed invention must have been, as of its earliest possible priority date, non-obvious in view of the prior art in the field. I understand that a patent claim is obvious when the differences between the subject matter sought to be patented and the prior art are such that the subject matter as a whole would have been obvious to a person of ordinary skill in the art at the time the alleged invention was made.

32. When considering the issues of obviousness, I have been told that I am to do the following:

- Determine the scope and content of the prior art;
- Ascertain the differences between the prior art and the claims at issue;
- Resolve the level of ordinary skill in the pertinent art; and
- Consider evidence of secondary indicia of non-obviousness (if available).

33. With respect to determining the proper scope of prior art to examine, I understand that in order for a prior art reference to be properly used in an obviousness ground under 35 U.S.C. § 103, the prior art reference must be analogous art to the claimed invention. I have been told that a reference is analogous art to the claimed invention only if: (1) the reference is from the same field of endeavor as the claimed invention; or (2) the reference is reasonably pertinent to the particular problem solved by the inventor.

34. I understand that factors relevant to determining the proper field of endeavor include the inventor's explanations of the subject matter (including the patent specification), as well as the claimed invention's structure and function. And I further understand that to be reasonably pertinent to the particular problem solved by the inventor, a prior art reference must logically commend itself to the inventor's attention in considering his or her problem.

35. I have been told that an analogous reference may be modified or combined with other analogous references or with the POSA's own knowledge if the person would have found the modification or combination obvious. I have also been told that a POSA is presumed to know all relevant, analogous prior art, and the obviousness analysis may take into account the inferences and creative steps that a POSA would employ.

36. In determining whether a prior art reference would have been combined with another prior art reference or other information known to a POSA, I have been told that the following principles may be considered:

- A combination of familiar elements according to known methods is likely to be obvious if it yields predictable results;
- The simple substitution of one known element for another is likely to be obvious if it yields predictable results;
- The use of a known technique to improve similar devices, products, or methods in the same way is likely to be obvious if it yields predictable results;
- The application of a known technique to a prior art reference that is ready for improvement is likely obvious if it yields predictable results;

- Any need or problem known in the field and addressed by the reference can provide a reason for combining the elements in the manner claimed;
- A skilled artisan often will be able to fit the teachings of multiple references together like a puzzle; and
- The proper analysis of obviousness requires a determination of whether a POSA would have a "reasonable expectation of success"—not "absolute predictability" of success—in achieving the claimed invention by combining prior art references.

37. I understand that whether a prior art reference renders a claim unpatentable as obvious is determined from the perspective of a POSA. I have also been told that, while there is no requirement for the prior art to contain an express suggestion to combine known elements to achieve the claimed invention, a suggestion to combine known elements to achieve the claimed invention may come from the prior art as a whole or individually, as filtered through the knowledge of one skilled in the art. In addition, I have been told the inferences and creative steps a POSA would employ are also relevant to the determination of obviousness.

38. I also understand that when a work is available in one field, design alternatives and other market forces can prompt variations of it, either in the same field or in another. I have also been told that if a POSA can implement a predictable

variation and would see the benefit of doing so, that variation is likely to be obvious. I have been told that in many fields, there may be little discussion of obvious combinations, and in these fields, market demand—not scientific literature—may drive design trends. I have been told that, when there is a design need or market pressure and there are a finite number of predictable solutions, a POSA has good reason to pursue those known options.

39. I have been told there is no rigid rule prescribing that a reference or combination of references must contain a "teaching, suggestion, or motivation" to combine references. But I also have been told that the "teaching, suggestion, or motivation" test can be a useful guide in establishing a rationale for combining elements of the prior art. I have been told this test poses the question as to whether there is an express or implied teaching, suggestion, or motivation to combine prior art elements in a way that realizes the claimed invention, and that it seeks to counter impermissible hindsight analysis.

VII. Level of Ordinary Skill in the Art

40. In my opinion, a person of ordinary skill in the art ("POSA") in the context of the '565 patent as of July 23, 2001 (the earliest possible priority date of the '565 patent) would possess a Bachelor of Science degree in electrical, mechanical, automotive, or a similar field of engineering; be knowledgeable of the principals and operation of internal combustion engines of that time periods; and

have the equivalent of two years' experience or hands-on education in the design or implementation of automotive or vehicular control systems or components. Experience could take the place of some formal training, as domain knowledge may be learned on the job. This description is approximate, and a higher level of education or skill might make up for less experience and vice versa.

41. I am well qualified to determine the level of ordinary skill in the art. First, I am very familiar with the technology of the '565 patent as of the July 23, 2001 timeframe. My academic and teaching background in both Electrical and Mechanical Engineering also provides significant insight into the expectations of a person of a given academic level or graduate certification. As mentioned above, by 2001, I had acquired extensive experience relating to engine control systems in vehicles, including developing microprocessor-based engine control systems for regulating air intake, fuel injection, and ignition. Specifically, by 2001, I had over 20 years of experience working with advanced control technologies for internal combustion engines, technologies including, for example: electronic engine control of fuel and air delivery, electronic equipment for regulating air intake, fuel injection and ignition systems. *See supra* Section IV.

VIII. Overview of the ’565 Patent

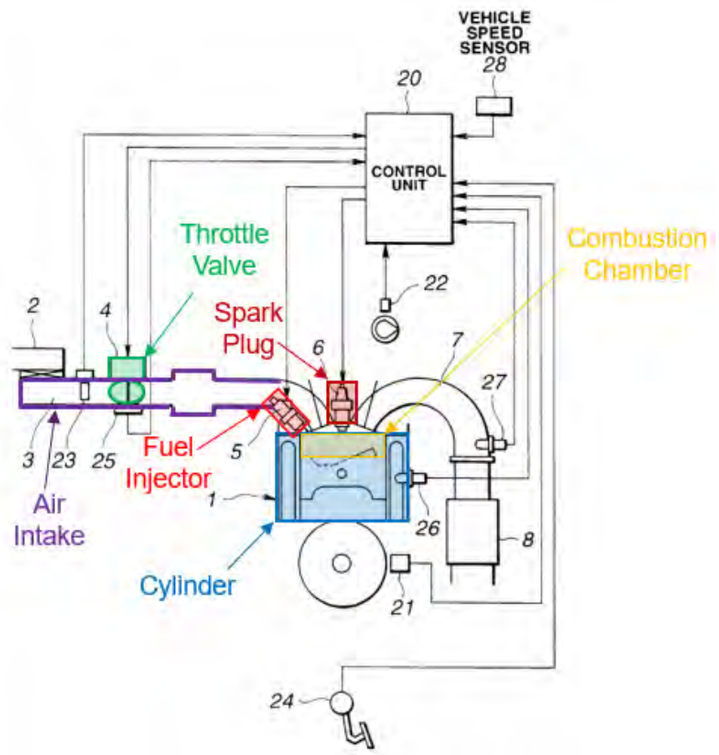
A. Technology Overview

1. Direct Injection Spark Ignition Engine Operating in Two Combustion Modes

42. Direct injection spark ignition (DISI) engines, also known as direct cylinder injection (DCI) or gasoline direct injection (GDI or DGI) engines, were well known for decades before the ’565 patent. EX1009, 19-21, 26. For example, automobile manufacturers, such as Robert Bosch GmbH and Mercedes Benz, began experimenting with timed, high-pressure, direct gasoline injection in the mid-1930s. EX1009, 19-21, 26. By the 1950s, Mercedes Benz started implementing “the direct (into the combustion chamber) injection scheme used in diesels” in its gasoline-powered Formula One engines and the 300SL model. *Id.*, 21-22. By the 1990s, DISI engines were implemented in large-scale passenger car production. EX1005, Suzuki, 1:18-20; EX1009, 30-32. Thus, the auto industry had been using DISI engines well before the ’565 patent.

43. Suzuki discloses an example of a prior-art DISI engine 1.

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EX1005, FIG. 2 (annotated).

44. As shown above in Figure 2, a DISI engine 1 typically includes an air intake 3 for directing air toward the engine cylinders and an adjustable throttle valve 4 for controlling the volume of air drawn through the air intake 3. EX1005, 3:23-31. The DISI engine 1 further includes an electrically-actuated fuel injector 5 associated with each engine cylinder for injecting fuel directly into the cylinder's combustion chamber and a spark plug 6 disposed in the cylinder's combustion chamber for igniting the cylinder's air-fuel mixture. *Id.*, 3:23-51. By forming the air-fuel mixture within the cylinder's combustion chamber, DISI engines can form the fuel-air charge in the cylinder in two ways: a homogeneous charge in which a stoichiometric well-mixed charge populates the entire combustion chamber, and a stratified charge

in which a stoichiometric mixture is formed near the spark plug to assure proper ignition, but the overall mixture in the combustion chamber is lean (more air than available fuel). Direct cylinder injection provides other benefits for engine efficiency and emissions, including the elimination of precipitating or condensing injected fuel on the walls of the intake manifold—a common problem for engines using manifold, port fuel injection, or carburetors. EX1012, 464; EX1009, 33.

45. Operating DISI engines in either a stratified charge mode or a homogenous charge mode was well known before the ’565 patent. EX1005, 1:18-28; EX1012, 464, 509; EX1014, 37-38 (“Since the 1920s, attempts have been made to develop a hybrid internal combustion engine that combines the best features of the spark-ignition engine and the diesel.”). In the homogenous mode, fuel is injected during the intake stroke to allow maximum time for the air and fuel to combine evenly throughout the entire combustion chamber. EX1005, 1:18-28; EX1012, 464. In the stratified mode, fuel is injected during the compression stroke to provide the heterogeneous charge, as discussed above. EX1005, 1:18-28; EX1012, 464; EX1014, 38. Direct cylinder fuel injection makes possible the formation of the heterogeneous or stratified fuel-air mixture in the cylinder simply by altering the injection timing and fuel delivery, functions easily performed by an electronic engine control system.

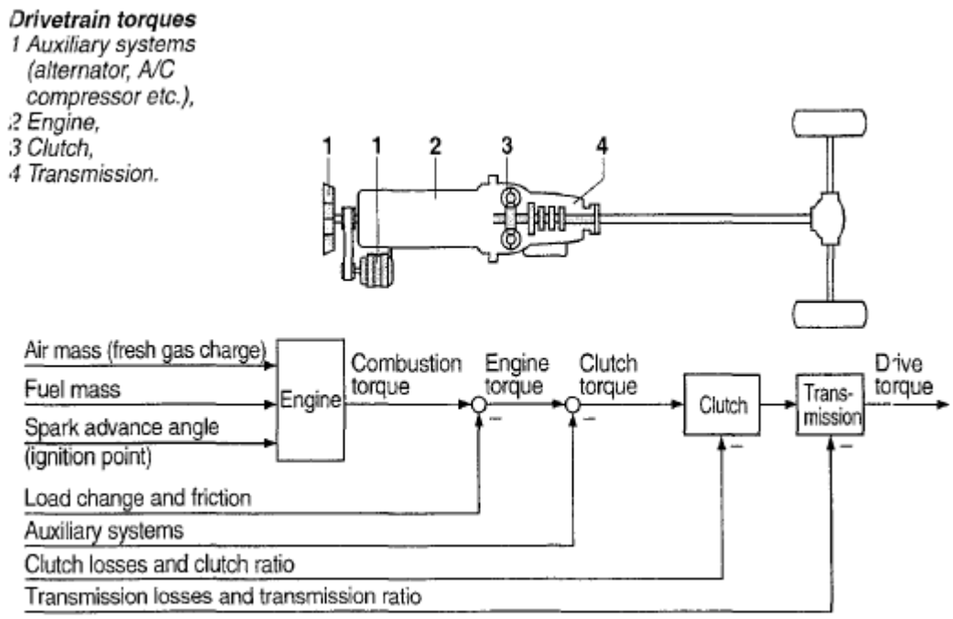
46. Similar to diesel engines, stratified-mode DISI engines can at least partially control torque output through the timing and quantity of fuel injection. EX1010, 6:5-9, 7:8-15, 8:34-37; EX1014, 6, 38, 778 ("Alternative types of internal combustion engines, such as the stratified-charge … combines characteristics normally associated with either the spark-ignition or diesel… ."). During stratified-mode operation, the DISI engine can reduce fuel consumption and emissions when operating at lower engine loads, and while during homogeneous-mode operation, the DISI engine can generate maximum power for higher engine loads. EX1012, 509. Thus, the engine's overall efficiency and emissions can be improved during the mixed driving conditions that are most common for passenger vehicles and trucks. EX1012, 507, 509 ("With gasoline direct injection in SI engines, fuel consumption can be reduced by up to 20% when compared with conventional manifold injection… ."); EX1014, 38.

2. Torque Feedback Control

47. Long before the '565 patent, using torque feedback control via an engine controller was common practice. EX1012, 498; EX1011, 139; EX1019, 224.

48. As shown below, the engine controller typically regulates engine torque output by adjusting three primary parameters: (1) the available air mass in the cylinder's combustion chamber, (2) the available fuel mass in the cylinder's combustion chamber, and (3) the ignition's spark angle (timing). EX1011, 1:25-31

("The conversion of a torque desired value for … an internal combustion engine … is achieved by influencing the ignition angle, by interrupting or resuming the metering of fuel to individual cylinders and/or by influencing the air supplied to the engine."); EX1012, 452, 498 ("[T]he variables for determining the engine torque: the charging of the cylinders with air, the mass of the injected fuel and the ignition angle."); EX1019, 147 ("Engine control in the vast majority of engines means regulating fuel and air intake as well as spark timing to achieve desired performance in the form of torque or power output.").



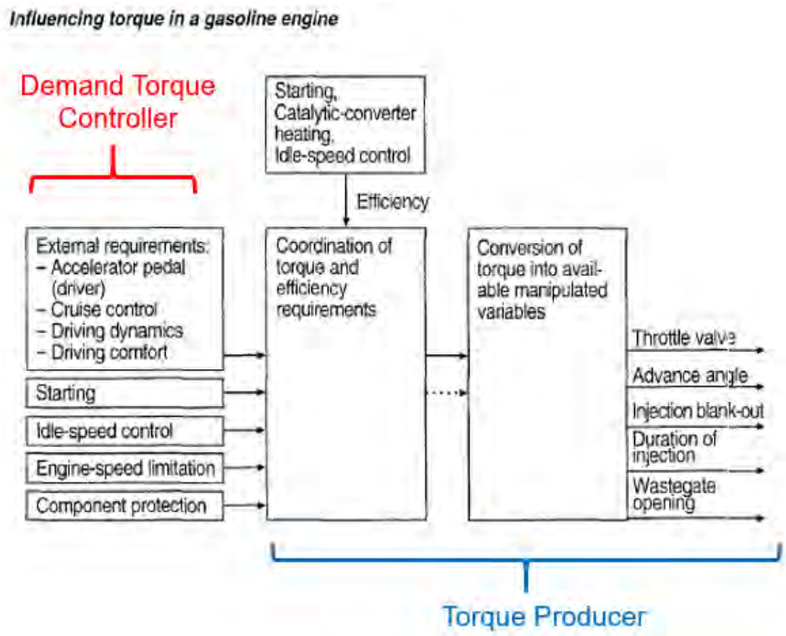
EX1012, 452.

49. The engine controller typically includes a sub-module (i.e., air charge controller) directed to actuating the throttle valve to adjust the cylinder's air mass

(also known as air charge) at any RPM. EX1012, 452, 500-501; EX1019, 154. The engine controller typically includes a sub-module (i.e., fuel pump controller) directed to regulating the timing and duration of the fuel injector to adjust the cylinder's fuel mass. EX1012, 452, 463-464 ("[B]oth the fuel mass appropriate to each cylinder and the correct start of injection are calculated by the control unit (ECU)."); EX1019, 154. The engine controller typically includes a sub-module (i.e., ignition controller) directed to regulating the cylinder's spark plug to adjust the ignition spark timing. EX1012, 452, 493; EX1015, 12.10; EX1019, 154, 239-243.

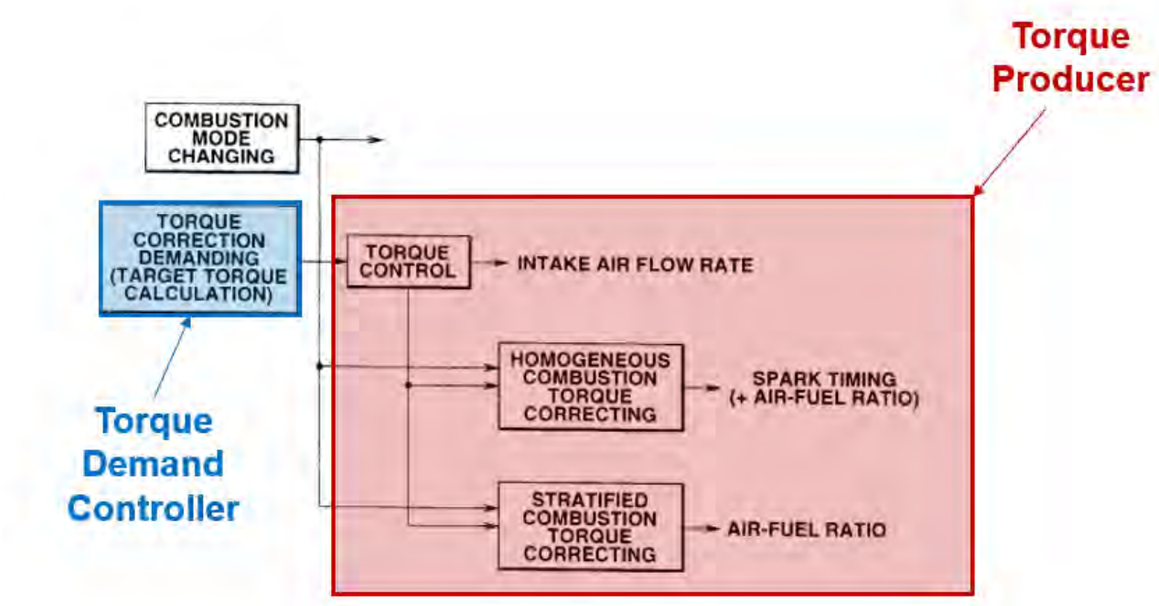
50. The engine controller's objective for controlling torque output is to make available the torque requested by the driver, while also accommodating the variable torque demands on the engine. EX1012, 453, 498. As recognized by the '565 patent, an engine controller typically includes a demand torque controller and a torque feedback control system—a torque producer. EX1001, 1:11-15; EX1005, 3:10-22; EX1011, 2:36-38; EX1012, 503, 507. As shown below, the demand torque controller generates a demand torque signal in accordance with a change in engine operation, such as a depressed accelerator pedal. EX1001, 1:11-15; EX1005, 4:48-57; EX1012, 507. The torque producer receives the torque demand signal and, in response, adjusts the torque output of the engine by modifying the air supply, the fuel supply, or the spark timing so that the output torque meets the demanded torque. EX1001, 1:11-15; EX1005, 3:5-22; EX1012, 452, 498, 507.

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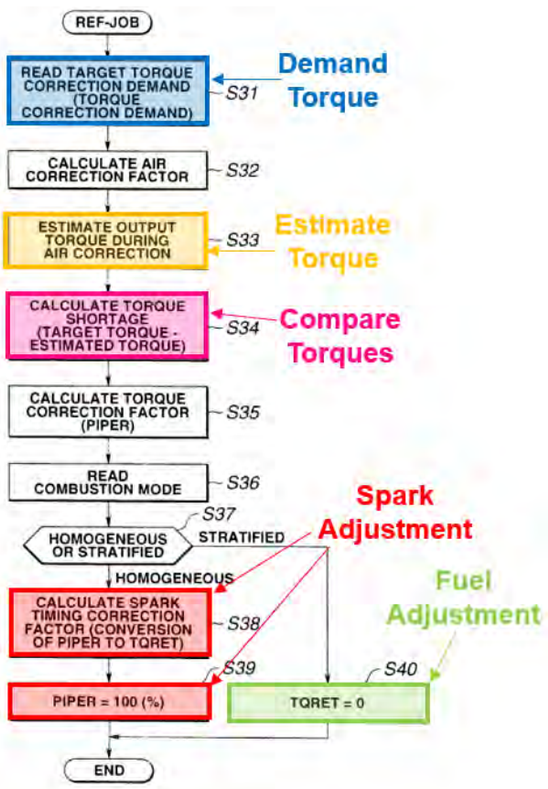
EX1012, 503.

51. Suzuki discloses another example of a prior art engine controller that includes a torque demand section and a torque producer section, as shown below in Figure 1B. EX1005, 3:5-22, FIG. 1B. Similar to other typical engine controllers, Suzuki's torque producer adjusts the cylinder's available air mass (i.e., air charge) through control of the throttle valve, the cylinder's available fuel mass through control of the fuel injector, and the spark timing through control of the spark plug. *Id.*, 4:33-38 ("The control unit 20 … includes a microcomputer … for making the calculations described herein to control the degree of opening of the electronic controlled throttle valve 4, the amount of fuel injected to the engine by the fuel injector 5, and the spark timing of the spark plug 6.").



EX1005, FIG. 1B (annotated).

52. Using feedback control based on various sensor inputs to align the produced torque with the demanded torque was common practice before the '565 patent. EX1005, 1:7-17, EX1011, 1:25-31; EX1012, 498, 503, 507, 508. This alignment typically included estimating a torque output and modifying engine parameters, such as spark timing and the air/fuel ratio, so that the measured or estimated torque output converges with the demanded torque value. EX1005, 1:7-17; EX1011, 3:49-61, 4:42-45; EX1012, 503, 504, 507, 508. As shown below in Figure 6, Suzuki discloses an example prior-art technique for controlling torque output based on compensating for the difference between the demand torque and the estimated output torque. EX1005, 7:7-67, FIG. 6.



EX1005, FIG. 6 (annotated).

53. As to compensating for the difference between the demand torque and estimated torque in dual-mode DISI engines, it was well known before the '565 patent that torque was best controlled by adjusting the amount and timing of injected fuel when set in a stratified charge mode and by adjusting the spark timing when set in a homogenous mode. EX1005, 3:10-22; EX1010, 6:5-9, 7:8-15, 8:34-37. Ignition (spark) timing angle has only a minor influence on torque when operating in stratified charge mode, so torque output is typically adjusted by modifying the injected fuel quantity. EX1005, 3:10-22; EX1014, 37-38. Conversely, when the

engine is operating in the homogeneous mode, torque output is modified by adjusting the ignition timing. EX1005, 3:10-22.

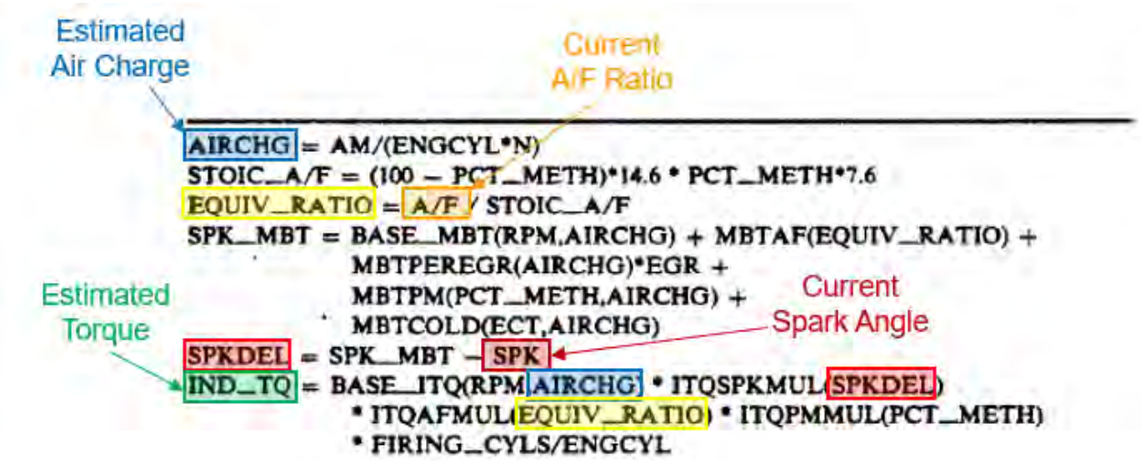
3. Engine Parameter Estimation Techniques for Torque Feedback Control

54. As explained above, using torque feedback control was well known before the ’565 patent. Estimating various engine parameters, such as the current engine torque output and cylinder air charge, was also common for executing feedback torque control before the ’565 patent.

55. Given that the direct real-time measurement of engine torque is challenging and expensive, output torque is commonly estimated by a real-time computer model of the engine and vehicle, producing an indirect measure that is accurate enough for the torque feedback control process. The engine controller typically estimated the output torque based on numerous operational parameters to account for various engine operations that influence the actual torque output. EX1005, 4:48-57, EX1006, 2:26-42; EX1011, 2:58-67.

56. As shown below, Cullen discloses an example of a prior-art technique for calculating an estimated torque output. EX1006, 5:32-54. Specifically, Cullen discloses using “a spark timing input 13, … an air/fuel ratio input 16, an engine rpm input 17, [and] an engine air charge input 18,” as inputs for estimating the engine torque output. *Id.*, 5:32-53; 5:57-6:2. Cullen further discloses that estimating torque output based on such inputs provides a more accurate real-time calculation of the

engine torque output than alternative methods. EX1006, 1:13-15, 2:32-42 ("[A] predicted torque calculation can be made more accurate by predicting the air conditioning torque requirement versus head pressure, power steering torque requirements versus power steering pressure switch, cold engine friction versus time since start and engine coolant temperature, … [among other parameters].").



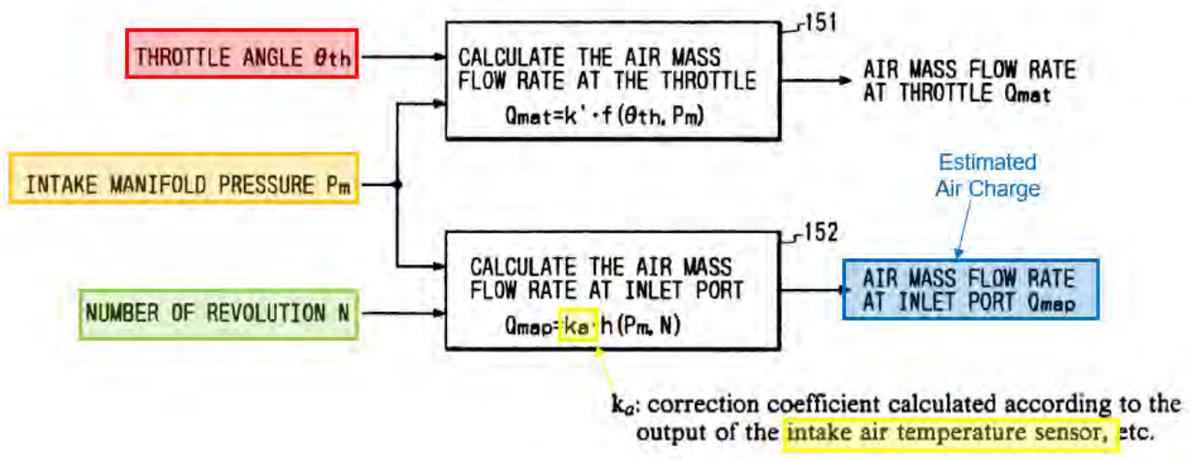
EX1006, 5:35-45 (annotated).

57. One of the common inputs for determining torque output is air charge—the mass of air that is drawn into the engine cylinder. EX1006, 5:32-52; EX1008, Takahashi, 3:42-55; EX1012, 452, 501-502 ("[A]ir charge … serves to calculate the torque currently being delivered by the engine."); EX1015, 12.6; EX1019, 176. Because there is no feasible way to measure the air mass in the engine cylinder directly, engine controllers typically estimate the current air charge. EX1012, 503 ("The relative charge cannot be measured directly but it can be determined from the available measurement signals."); EX1014, 294-296; EX1015,

12.6; EX1019, 176-177 ("There is no practically feasible way of measuring the mass of air in the cylinder directly.")

58. There are two primary techniques for estimating air charge: (1) speed-density model and (2) air flow measurement model. EX1006, 4:5-9; EX1012, 501-502; EX1014, 294-97; EX1015, 12.6; EX1019, 177. In applying the speed-density model, the engine controller determines the cylinder air charge based on the intake manifold pressure, the engine speed, and the intake manifold temperature (i.e., air charge temperature). EX1012, 501-02; EX1014, 296 ("In the speed-density system, the primary inputs to the ECU are the outputs from the manifold pressure sensor, the engine speed sensor …, and the temperature sensors installed in the intake manifold to monitor air temperature… ."); EX1015, 12.6 ("In the speed density method, the air charge is calculated by the engine electronic control unit based on the measurement of air inlet temperature, intake manifold pressure, and engine RPM."); EX1019, 177-179. In applying the air flow measurement model, the engine controller measures the air mass flow rate in the intake manifold using an air-mass sensor. EX1006, 4:5-8; EX1014, 297; EX1015, 12.6; EX1019, 230. The engine controller then calculates the air charge based on function of the measured mass flow rate and the measured engine speed. EX1006, 4:5-8; EX1014, 297; EX1015, 12.6; EX1019, 230 ("The quantity of air drawn into the cylinder, A, is computed from the mass air flow rate and the RPM.")

59. Takahashi discloses an example of a prior-art engine air charge controller that calculates an estimated air charge according to the speed-density model. As shown below, Takashi discloses a throttle control controller with a status estimating block 152 that calculates the air charge on intake pressure P_m, engine speed N, and a correction coefficient k_a determined from a current intake temperature sensor. EX1008, 10:54-66. Takahashi's control unit adjusts both the throttle valve position and the fuel injection quantity based on the estimated air charge, which ultimately controls the torque output of the engine. *Id.*, 3:24-27, 5:53-66, 10:21-27.



EX1008, FIG. 15 (annotated).

4. Steady State and Transient Components of Demand Torque

60. Long before the ’565 patent, it was known that the demanded torque signal includes a steady state or low frequency component and a transient or high frequency component. The so-called low frequency component represents torque demand during quasi-static conditions (e.g., idle or cruising–operating speed conditions), and the so-called high frequency component represents abrupt changes in in this signal that result from torque transients (e.g., a rapidly depressed accelerator pedal, the momentary torque drop occurring during a gear shift, or the abrupt increase or decrease of an accessory load such as an air conditioner). EX1005, 4:48-55; EX1007, 1:25-29; EX1012, 478, 505.

61. It was also well known that these transient (high frequency) components of demanded torque could not be adequately corrected by an electronic (drive-by-wire) throttle actuator—an electromechanical device that cannot react quickly enough to vary the air intake rate at the fast rate required to compensate for the abrupt torque transients. EX1005, 1:13-17 (“In order to achieve the target torque, the torque control … requires a faster response than intake air flow rate control can provide.”); EX1007, 1:21-25 (“The dynamics of engine torque regulation by controlling only the air flow rate are significantly restricted by the finite speed of the throttle valve control element.”) Accordingly, control systems commonly addressed dynamic torque demands by isolating the transient component

from the demanded torque signal. EX1007, 2:38-3:10. For example, Scherer discloses an example controller that includes a high-pass filter. *Id.*, 4:20-53. Scherer's high-pass filter isolates the transient torque component from the desired torque signal and outputs the transient torque component to a transient torque controller, thereby expediting the controller's response time to correcting torque output. *Id.*, 4:20-53, 5:9-14.

62. Correcting transient components of the demand torque signal were commonly addressed by adjusting either the ignition or fuel injection timing. EX1005, 1:13-17; EX1007, 2:67-3:5 ("**highly dynamic** engine torque adjustment (by regulating the ignition point or the injection start)");[1] EX1012, 503 ("For setting the internal torque, the ME-Motronic's torque converter has a slow path … for the throttle valve (ETC), and **a high-speed path** … for variation of the ignition angle and/or injection blank-out of individual cylinders.").

63. Thus, the recited elements of the '565 patent's claims—generating a torque demand, estimating a torque output, comparing the estimated and demand torque outputs to output a difference signal, using a high-pass filter to remove the low frequency component of the torque difference signal, and outputting fuel and spark adjustments based on the filtered torque difference signal—were well known,

[1] Emphasis added throughout unless otherwise indicated.

basic techniques executed by electronic controllers for a DISI engines at the time of the alleged invention.

B. Alleged Problem in the Prior Art

64. The ’565 patent is directed to the problem of compensating for differences between the torque estimated by the torque producer and the torque demanded by the demand controller, even during rapid transients in the torque demand or engine load. EX1001, 1:57-59, 3:23-29. But as explained above, the problem of compensating for differences between estimated torque and demand torque, as well as solutions for this problem, was well known long before the ’565 patent. And as discussed below, the ’565 patent adds nothing to the realm of previously known solutions.

C. Alleged Invention of the ’565 Patent

65. The ’565 patent admits that it was already known for a DISI engine controller to modify torque output in terms of fuel adjustment when set in stratified mode and spark timing when set in homogeneous mode. *Id.*, 1:36-45. But according to the ’565 patent, these known DISI engine controllers allegedly could not provide fuel and spark adjustment signals that accounted for the differences between the estimated output torque and the demand torque. *Id.*, 1:46-58.

66. To allegedly solve the known problem of compensating for differences between estimated torque and demand torque, the ’565 patent provides “a torque controller and a method of controlling torque for an engine in which torque is

controlled in dependence upon a filtered difference signal where the filtered difference signal is the difference between a desired torque signal and a signal representing an estimate of the current torque." EX1001, Abstract. As shown below, the '565 patent's control system included: (1) a current torque estimator 22 for estimating a current torque signal; (2) a comparator 18 for comparing the estimated current torque signal with a desired torque signal; (3) a high pass filter 20 for filtering out the low frequency component of the desired torque signal; and (4) a transient torque controller 21 for adjusting spark timing and the amount of injected fuel. *Id.*, 3:29-50, FIG. 3.

67. But well before the '565 patent's earliest possible priority date, this problem (compensating for differences between estimated torque and demand torque) had been solved in the same way. As already discussed, Suzuki discloses calculating the difference between the estimated torque and the demand torque and controlling fuel and spark adjustment dependent upon these calculated differences. EX1005, 7:7-8:6. Cullen discloses using a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal[2] to represent the torque

[2] To a POSA, the plain and ordinary meaning of the term "air charge" is the air mass that is drawn into the engine cylinder during each intake stroke. EX1019, 176. There is no truly direct way to measure air charge. *Id.* Rather, air charge is estimated from the mass air flow rate entering through the intake.

output for engine control. EX1006, 5:32-56. And Scherer discloses using a high-pass filter to isolate the transient component of a torque error signal to adjust torque output with a quicker response time during rapid changes in torque demand or load. EX1007, 4:20-56.

68. Thus, the claim elements that purport to capture the alleged inventive concept of the ’565 patent recite nothing more than what was already taught in the prior art and would have been well known to a POSA.

D. Prosecution History Summary

69. The application that issued as the ’565 patent underwent very limited prosecution at the U.S. Patent and Trademark Office. The Examiner issued a Notice of Allowance without a single Office Action. *See generally* EX1002. Moreover, the Examiner did not provide any reasons for allowing the claims in the Notice of Allowance. *See id.*, 0045-52.

70. Suzuki, Cullen, and Takahashi, references upon which this Petition relies, were not before the examiner during prosecution of the ’565 patent. *Id.* And Scherer was never expressly considered or applied by the Examiner during prosecution.

E. Claim Construction

71. It is my understanding that the challenged claims of the ’565 patent are to be given their ordinary and customary meaning as understood by one of ordinary skill in the art at the time of the alleged invention in light of the specification and the

prosecution history pertaining to the patent. Therefore, for the purposes of this Declaration, all claim terms are given their plain and ordinary meaning.

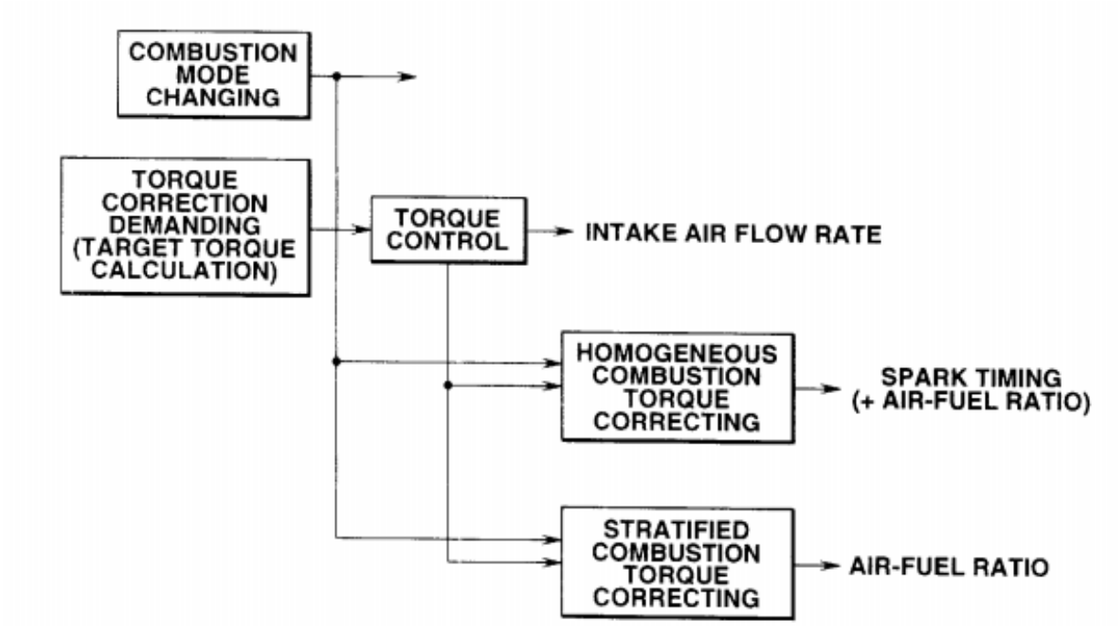
IX. Summary of the Applied References

72. Each applied reference discloses a method and system for SI engine torque control and thus is from the same field of endeavor as the ’565 patent.

A. Suzuki

73. Suzuki, like the ’565 patent, is directed to a direct-injection spark-ignition engine controller for correcting torque output by controlling fuel delivery and spark timing. EX1005, 1:39-43.

74. As shown below in Figure 1B, reproduced below, the controller includes a combustion mode changing section that switches engine operation between a homogenous mode and a stratified mode. *Id*., 3:5-10.



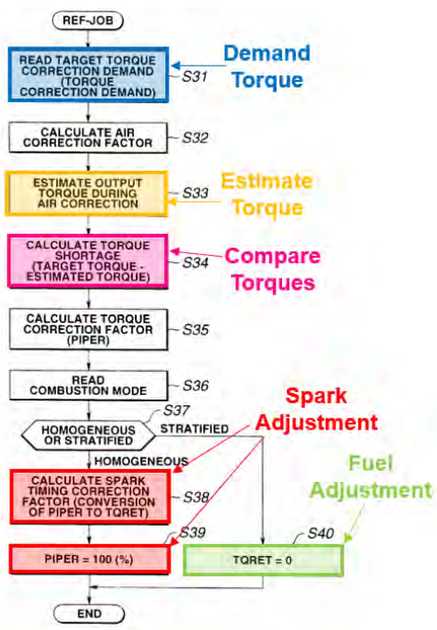
EX1005, FIG. 1B.

75. The controller includes a torque correction demanding section that generates a torque correction demand signal in response to a change in engine operating conditions. EX1005, 2:61-63. The controller includes a torque control section that controls the amount of air permitted to enter into the engine in response to receiving the torque correction demand signal. *Id*., 3:12-15. The controller includes a homogenous combustion torque correcting section and a stratified combustion torque correcting section that modify the torque output in response to receiving the torque correction demand signal. *Id*., 2:64-3:22, 15:53-16:6.

76. The engine controller of Suzuki addresses the same problem as the ’565 patent does—compensating for differences between a demand torque and an estimate of the current engine torque. *Id.*, 7:35-67. And Suzuki’s engine controller

addresses this problem the same way as the '565 patent through executing the torque correction routine, as shown in Figure 6, reproduced below. *Id.*, 7:7-67.

77. The torque correction demanding section initiates the routine by generating a demand (target) torque signal in response to detecting a change in engine operation conditions, such as shifting gears in the transmission or starting the compressor of the air conditioner. *Id.*, 7:14-19. Responding to the demand torque signal, a torque correction section of the controller estimates an output torque that compensates for the time required by the electronic throttle to change the volume of air drawn through the engine intake. *Id.*, 7:33-34, 8:52-56, 15:53-56, 16:11-22.



EX1005, FIG. 6 (annotated).

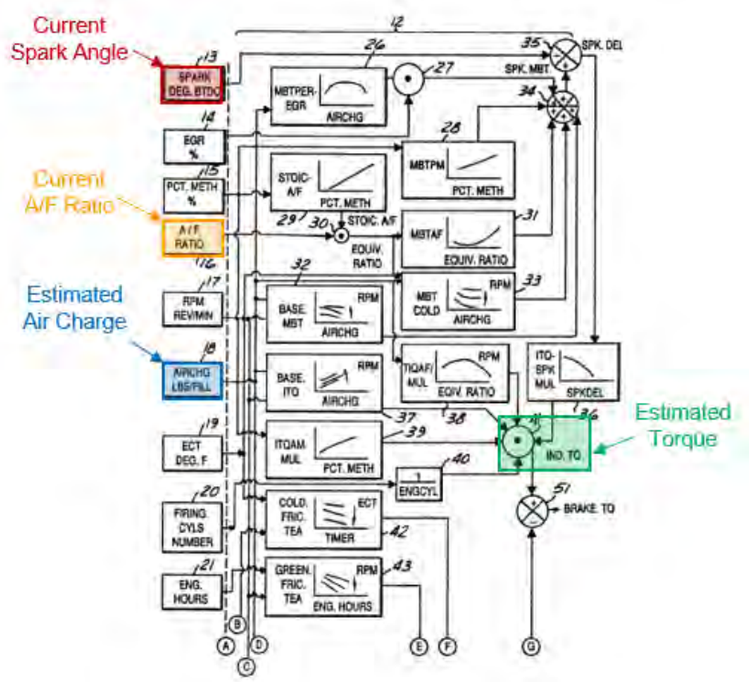
78. After estimating an output torque that accounts for intake air correction (step S33), the torque correction section subtracts the estimated torque from the

target torque to calculate a torque shortage (step S34). EX1005, 7:33-39. If the engine is set in a homogenous combustion mode, the torque correction section adjusts the spark timing based on the calculated torque shortage (steps S38 and S39). *Id*., 5:59-6:6, 7:51-54, 8:1-2, 15:56-58. If the engine is operating in a stratified charge combustion mode, the torque correction section adjusts the fuel delivery to the engine based on the calculated torque shortage (step S40, as well as steps 22-25 in Figure 5). *Id*., 6:20-57, 7:60-64, 8:3-4, 16:1-2. Specifically, the torque shortage value is used to correct the fuel delivery in order to maintain a target air/fuel equivalence ratio. *Id*., 6:35-68.

B. Cullen

79. Cullen, like Suzuki, discloses an engine controller that uses a torque estimator for feedback torque control. EX1006, 1:7-11. Cullen's engine controller calculates estimated torque for use as an input to control operational parameters of the engine. *Id.*, 1:8-11. Cullen discloses a control module 12 that calculates a predicted torque based on "a spark timing input 13, … an air/fuel ratio input 16, an engine rpm input 17, [and] an engine air charge input 18," among other engine parameters. *Id*., 5:59-6:2. Cullen discloses a torque calculation procedure that estimates the torque by inputting a current spark timing angle ("SPK"), a current air/fuel ratio ("A/F"), and an estimated air charge ("AIRCHG"). *Id*., 4:5-14, 5:34-52.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565



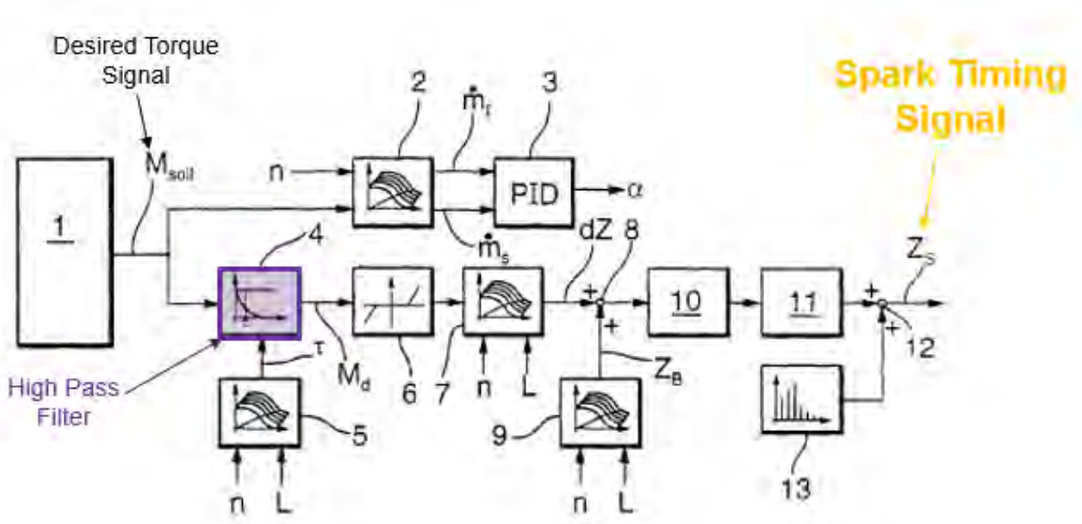
EX1006, FIG. 3.

C. Scherer

80. Scherer, like Suzuki and Cullen, is directed to an engine controller. EX1007, 1:7-11. Scherer's controller controls torque output in terms of air flow adjustment and ignition timing. *Id.*, 3:3-67. The engine controller includes an engine torque coordination unit 1 that generates a desired engine torque signal M_{des}.[3] *Id.*,

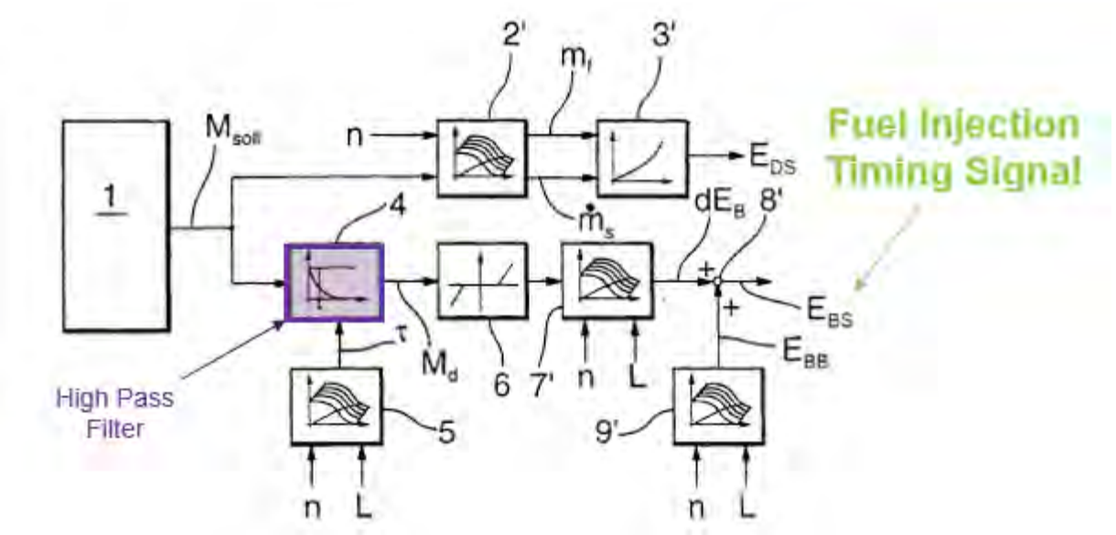
[3] In Scherer, there is a discrepancy between the reference symbols disclosed in the specification and the reference symbols shown in the figures regarding the element "desired engine torque signal." In the specification, Scherer refers to the "desired engine torque signal" using the reference symbol M_{des}. EX1007, 3:62,

3:60-63, 8:24. To correct the spark timing and air flow during abrupt transients in the desired torque signal, the controller includes a signal processing block (implementing a high-pass filter 4) that receives the desired engine torque signal as an input and outputs a dynamic desired torque component to a torque controller that adjusts torque output in terms of spark timing for homogeneous fuel charged engines or fuel injection for heterogeneous fuel charged engines. EX1007, 2:51-55, 4:20-45, 5:35-55, 8:26, FIGS. 1, 2. The high-pass filter allows the engine controller to more quickly correct transient torque demand. *Id.*, 2:38-42, 4:40-45; 5:10-15.



EX1007, FIG. 1 (annotated).

3:64, 4:5, 5:30, 6:58. However, in Figures 1-4 of Scherer, the "desired engine torque signal" is represented by the reference symbol M_{soil}.



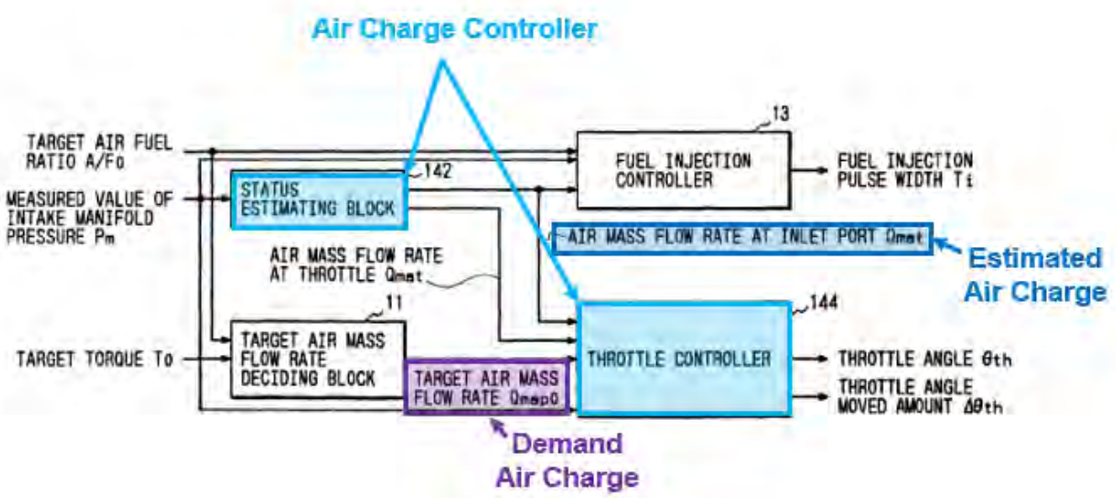
EX1007, FIG. 2 (annotated).

81. As shown in Figures 1 and 2 above, the graph represented in Scherer's block 4 illustrates the time domain behavior of a high-pass filter. An equivalent way to describe a high-pass filter in the frequency domain is to say that it removes the *low frequency* or *unchanging* component of a signal and outputs a signal containing only the *high frequency* or *transient* components of the signal, as described in the '565 patent. EX1001, 3:34-38.

82. The transient pulse output from the high-pass filter of block 4 is the desired torque correction value M_d during transient operation conditions. Isolating the transient part of the desired engine torque signal M_{des}, Scherer's engine controller effectively compensates for an abrupt torque change with a shorter reaction time than is possible with an engine controller lacking a high-pass filter. EX1007, 2:38-42, 5:10-15.

D. Takahashi

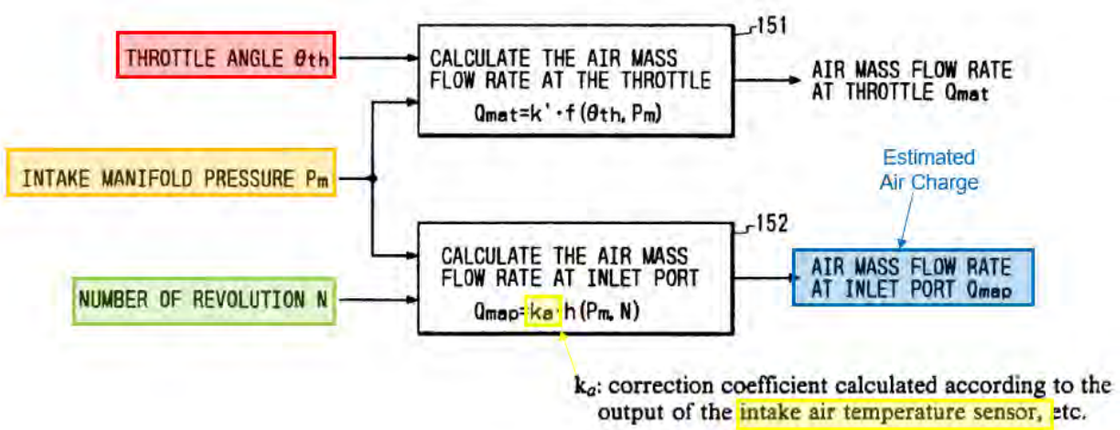
83. Like Suzuki, Cullen, Scherer, and the '565 patent, Takahashi is directed to an engine torque controller. Takahashi's controller achieves a desired torque output by fuel adjustment and throttle control. EX1008, 1:5-9, 3:4-16. As shown below in Figure 14, the control unit includes a target air mass flow rate module 11, a status estimating block 142, a fuel injection control block 13, and a throttle controller 144. *Id*., 3:16-24, 10:32-50, FIG. 14. The throttle controller 144 calculates a desired throttle position for the throttle valve to set the air flow into the engine cylinder at a desired air charge value, ultimately allowing the engine to achieve a target torque value. *Id.*, 3:20-27, 6:10-12, 7:50-58.



EX1008, FIG. 14 (annotated).

84. The throttle controller 144 determines the desired throttle position based on a function of a target air mass flow rate (i.e., demand air charge) and an estimated air mass flow rate (i.e., estimated air charge) at the inlet port. EX1008,

10:42-47, FIG. 14. The throttle controller 144 receives the target air mass flow rate from a target air mass flow rate deciding block 11 and estimates the current air mass flow rate using a status estimating block 142. *Id.*, 10:43-60, FIG. 14. The status estimating block 142 estimates the current air mass flow rate based on throttle position, engine speed, intake manifold pressure, and intake air temperature as inputs. *Id.*, 10:43-66, FIG. 15. The target air mass flow rate module 11 receives a target air/fuel ratio signal, a target torque signal, an engine speed signal, and a spark advance signal as inputs and generates a target air mass flow rate signal as an output. *Id.*, 3:20-41.



EX1008, FIG. 15 (annotated).

X. Ground 1: The combination of Suzuki, Cullen, and Scherer renders obvious claims 1, 4, and 7.

A. Rationale for combining Suzuki with Cullen and Scherer

85. In my opinion, a POSA would have been motivated to combine the teachings of Suzuki with Cullen and Scherer and would have had a reasonable expectation of success in doing so for at least the reasons discussed below.

86. To start, Suzuki, Cullen, and Scherer are from the same field of endeavor— control systems for an internal combustion engine. Particularly, Suzuki, Cullen, and Scherer are directed to engine controllers that adjust operational parameters, such as fuel quantity, spark timing, and air intake based on torque feedback control. Indeed, Suzuki's "invention is directed to a direct-injection spark-ignition type engine control apparatus for correcting engine torque based on engine operating conditions." EX1005, 1:4-6. Likewise, Cullen's "invention relates to … inferring the torque produced by an engine," whereby "such an inferred engine torque is as an input parameter for a control system." EX1006, 1:7-11. Similarly, Scherer's "invention relates to a process and apparatus for adjusting the torque of an internal-combustion engine by regulating the ignition point and the air flow rate in an Otto engine." EX1007, 1:7-11. Thus, a POSA would have recognized Suzuki, Cullen, and Scherer, as disclosing similar control systems, namely engine control systems for monitoring torque output and controlling engine parameters in accordance with monitored torque output.

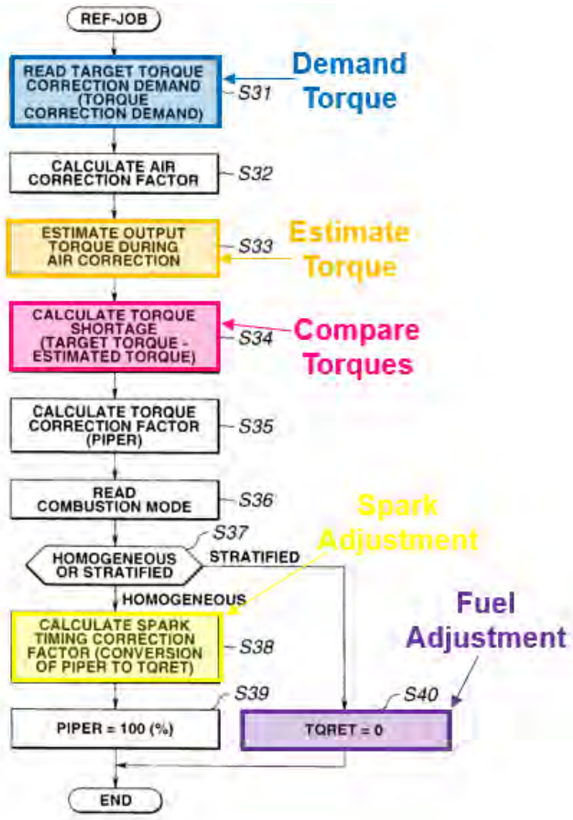
87. Suzuki, Cullen, and Scherer each disclose controllers receiving similar measured engine parameters (e.g., engine speed, air flow rate, and air/fuel ratio) as inputs and using these inputs to control ignition timing and the engine air-fuel ratio to achieve a target engine torque value. EX1005, 4:17-31; EX1006, 5:57-6:2; EX1007, 4:60-67. Accordingly, a POSA would have recognized that Suzuki, Cullen,

and Scherer's control systems include analogous components, such as an engine speed sensor, an air mass flow sensor, an exhaust oxygen gas sensor, and a throttle position sensor, for receiving such inputs. Because Suzuki, Cullen, and Scherer's control systems include analogous components that receive common inputs, a POSA would have recognized that combining their teachings would have simply involved reprogramming stored instructions in the microcomputer of Suzuki's control unit 20. EX1019, 102, 223 ("In a **computer-based controller**, however, the control law and system parameters are changed via program (i.e., software) control."). That is, combining the teachings of Suzuki with Cullen and Scherer would not require any substantial structural changes to Suzuki's engine control system. *Id.*, 223 ("The hardware remains fixed but the software are reconfigured in accordance with operating conditions as determined by sensor measurements and switch inputs to the controller.") Thus, combining their teachings would have, at most, involved modifying the engine controller to perform the steps taught in the references—a basic task for a POSA.

1. Combining Suzuki and Cullen

88. Suzuki discloses a DISI engine controller for adjusting torque by controlling fuel delivery and spark timing. EX1001, 1:62-2:4; EX1005, 1:39-63. Suzuki's control unit 20 generates a demand torque signal, estimates a torque output of the engine, compares the demand torque to the estimated torque to determine the

difference between the demand and estimated torques, and determines fuel quantity and spark timing adjustments based on the calculated differences between the demand and estimated torques, as shown below in Figure 6. EX1001, 4:2-22; EX1005, 7:7-67, FIGS. 4-6.

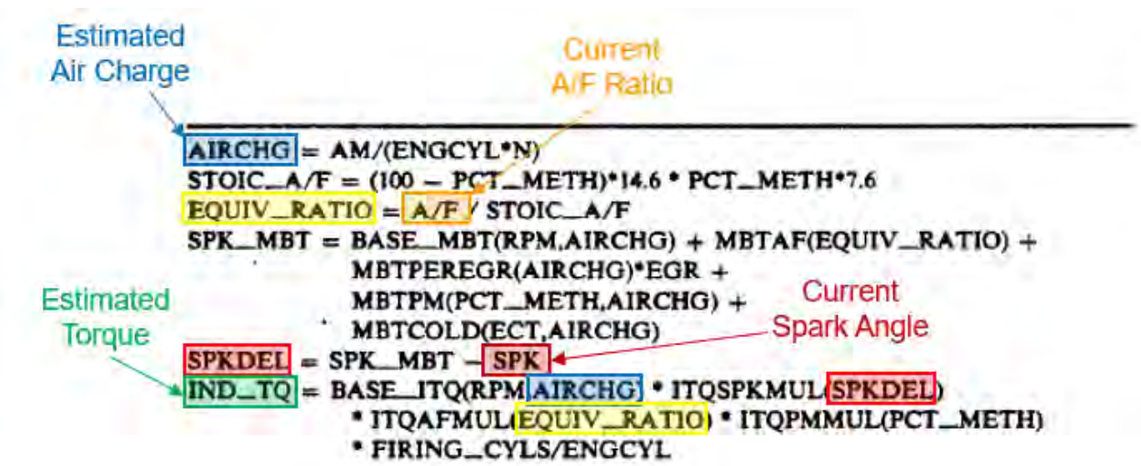


EX1005, FIG. 6 (annotated).

89. While Suzuki discloses an estimator outputting an estimated torque signal, Suzuki does not expressly disclose an estimator receiving a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal.

90. However, Cullen discloses specific implementation details of an estimator outputting an estimated torque signal that would have been readily

applicable to Suzuki's control unit 20. Specifically, Cullen discloses a controller that calculates a predicted torque by processing "**a spark timing input 13**, an exhaust gas recirculation rate input 14, a percent methanol fuel input 15, **an air/fuel ratio input 16**, an engine rpm input 17, **an engine air charge input 18**, … and a flag input 25 indicating air conditioning on or off." EX1006, 5:59-6:2. Furthermore, as shown below, Cullen discloses a torque calculation procedure that estimates the torque (i.e., "IND_TQ") as a function of the current spark angle ("SPK"), a current air/fuel ratio ("A/F"), and an estimated air charge ("AIRCHG"), among other inputs. EX1006, 5:32-52.



EX1006, 5:34-45 (annotated).

91. Because Suzuki is silent on the implementation details of estimating a torque output, a POSA would have sought out these details provided by Cullen's analogous control module. Combining the teachings of Suzuki and Cullen would have yielded predictable benefits and results—for example, making a more accurate

estimation of the output torque. EX1006, 2:32-42 ("This invention recognizes that a predicted torque calculation can be made **more accurate** by predicting the air conditioning torque requirement versus head pressure, power steering torque requirements versus power steering pressure switch, cold engine friction versus time since start and engine coolant temperature, [among other parameters]."). A POSA would have understood that combining Cullen's routine for estimating torque output with Suzuki's control unit 20 would have provided a more accurate estimation of the engine output torque, thereby allowing Suzuki's control unit 20 to converge the current torque output to the desired torque more precisely. *Id.*, 2:21-42. Thus, combining Cullen's routine for estimating torque output with Suzuki's control unit 20 would have merely been applying Cullen's known technique for estimating torque with Suzuki's similar, known torque estimator in the same way.

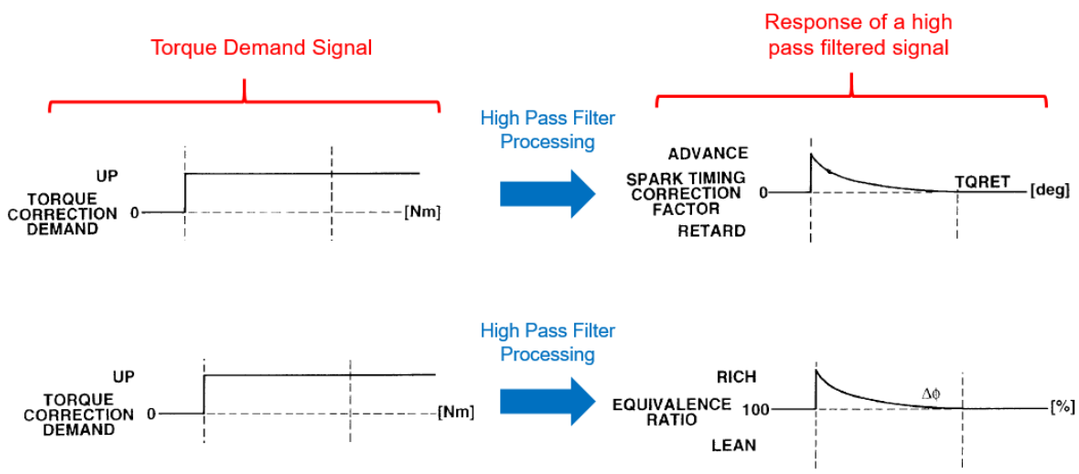
92. Moreover, a POSA would have had a reasonable expectation of success in combining Suzuki and Cullen. Indeed, a POSA would have recognized that the torque estimation technique in Cullen would have been easily implemented in Suzuki's control unit 20 by modifying the software instructions stored in the microcomputer of Suzuki's control unit 20, such that the estimator section receives a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal as inputs. Considering the similarities in Suzuki's and Cullen's control

systems, any modification to implement Cullen's teachings into Suzuki's system would have been within the skill level of a POSA.

93. Accordingly, it would have been obvious to combine the teachings of Suzuki and Cullen.

2. Combining Scherer with Suzuki and Cullen

94. Suzuki does not expressly disclose using a high-pass filter to receive the torque difference signal as an input and output a filtered difference signal in which low frequency components are removed. But Suzuki's spark and fuel correction factor curves in Figures 12-15 suggest that a high-pass filter is in fact being used. To a POSA, the shape of these curves suggests that the torque correction demand signal is filtered with a high-pass filter.

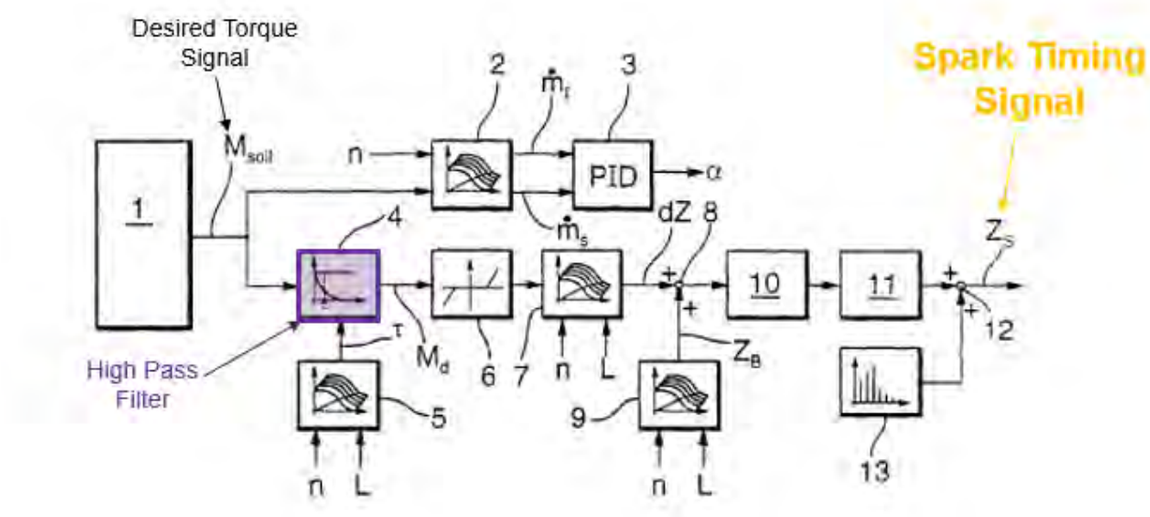


EX1005, FIG. 13 (annotated).

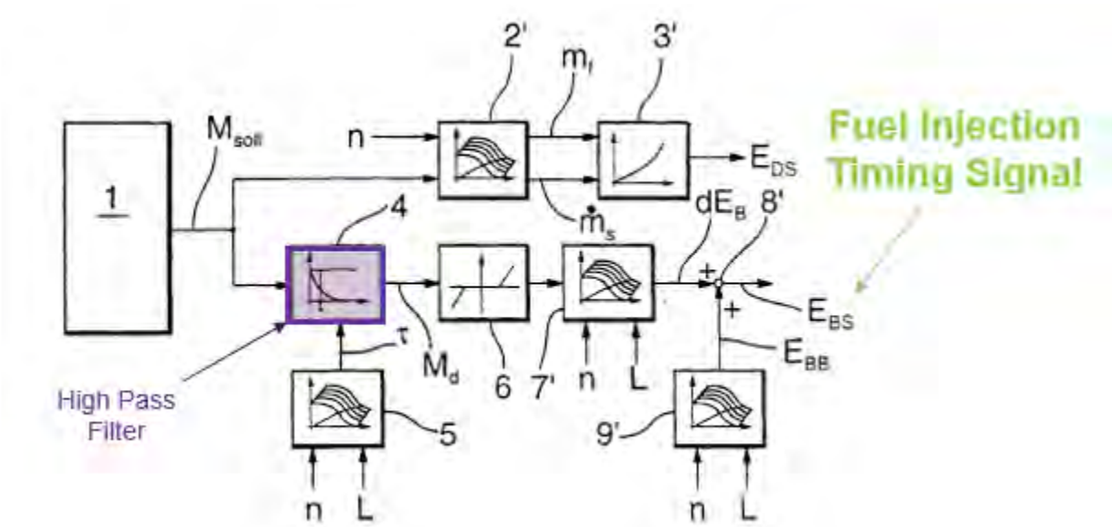
95. Moreover, Scherer expressly discloses using a high-pass filter to remove a low frequency component from a torque signal, thereby isolating the torque signal's high frequency, dynamic component. EX1007, 4:40-45. Scherer's high-pass filter would have been readily applicable to Suzuki's control unit 20.

96. Specifically, Scherer discloses that a high-pass filter isolates the dynamic, desired engine torque component from the entire desired engine torque signal: "the high pass filter 4 filters the dynamic desired engine torque part (M_d), as a function of the engine operating point, from the desired engine torque (M_{des}) supplied to it, and in turn provides the dynamic desired engine torque (M_d)." *Id.* Removing the desired torque signal's low frequency component allows Scherer's controller to "react very rapidly to sudden changes of the engine torque," arising during transient engine operations. *Id.*, 4:20-25, 4:40-45, 5:10-15.

97. Scherer also discloses that the filtered dynamic component of the desired torque signal is used for both spark ignition timing adjustments (as shown in Figure 1 below) and for fuel injection adjustment (as shown in Figure 2 below). *Id.*, 2:51-54, 4:20-52, 5:16-55, FIGS. 1, 2.



EX1007, FIG. 1 (annotated).



EX1007, FIG. 2 (annotated).

98. To further improve the response of Suzuki's controller to dynamic changes in demanded torque, a POSA would have sought out the implementation details of using a high-pass filter to remove the low frequency component from the torque difference signal, as provided by Scherer's analogous controller. Specifically,

a POSA would have understood that Scherer's technique for adjusting ignition timing and fuel injection based on the demanded torque signal filtered with a high-pass signal correspond to Suzuki's homogeneous and stratified torque correction sections, which output an ignition timing adjustment signal and fuel injection adjustment signal like Scherer. EX1007, 4:20-5:9; EX1012, 372-73, 376. Moreover, combining the teachings of Suzuki and Scherer would have yielded predictable benefits and results—for example, adjusting the torque output with a quicker response time during transient engine operations. EX1007, 4:40-45, 5:10-15. Thus, combining Scherer's high pass filter 4 with Suzuki's control unit 20 would have merely been applying a known technique in a similar, known device in the same way.

99. Furthermore, a POSA would have had a reasonable expectation of success in combining Suzuki and Scherer. Suzuki suggests the use of a high-pass filter. And a POSA would have recognized that Scherer's high-pass filter 4 would have been easily implemented in Suzuki's control unit 20 by modifying the software instructions stored in the microcomputer of Suzuki's control unit 20, so that the torque difference signal is inputted into a high-pass filter. EX1019, 138 ("Digital filtering … can be performed by a computer under the control of the software. … [T]he characteristics of the digital filter can be changed by changing the software."). In view of Scherer, a POSA would have understood that the high-pass filter may be

represented in the software instructions as a transfer function having a variable time constant adjusted according to detected engine speed. EX1007, 4:31-38 ("The high pass filter stage ... consists of a high pass filter 4 with an adjustable decay time constant (τ), and a characteristic time constant diagram unit 5 which indicates the decay time constant (2) … as a function of the rotational engine speed (n) and of the engine load (L)."). Moreover, a POSA would have understood that Scherer teaches that the high pass filter should output the filtered signal to the transient torque controller (i.e., the ignition point adjustment branch or injection start adjusting branch). *Id.*, 4:53-56 ("The device for the ignition point adjustment receives the dynamic desired torque component (M_d) from the high pass filter 4."); *see also id.*, 5:58-64 ("The comparatively rapidly reacting injection start adjusting branch regulates precisely that dynamic desired engine torque part (M_d) …for adjusting the injection duration in the case of sudden changes of the desired engine torque."). Accordingly, a POSA would have recognized that in combining Scherer's and Suzuki's teachings, the high-pass filter would output the filtered signal to the transient torque control sections of Suzuki (i.e., the homogeneous and stratified torque correction sections).

100. A POSA would have further understood that combining Scherer's high-pass filter 4 with Suzuki's control unit 20 would have expedited the response time for correcting the transient component of the demand torque. *Id.*, 4:40-45, 5:10-15

("The embodiment of FIG. 1 therefore permits a comparatively rapid engine torque adjustment which can follow very fast desired engine torque changes."). Given that the homogeneous and stratified torque correction sections in Suzuki's control unit 20 are intended to respond to dynamic changes in torque demand, a POSA would have been motivated to use Scherer's high-pass filter 4 to receive Suzuki's torque difference signal and output the dynamic component of the torque difference signal to Suzuki's homogeneous and stratified torque correction sections. EX1005, 1:44-63, 3:10-22.

101. Considering the similarities in Suzuki's and Scherer's control systems, any modification to implement Scherer's teachings into Suzuki's system would have been trivial and well within the skill level of a POSA.

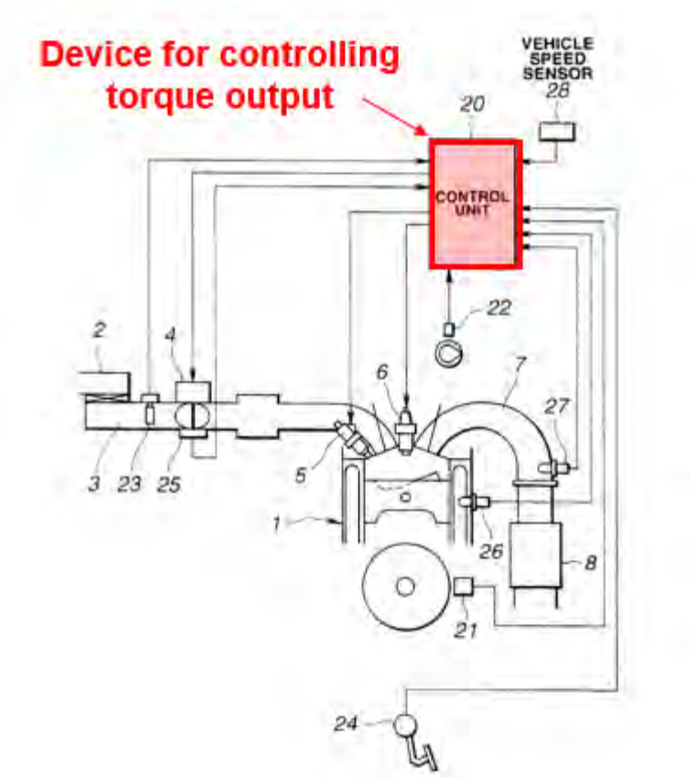
102. Suzuki's control unit 20 for controlling torque output in terms of fuel and spark adjustment, Cullen's control module for estimating engine output torque, and Scherer's high-pass filter for removing the low frequency component of a desired torque signal were known elements that a POSA would have been motivated to and known how to combine in a known way to provide the predictable benefits disclosed in the references for providing precise control of engine torque output.

103. Accordingly, in my opinion, it would have been obvious to a POSA to combine the teachings of Suzuki, Cullen, and Scherer.

B. Suzuki, Cullen, and Scherer render obvious claim 1.

1. [1.P] "A device for controlling a torque output of an engine, the device comprising:"

104. Suzuki discloses a device for controlling an engine's torque output as claimed. As shown below in Figure 2, Suzuki discloses a DISI engine 1 with a control unit 20 that receives input signals from various sensors, including a crank angle sensor 21, an airflow meter 23, an accelerator sensor 24, a throttle valve sensor 25, and an O_2 sensor 27. Suzuki's control unit 20 includes a microcomputer that makes calculations based on the sensor input "to control the degree of opening of the electronic controlled throttle valve 4, the amount of fuel injected to the engine by the fuel injector 5, and the spark timing of the spark plug 6." EX1005, 4:33-38.



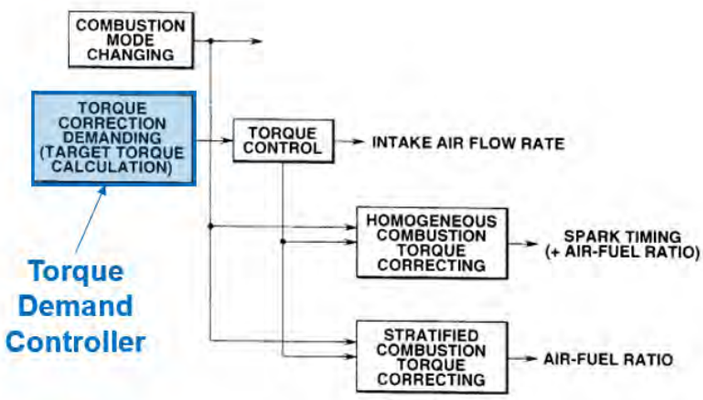
EX1005, FIG. 2 (annotated).

105. Suzuki further discloses that the control unit 20 includes a torque correction demanding section that produces a torque correction demand based on the sensor input and a torque correction section that responds to the torque correction demand by modifying the engine torque output through spark timing and air/fuel ratio adjustment. EX1005, 3:5-22, 15:53-56; *see also id*. 4:3-5 ("The sections described herein are implemented in hardware, software, or a combination of both, in the control unit 20.").

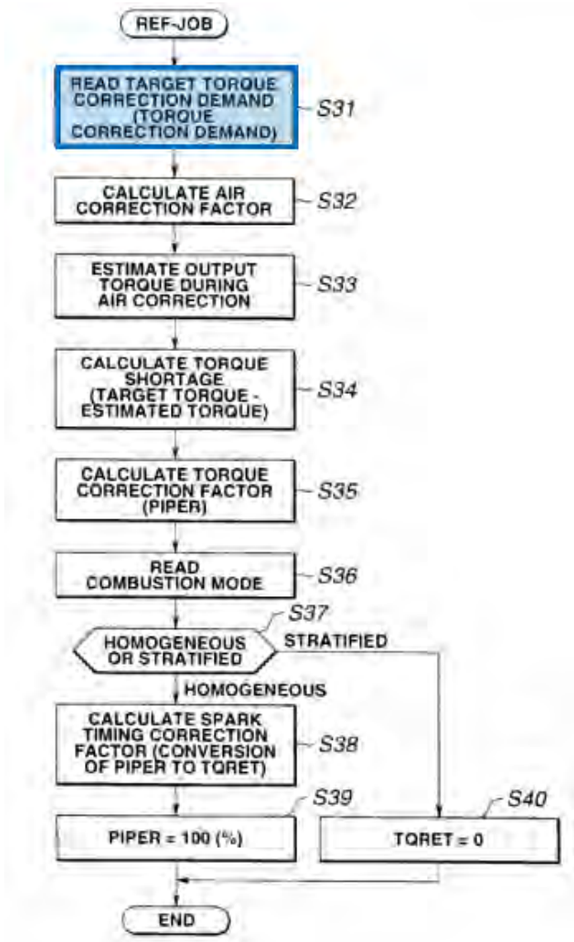
106. Thus, Suzuki discloses [1.P].

2. [1.A] "a torque demand controller for generating a torque demand signal; and;"

107. Suzuki discloses a torque demand controller as claimed. As shown in FIG. 1B, reproduced below, Suzuki's control unit 20 includes a "torque correction demanding section [that] produces a torque correction demand based on engine operating conditions." EX1005, 3:10-12. The torque correction demanding section calculates a target torque representing an increase or decrease in torque output to account for a change in engine operation, such as shifting a transmission gear, cranking the air conditioner, or recovering from a fuel cut. *Id.*, 7:14-19.



EX1005, FIG. 1B (annotated).



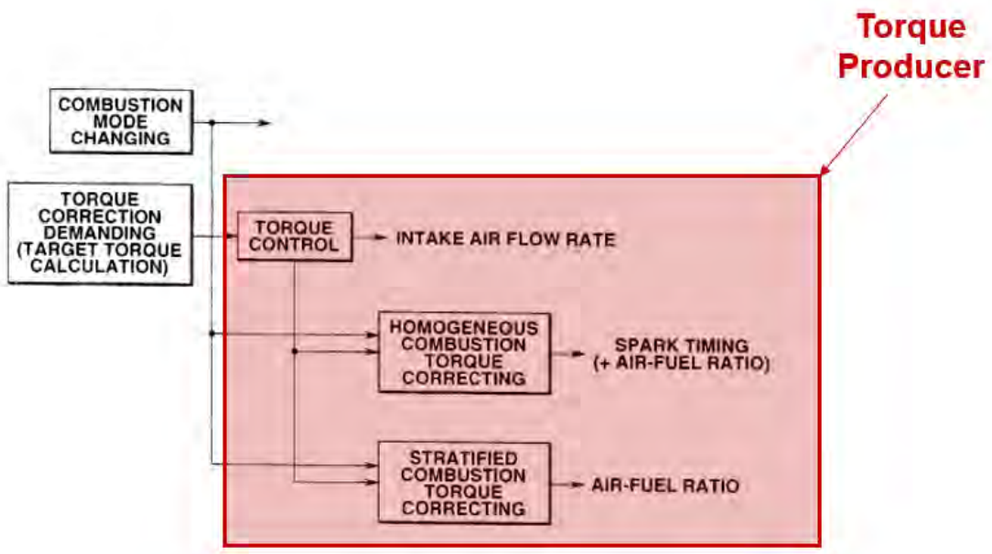
EX1005, FIG. 6 (annotated).

108. A POSA would have understood that Suzuki's torque correction demanding section is a "torque demand controller," as recited in claim 1, because the torque correction demanding section generates a torque demand signal indicating a desired torque output, which is used to control torque output. Indeed, Suzuki's torque correction demanding section operates in the same manner as the torque demand controller 11 disclosed by the '565 patent, which calculates a required output torque signal based on a changing engine operation. EX1001, 2:57-67.

109. Thus, Suzuki discloses [1.A].

3. [1.B] "a torque producer which receives the torque demand signal,"

110. Suzuki discloses a torque producer as claimed. Specifically, Suzuki discloses that the control unit 20 includes "a torque correction section, … which receives a torque correction demand and produces a torque correction output in response to the torque correction demand." EX1005, 15:53-56. As shown below in Figure 1B of Suzuki, the torque correction section includes a torque control section for adjusting air flow into the engine cylinder, a homogeneous combustion torque correction section for adjusting spark timing (and fuel quantity), and a stratified combustion torque correction section for adjusting fuel quantity in response to receiving the torque correction demand signal. *Id.*, 3:12-22.



EX1005, FIG. 1B (annotated).

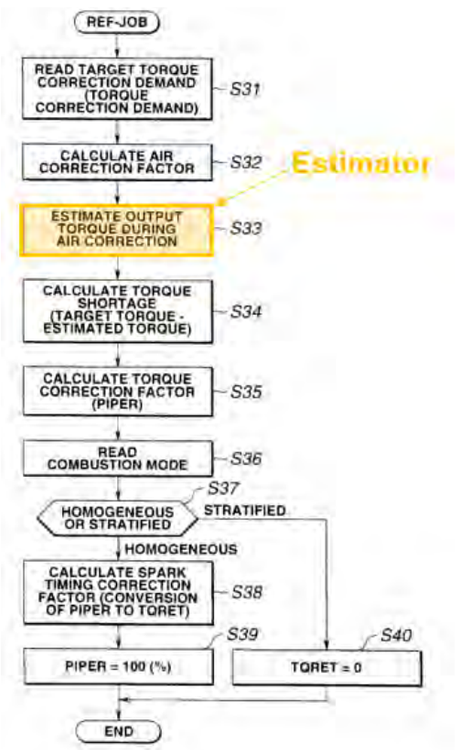
111. A POSA would have understood that Suzuki's torque correction section, homogeneous combustion torque correction section, and stratified combustion torque correction section, collectively form a torque producer, as recited in claim 1. Each of these sections adjusts a parameter (e.g., air flow rate, spark timing, and air-fuel ration) for producing torque. Accordingly, these sections compose, at least in part, Suzuki's torque producer.

112. Thus, Suzuki discloses [1.B].

4. [1.C] "the torque producer includes: an estimator which receives as inputs a current spark angle signal, a current air/fuel ratio signal and an estimated air charge signal and outputs an estimated torque signal;"

113. Suzuki and Cullen render obvious the torque estimator as claimed. As shown below in Figure 6, Suzuki discloses that the torque correction section, which is part of Suzuki's torque producer, receives a torque demand (step S31) and, in response, estimates an output torque that takes into account an intake air correction factor (step S33). EX1005, 7:33-34 ("In step S33, the output torque during intake air correction is estimated.").

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US PATENT NO. 6,581,565

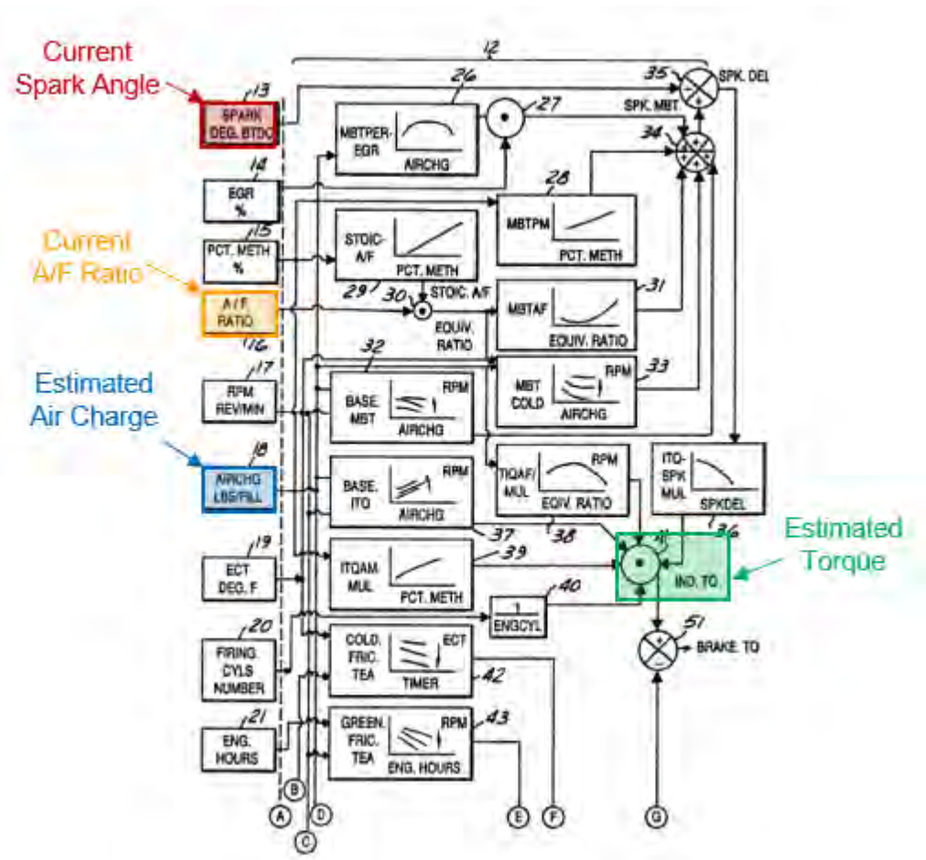


EX1005, FIG. 6 (annotated).

114. Thus, Suzuki's torque correction section includes an "estimator," as recited in claim 1, to execute the step of estimating a torque output.

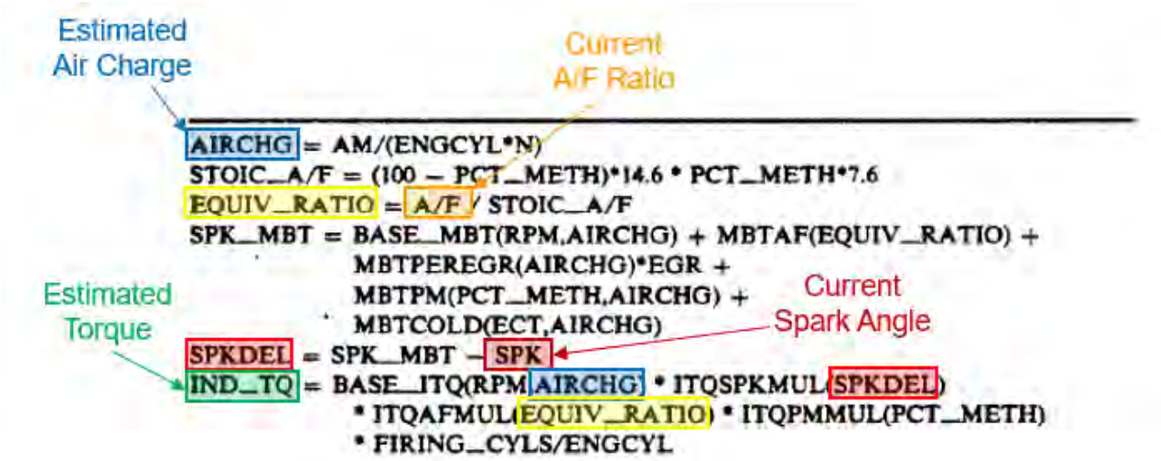
115. Suzuki does not expressly disclose that the estimator receives as inputs a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal. However, this feature is explicitly disclosed in Cullen.

116. As shown below in Figure 3, Cullen discloses a control module that calculates a predicted torque ("IND_TQ") by processing "**a spark timing input 13**, an exhaust gas recirculation rate input 14, a percent methanol fuel input 15, **an air/fuel ratio input 16**, an engine rpm input 17, **an engine air charge input 18**, … and a flag input 25 indicating air conditioning on or off." EX1006, 5:59-6:2.



EX1006, FIG. 3 (annotated).

117. As shown below, Cullen discloses a torque calculation procedure that estimates the torque (i.e., "IND_TQ") by inputting a current spark angle ("SPK"), a current air/fuel ratio ("A/F"), and an estimated air charge ("AIRCHG"). EX1006, 4:5-14, 5:34-52.



EX1006, 5:34-45 (annotated).

118. It would have been obvious for a POSA to reprogram Suzuki's controller 20, in view of Cullen, to receive a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal as inputs for Suzuki's estimator, so that the estimated torque may be calculated more accurately. Indeed, Cullen explains that the use of these inputs accounts for various engine operations that influence torque output, thereby providing a more accurate torque estimation. EX1006, 1:13-15, 2:26-42 ("Thus an improved torque prediction algorithm would be desirable to account for operating variables which influence torque output."). A POSA would have further understood that any engine control system, such as the control system in Suzuki, would include sensors detecting the spark angle, air/fuel ratio, and air charge. Accordingly, such modification would have simply been

applying a known technique of calculating torque to a known engine control device to yield the predictable result of calculating torque more accurately. Accordingly, a POSA would have been motivated to modify Suzuki's control unit 20 so that the estimator receives a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal as inputs. *See supra* Section X.A.1.

119. Likewise, a POSA would have been able to easily implement the teaching in Cullen by modifying the application instructions stored in the microcomputer of Suzuki's control unit 20, such that the estimator section receives a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal as inputs. S*ee supra* Section X.A.1.

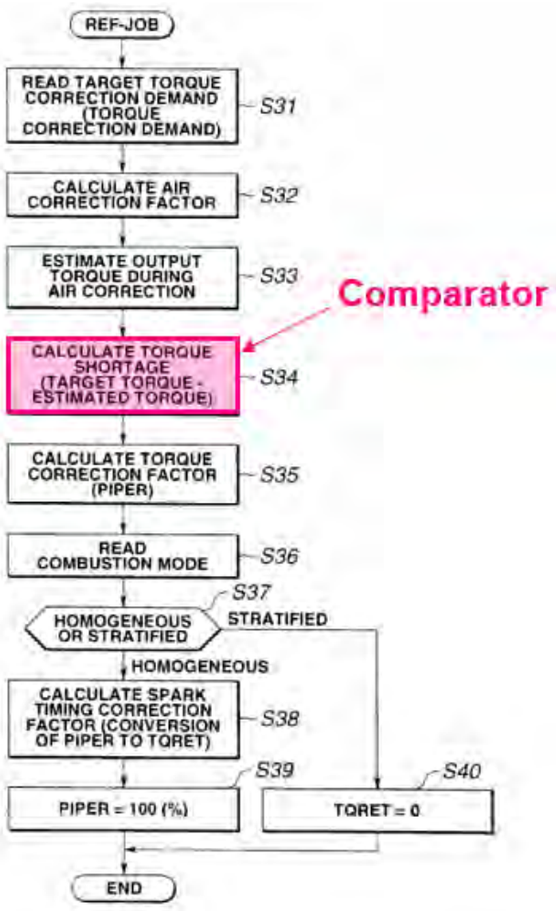
120. Thus, Suzuki and Cullen render obvious [1.C].

5. [1.D] "a comparator which receives as inputs the estimated torque signal and a desired torque signal and outputs a difference signal;"

121. Suzuki discloses a comparator that outputs a difference signal as claimed. As shown below in Figure 6, Suzuki discloses that after estimating an output torque, the torque correction section subtracts the estimated torque from the demand torque to output a torque shortage (torque error) signal (step S34). EX1005, 7:35-39. ("In step S34, the estimated torque is subtracted from the target torque … to calculate the torque shortage due to the delay involved with changing the amount of intake air.").

122. Suzuki's torque correction section includes a "comparator," as recited in claim 1, to execute the step of subtracting the estimated torque from the target torque. Indeed, Suzuki's torque correction section operates in the same manner as the comparator disclosed by the '565 patent, which generates an error signal representing a shortage between the estimated torque and the desired torque. EX1001, 3:34-39. Moreover, the calculated torque shortage in Suzuki is a "difference signal," as recited in claim 1. Suzuki's torque shortage represents the difference between the estimated torque and the desired torque. Specifically, Suzuki discloses that "the estimated torque is subtracted from the target torque … to calculate the torque shortage due to the delay involved with changing the amount of intake air." EX1005, 7:35-39.

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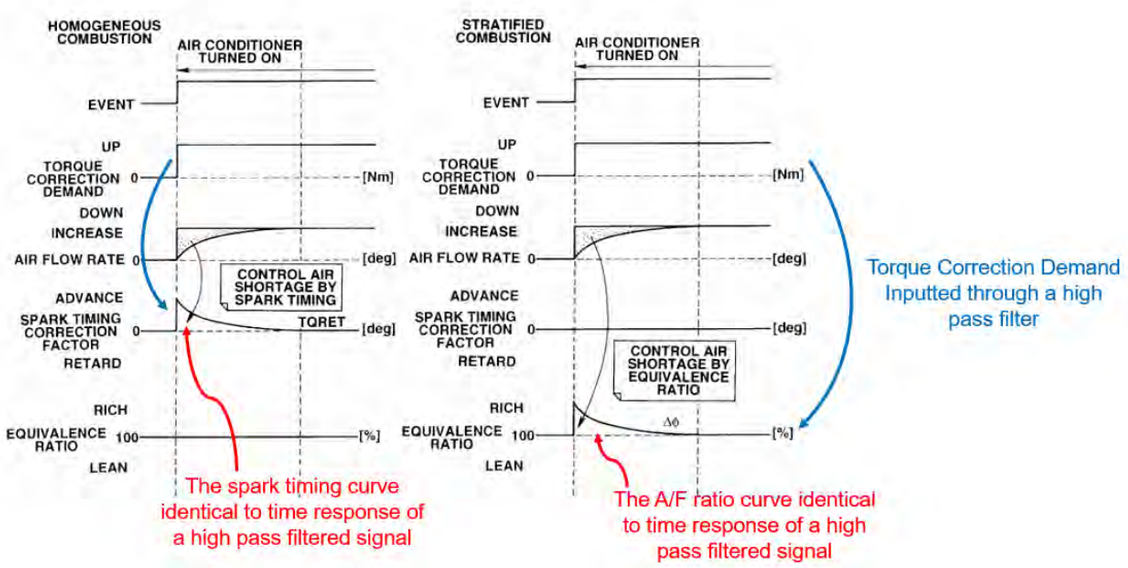
EX1005, FIG. 6 (annotated).

123. Thus, Suzuki discloses [1.D].

6. [1.E] "a high pass filter which receives as an input the difference signal and outputs a filtered difference signal in which low frequency components are absent; and"

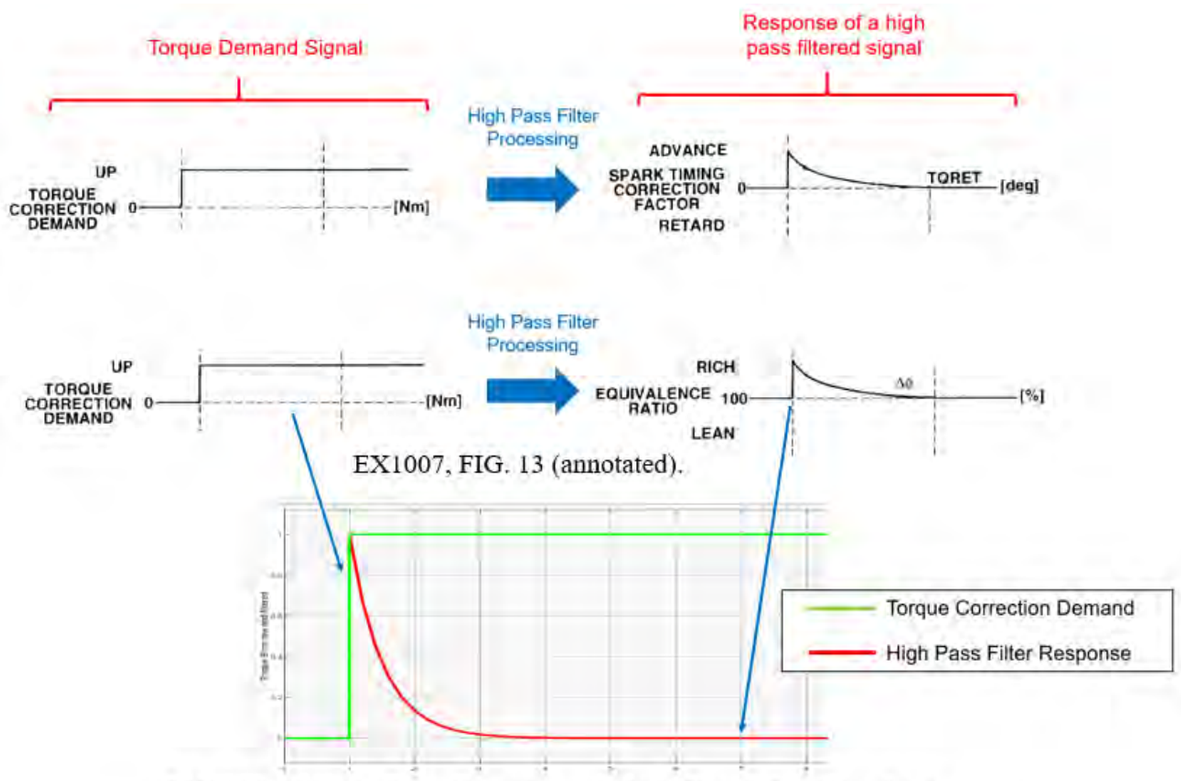
124. Suzuki and Scherer render obvious the high-pass filter as claimed. Although Suzuki does not expressly disclose a high-pass filter, a POSA would have understood that Suzuki suggests using a high-pass filter based on the correction factor response curves shown in Figures 12-15 of Suzuki.

125. For example, as shown below in Figure 13, Suzuki discloses a torque correction demand signal that represents an abrupt demand for increased torque output in response to starting the vehicle air conditioner. EX1005, 7:51-63, 8:51-60. Under the homogeneous mode, Suzuki discloses a spark timing correction factor signal that is generated from processing the torque correction demand signal through the torque correction routine shown in Figures 4 and 6. *Id.*, 7:51-58, 8:1-2. Under the stratified mode, Suzuki discloses an equivalence ratio correction factor signal (i.e., a signal representing a fuel adjustment for modifying air/fuel ratio) from processing the torque correction demand signal through the torque correction routine shown in Figures 5 and 6. *Id.*, 7:60-64, 8:2-4.



EX1005, FIG. 13 (annotated).

126. In my opinion, a POSA would have recognized that both the spark timing and equivalence ratio correction factor signals match the time response curve of a high-pass filter. For example, the below simulated correction signal (red) outputted from a high-pass filter in response to a step function (green) matches the spark timing and equivalence ratio correction factor signals in response to step correction demands.



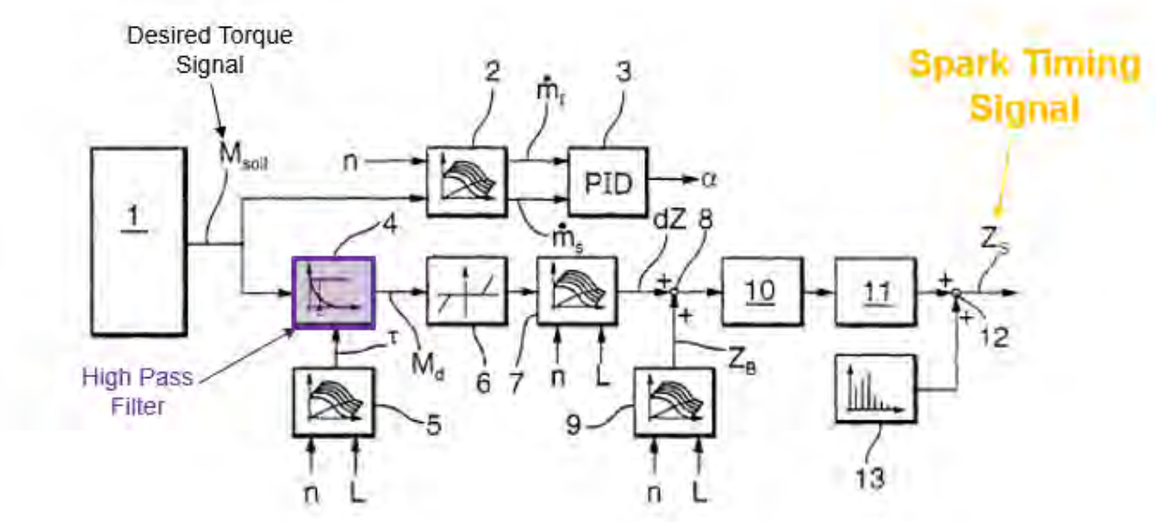
EX1007, FIG. 13 (annotated).

EX1003, FIG. A: Time Response of High-Pass Filter Simulation.

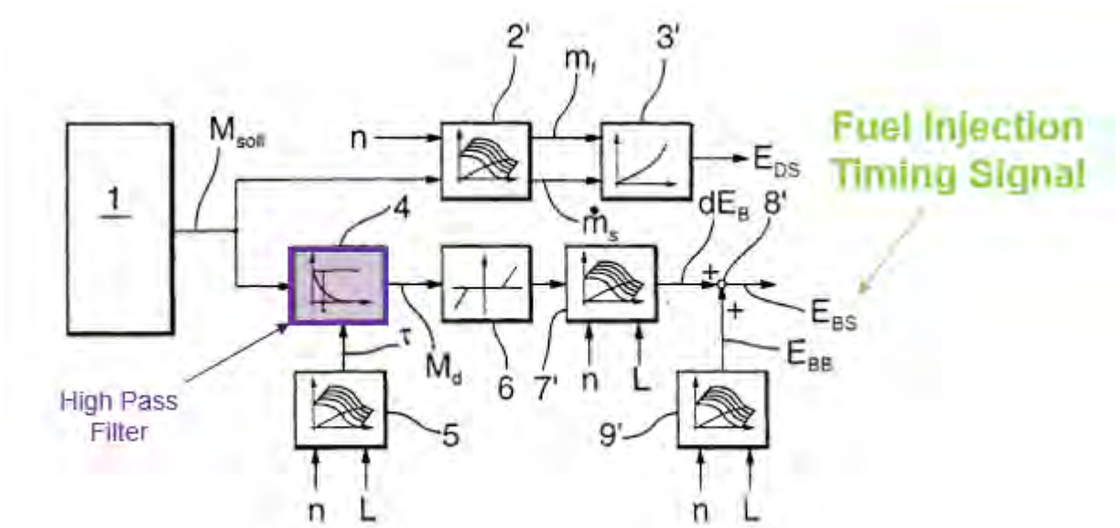
127. Suzuki's spark timing and equivalence ratio correction factors provide significant adjustments within a short time period and then disappear over time, as the torque demand signal reaches a steady state. Accordingly, in my opinion, a

POSA would have understood that Suzuki implicitly discloses a high-pass filter, as recited in claim 1.

128. Even assuming that Suzuki does not disclose or suggest a high-pass filter, Scherer explicitly discloses this feature. Scherer discloses a device for controlling torque output of an internal combustion engine in terms of air flow adjustment and ignition timing. EX1007, 3:59-60, 8:21-25. As shown below in Figure 1, the device includes an engine torque coordination unit 1 that generates a desired engine torque signal M_{soil} and a high-pass filter 4 that receives the desired engine torque signal M_{soil} as an input and generates a dynamic desired torque component as an output for a torque controller. *Id.*, 3:60-63, 4:20-45, 8:26. Specifically, Scherer discloses a "high pass filter 4 filter[ing] the dynamic desired engine torque part (M_d), as a function of the engine operating point, from the desired engine torque (M_{des}) supplied to it, and in turn provid[ing] the dynamic desired engine torque (M_d)." *Id.*, 4:40-45.



EX1007, FIG. 1 (annotated).



EX1007, FIG. 2 (annotated).

129. Additionally, Scherer discloses that the dynamic (transient) component of the desired torque signal is used to adjust both the timing of the spark ignition and fuel injection. EX1007, 2:51-54, 4:20-5:9, 5:16-55, FIGS. 1, 2. Specifically, Scherer discloses a controller that adjusts torque output by adjusting the spark timing for

homogeneous fuel-charged engines or by adjusting fuel delivery for heterogeneous fuel-charged engines. *Id*., 2:51-55, 4:20-45, 5:35-55, 8:26; FIGS 1, 2.

130. Moreover, Scherer's high-pass filter 4 functions the same as the '565 patent's high-pass filter, removing the low frequency component of the torque signal to isolate and pass the transient component of the torque signal for correcting dynamic torque changes.

131. In my opinion, it would have been obvious for a POSA to incorporate Scherer's high-pass filter 4 into Suzuki's control unit 20 to remove the low frequency component from Suzuki's target shortage signal, so that Suzuki's torque correction section may adjust torque output to a desired value with a quicker response time during transient engine operation conditions. Indeed, Scherer expressly discloses that using the high-pass filter to receive the desired torque signal allows the controller to provide a dynamic desired engine torque signal to the transient torque controller, thereby "permit[ing] a comparatively rapid engine torque adjustment which can follow very fast desired engine torque changes." EX1007, 4:40-45, 5:10-15. A POSA would have been motivated to incorporate Scherer's high-pass filter 4 into Suzuki's control unit 20 to remove the low frequency components from the torque shortage signal so that Suzuki's control unit 20 "adjusts the engine torque to a desired value with the least possible expenditures in both

steady-state and transient engine operation with a comparatively short reaction time." EX1007, 2:38-42.

132. Likewise, a POSA would have been able to easily implement the teaching in Scherer by modifying the software instructions stored in the microcomputer of Suzuki's control unit 20, such that torque shortage signal is inputted into a high-pass filter. In view of Scherer, a POSA would have understood that the high-pass filter is represented by a transfer function having a variable time constant adjusted according to detected engine speed. EX1007, 4:31-38 ("The high pass filter stage ... consists of a high pass filter 4 with an adjustable decay time constant (τ), and a characteristic time constant diagram unit 5 which indicates the decay time constant (2) … as a function of the rotational engine speed (n) and of the engine load (L)."). A POSA would have recognized that such a transfer function may be implemented into Suzuki's control unit 20 through a minor software change. Such modification would have simply been applying a known technique to a known device to yield the predictable result of addressing dynamic torque changes with a faster response time. Accordingly, in my opinion, a POSA would have had a reasonable expectation of success in combining Suzuki and Scherer.

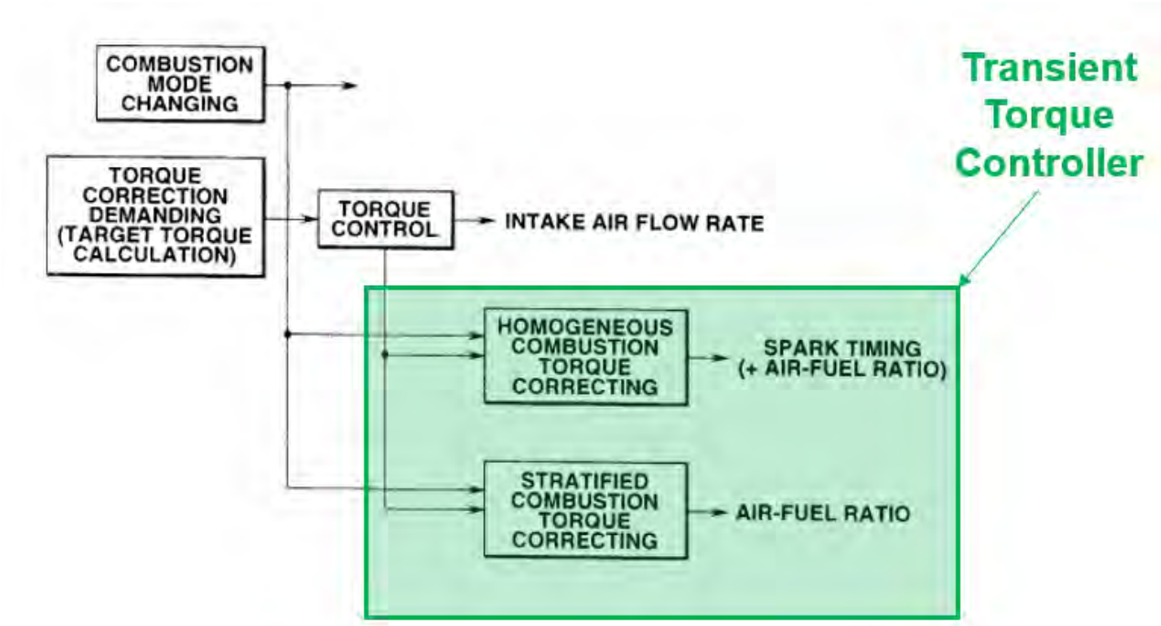
133. In addition, a POSA would have understood that Scherer's technique for adjusting ignition timing and fuel injection based on the filtered torque signal is analogous to Suzuki's homogeneous and stratified torque correction sections.

EX1007, 4:20-5:9, 5:16-55; EX1012, 372-73, 376-78, 383. Accordingly, combining Scherer's high-pass filter 4 with Suzuki's control unit 20 that adjusts ignition timing in homogeneous mode and injected fuel quantity in stratified mode would have simply been applying a known technique to a known device to yield the predictable result of more quickly correcting dynamic torque changes. Therefore, a POSA would have had a reasonable expectation of success in combining Suzuki and Scherer.

134. Thus, Suzuki and Scherer render obvious [1.E].

7. [1.F] "a transient torque controller which receives as an input the filtered difference signal and outputs a fuel adjustment signal and a spark adjustment signal."

135. Suzuki discloses a transient torque controller as claimed. As shown below in Figure 1B, Suzuki discloses that the torque correction section includes "a homogenous combustion torque correcting section [that] **corrects at least the spark timing** in order to make a torque correction **with a fast response** … during homogenous combustion" and a "stratified combustion torque correcting section [that] **corrects at least the air-fuel ratio** to make torque correction during stratified combustion." EX1005, 3:10-22. Moreover, Suzuki's homogeneous and stratified torque correction sections are configured to adjust torque output during transient engine operations: "[Suzuki's engine control apparatus] widens the range (**dynamic range**) over which torque can be controlled . . . ." *Id.*, 1:44-63, 3:10-22.



EX1005, FIG. 1B (annotated).

136. Suzuki further discloses that the homogenous combustion torque correcting section converts the torque correction factor processed from the torque shortage signal into a spark timing adjustment when the engine is set in a homogeneous mode (step S38): "If the combustion mode is homogeneous combustion, then the program proceeds to step S38 wherein the torque correction factor PIPER is converted to a spark timing correction factor." EX1005, 7:51-59. As shown in Figure 4, the torque correction factor is processed according to a spark-timing calculating routine that determines spark timing ("spark adjustment signal") from a characteristic map, which is based on a function of engine speed and one of target torque or fuel quantity (steps S12 and S13). *Id.*, 5:41-6:9, 8:1-2 ("The steps S31 to S37, S38, S39, S12 and S13 perform a homogeneous combustion torque

correcting function.") Thus, Suzuki's homogenous combustion torque correcting section "outputs . . . a spark adjustment signal," as recited in claim 1.

137. Suzuki also discloses that the stratified combustion torque correcting section uses the torque correction factor processed from the torque shortage signal to calculate a fuel adjustment when the engine is set in a stratified mode (step S40). EX1005, 7:60-8:4 ("[T]he steps S31 to S37, S40 and S22 to S25 perform a stratified combustion torque correcting function."). As shown in Figure 5, the torque correction factor is processed according to a fuel delivery requirement calculating routine that determines the fuel injector's injection pulse ("fuel adjustment signal") by an equation using the measured air/fuel ratio, the measured airflow, and the engine speed as inputs. *Id*., 6:10-57. Thus, Suzuki's stratified combustion torque correction section "outputs a fuel adjustment signal," as recited in claim 1.

138. A POSA would have understood that Suzuki's homogeneous and stratified torque correction sections collectively compose a "transient torque controller," as recited in claim 1.[4] These correction sections are a controller, because

[4] Notably, a POSA would have understood that different software or instruction modules of a control unit constitute different controllers, as the term "controller" is used in the '565 patent. Neither the claims nor the '565 patent specification specify that the recited controllers, "torque demand controller" and "transient torque controller," are separate physical structures. Indeed, in a district

court complaint, the Patent Owner alleges that the software embedded within an engine control module constitutes a "controller," as recited in the '565 patent. EX1029, 34 ("[T]he transient torque controller (software within the ECM) receives as an input the filtered difference signal (described above) and outputs a fuel adjustment signal (to the ECM) and spark adjustment signal (used for engine control intervention)."). EX1029, 34. As such, a POSA would have understood that different modules of Suzuki's control unit 20 are each a controller, as that term is used in the '565 patent. And even assuming that the '565 patent required separate physical controllers, implementing Suzuki's homogeneous and stratified torque correction sections ("transient torque controller") as one physical controller and the torque correction demanding section ("torque demand controller") as a separate physical controller would have been an obvious design choice to a POSA. Indeed, a POSA would have understood that electronic engine control systems often consist of multiple physically separate controllers for controlling a particular engine parameter, such as fuel injection, spark timing, or air flow. *See* EX1019, 155, 187. Moreover, a POSA would have understood that these separate physical controllers can be integrated as a single controller merely by changing a controller's software code. See EX1019, 250 ("[A] fully integrated electronic engine control system can include these subsystems and provide additional functions. (Usually the flexibility of the digital control system allows such expansion quite easily because the

they generate spark timing adjustment and fuel adjustment signals used to control torque output. EX1005, 3:5-22. Indeed, Suzuki's torque correction sections operate in the same manner as the transient torque controller 21 disclosed by the '565 patent, which generates a fuel adjustment signal when the engine 100 is set in the stratified mode and a spark adjustment signal when the engine 100 is set in the homogenous mode. EX1001, 3:34-50.

139. Thus, Suzuki discloses [1.F].

C. Suzuki, Cullen, and Scherer render obvious claim 4.

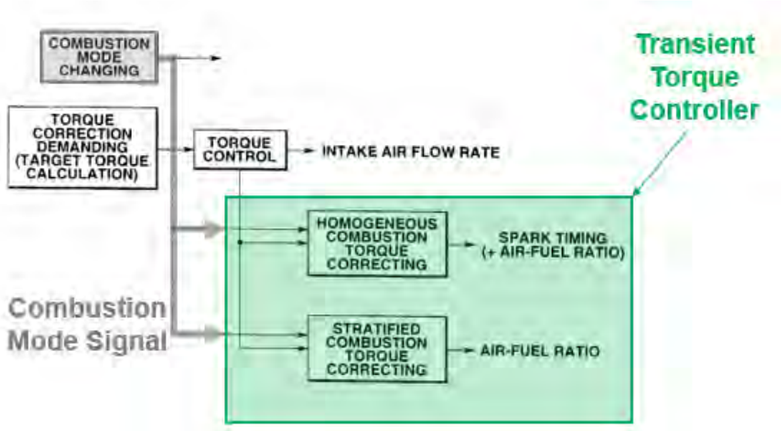
1. [4.A] "The device of claim 1, in which the engine is a direct injection spark ignition engine, wherein the transient torque controller is arranged to receive a combustion mode signal indicating whether the engine is operating in a stratified mode or a homogeneous mode"

140. Suzuki discloses a DISI engine and a transient torque controller that receives a combustion mode signal, as claimed. Suzuki discloses a "controller for a direct-injection spark-ignition type engine." EX1005, 3:6-7. The controller includes "a combustion mode changing section for making a combustion mode change between homogenous combustion and stratified combustion." *Id.*, 3:7-10. As shown below in Figures 1B and 6, Suzuki's homogeneous and stratified torque correction

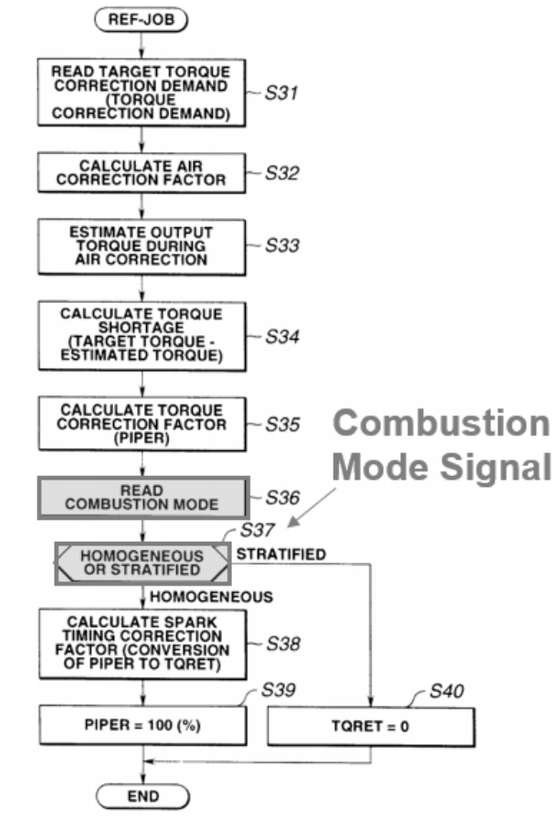
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computer program can be changed to accomplish the expanded functions.).") (Emphasis added). Thus, Suzuki discloses, or at least renders obvious, a "transient torque controller," as recited in claim 1.

sections ("transient torque controller") receive a signal from the combustion mode changing section to determine whether the engine is operating in the homogeneous or stratified mode. *Id.*, 7:45-8:4.



EX1005, FIG. 1B (annotated).



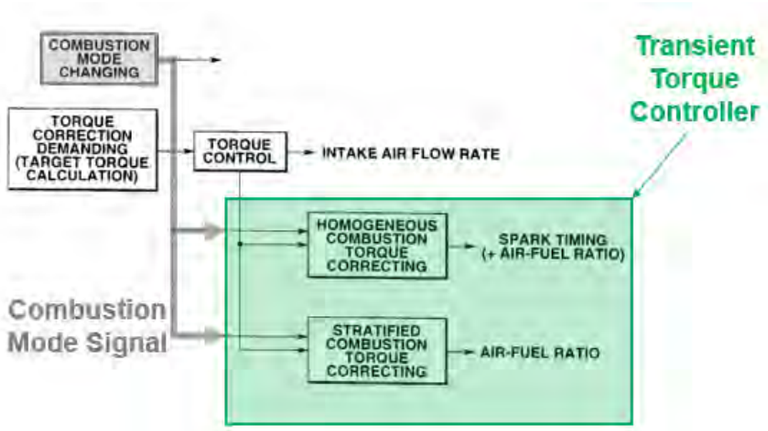
EX1005, FIG. 6 (annotated).

141. Suzuki's direct-injection spark-ignition engine is a "direct injection spark ignition engine," as recited in claim 4. And Suzuki's combustion mode changing section generates a "combustion mode signal" received by the homogeneous and stratified torque correction sections ("transient torque controller"), as recited in claim 4. This signal indicates whether the engine is operating in a stratified or a combustion mode. EX1005, 3:7-10.

142. Thus, Suzuki discloses [4.A].

2. [4.B] "wherein the transient torque controller is arranged to control the fuel adjustment signal when the combustion mode signal indicates that the engine is operating in the stratified mode, and"

143. Suzuki discloses the transient torque controller arranged to control the fuel adjustment signal as claimed. Again, Suzuki's stratified torque correction section composes, in part, the "transient torque controller" recited in claim 4. *See supra* Section X.B.7.



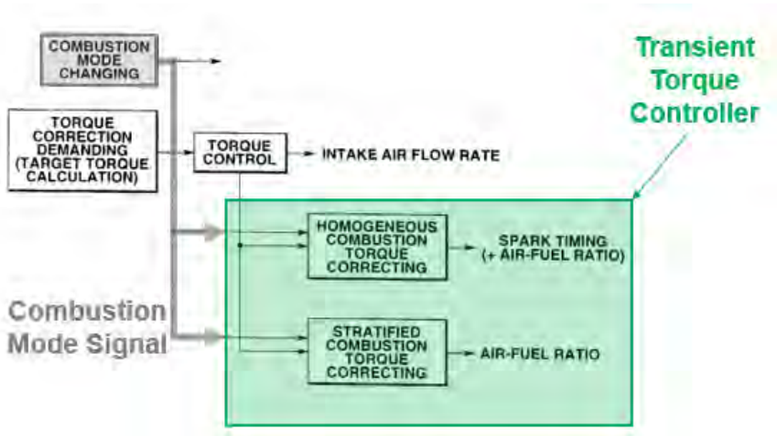
EX1005, FIG. 1B (annotated).

144. Suzuki discloses that the "stratified combustion torque correcting section **corrects at least the air-fuel ratio** to make torque correction **during stratified combustion**." EX1005, 3:10-22. To correct the air-fuel ratio, Suzuki's stratified combustion torque correction section adjusts the injection pulse signal ("fuel adjustment signal") transmitted to the fuel injectors 5 based on the fuel delivery calculation routine shown in Figure 5. *Id.*, 6:50-57, 7:60-8:4 ("[T]he steps S31 to S37, S40 [of Figure 6] and S22 to S25 [of Figure 5] perform a stratified combustion torque correcting function."). Specifically, Suzuki's control unit adjusts the pulse width of the fuel injection pulse signal to correspond to a fuel delivery requirement T_i that is derived ultimately from the torque shortage signal ("the difference signal") generated in step S34 of Figure 6. EX1005, 6:21-57, 7:35-44. Accordingly, in the stratified combustion mode, Suzuki's stratified torque correction section controls the fuel adjustment signal. Indeed, Suzuki's stratified torque correction operates in the same manner as the transient torque controller 21 disclosed by the '565 patent, which generates a transient fuel adjustment signal when the engine 100 is operating in the stratified mode. EX1001, 3:34-50.

145. Thus, Suzuki discloses [4.B].

3. [4.C] "wherein the transient torque controller is arranged to control the spark adjustment signal when the combustion mode signal indicates that the engine is operating in the homogeneous mode."

146. Suzuki discloses a transient torque controller arranged to control the spark adjustment signal as claimed.



EX1005, FIG. 1B (annotated).

147. Again, Suzuki's homogeneous torque correction section composes, in part, the "transient torque controller" recited in claim 4. *See supra* Section X.B.7. And Suzuki discloses that the "homogenous combustion torque correcting section corrects at least the **spark timing** in order to make a torque correction with a fast response … **during homogenous combustion**." EX1005, 3:10-22. To correct spark (ignition) timing, Suzuki's homogeneous combustion torque correction section modifies the timing of a command signal ("spark adjustment signal") transmitted to spark plug 6 based on the spark timing calculation routine shown in Figure 4. *Id.*, 6:7-9, 7:60-8:4 ("The steps S31 to S37, S38, S39 [of Figure 6], S12 and S13 [of Figure 4] perform a homogeneous combustion torque correcting

function."). Specifically, Suzuki's control unit retards or advances the timing of the ignition command signal based on a torque correction factor that is derived directly from the torque shortage signal ("the difference signal") generated in step S34 of Figure 6. *Id.*, 5:59-65, 7:35-59. Accordingly, in the homogeneous combustion mode, Suzuki's homogeneous torque correction section controls the spark adjustment signal. Indeed, Suzuki's homogeneous torque correction section operates in the same manner as the transient torque controller 21 disclosed by the '565 patent, which generates a spark adjustment signal when the engine 100 is set in the homogenous mode. EX1001, 3:34-50.

148. Thus, Suzuki discloses [4.C].

D. Suzuki, Cullen, and Scherer render obvious claim 7.

1. [7.P] "A method for controlling a torque output of an engine, the method comprising:"

149. Claim 7 recites a method analogous to the apparatus of claim 1. Element [7.P] is similar to [1.P], which is disclosed by Suzuki. *See supra* Section X.B.1. In particular, Suzuki discloses a "torque correcting routine," as shown above in Figure 6. EX1005, 7:10-13. Accordingly, Suzuki discloses [7.P] for at least the same reasons as [1.P].

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2. [7.A] "estimating a current torque signal from a received current spark angle signal, a received current air/fuel ratio signal and a received estimated air charge signal;"

150. Element [7.A] is similar to [1.C], which is rendered obvious by Suzuki and Cullen. *See supra* Section X.B.4. For example, Suzuki discloses "[i]n step S33, the output torque during intake air correction is estimated." EX1005, 7:33-34. While Suzuki does not expressly disclose receiving a current spark angle signal, a current air/fuel ratio signal, and an estimated air charge signal to estimate the torque output, Cullen discloses this limitation. Particularly, Cullen discloses a torque calculation procedure that estimates the torque (i.e., "IND_TQ") by inputting a current spark angle ("SPK"), a current air/fuel ratio ("A/F"), and an estimated air charge ("AIRCHG"). EX1006, 4:5-14, 5:34-50. And a POSA would have found it obvious to combine the teachings of Suzuki and Cullen to ensure that the estimated torque is calculated accurately, as described for [1.C]. Accordingly, Suzuki and Cullen render obvious [7.A] for at least the same reasons as [1.C].

3. [7.B] "comparing the estimated current torque signal with a desired torque signal to output a difference signal"

151. Element [7.B] is similar to [1.D], which is disclosed by Suzuki. *See supra* Section X.B.5. For example, Suzuki discloses that "[i]n step S34, the estimated torque is subtracted from the target torque … to calculate the torque shortage due to the delay involved with changing the amount of intake air." EX1005, 7:35-39. A POSA would have understood that Suzuki's step of subtracting

the estimated torque from target torque is the "comparing" step recited in claim 7. Accordingly, Suzuki discloses element [7.B] for at least the same reasons as element [1.D].

4. [7.C] "filtering out a plurality of low frequency components from the difference signal; and"

152. Element [7.C] is similar to [1.E], which is rendered obvious by Suzuki and Scherer. *See supra* Section X.B.6. For example, a POSA would have understood that Suzuki suggests a high-pass filter receiving the torque shortage signals to generate the correction factor signals shown in Figures 12-15. And Scherer explicitly discloses a "high pass filter 4 filter[ing] the dynamic desired engine torque part (M_d) … from the desired engine torque (M_{des}) supplied to it, and in turn provid[ing] the dynamic desired engine torque (M_d)." EX1007, 4:40-45. Scherer's high pass filter 4 performs the "filtering" recited in claim 7. And a POSA would have found it obvious to combine Scherer's use of the high-pass filter 4 with Suzuki's torque correction routine, so that Scherer's control unit 20 may adjust torque output to a desired value with a quicker response time during transient engine operation conditions, as explained for [1.E]. Accordingly, Suzuki and Scherer render obvious [7.C] for at least the same reasons as [1.E].

5. [7.D] "controlling a fuel adjustment signal and a spark adjustment signal in dependence upon a filtered difference signal"

153. Element [7.D] is similar to [1.F], which is disclosed by Suzuki. *See supra* Section X.B.7. For example, Suzuki discloses that "a homogenous combustion torque correcting section **corrects at least the spark timing** in order to make a torque correction with a fast response … during homogenous combustion" and a "stratified combustion torque correcting section **corrects at least the air-fuel ratio** to make torque correction during stratified combustion." EX1005, 3:10-22. Suzuki's spark timing adjustments during the homogenous combustion mode and fuel quantity adjustments during stratified mode constitute the "controlling" recited in claim 7. Accordingly, Suzuki discloses [7.D] for at least the same reasons as element [1.F].

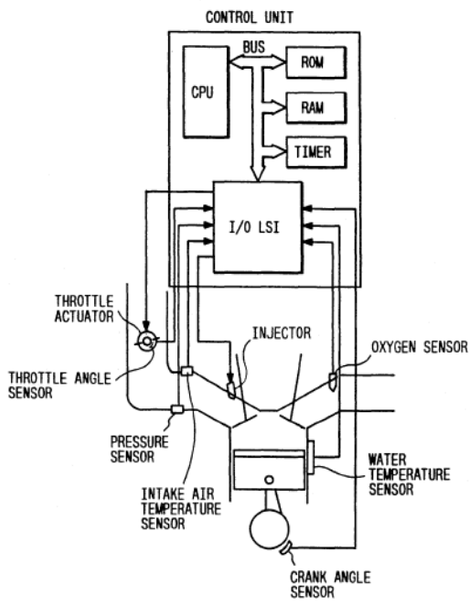
XI. Ground 2: The combination of Suzuki, Cullen, Scherer, and Takahashi renders obvious claims 2, 3, 5, and 6.

A. Rationale for combining Suzuki, Cullen, Scherer, and Takahashi

154. In my opinion, a POSA would have been motivated to combine the teachings of Takahashi with Suzuki, as modified by Cullen and Scherer, and would have had a reasonable expectation of success in doing so for at least the reasons discussed below.

155. As an initial matter, Suzuki, Cullen, Scherer, and Takahashi are from the same field of endeavor—control systems for an internal combustion engine. Similar to Suzuki, Cullen, and Scherer, Takahashi is directed to using a target torque

value as input for controlling engine parameters, such as fuel quantity and air/fuel ratio. Like Suzuki, Cullen, and Scherer, Takahashi's "invention is related to the method and system for simultaneous control of the throttle valve and fuel injection to ensure that the torque and air fuel ratio of the automobile engine will reach target values." EX1008, 1:6-9. Moreover, Takahashi discloses an engine and electronic control module (ECM) 11 having a control unit, a throttle position sensor, an engine speed sensor, an exhaust oxygen sensor, an engine water temperature sensor, and an airflow meter. EX1005, 4:17-40, FIG. 2; EX1008, 3:8-16, FIGS. 1 and 13.



EX1008, FIG. 13.

156. These components are similar to the components used in the control systems of Suzuki, Cullen, and Scherer. For example, Suzuki discloses a control unit 20 operatively linked to crankshaft angle sensors 21-22, an airflow meter 23, a

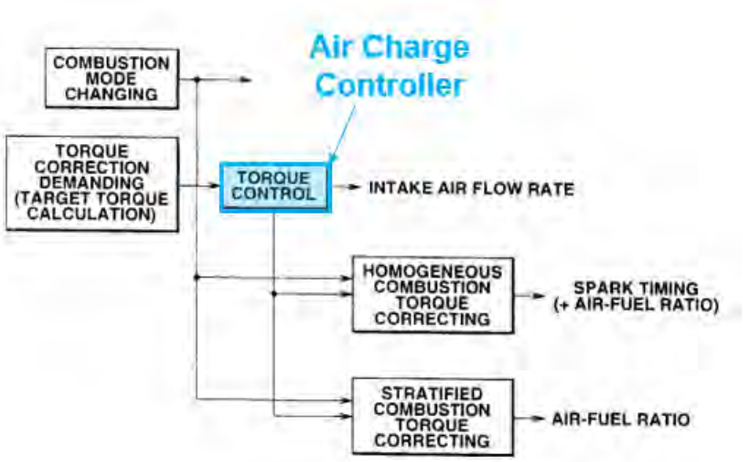
throttle valve sensor 25, and an O_2 sensor 27. EX1005, 4:6-40. Cullen discloses an engine control module 12 that receives a spark timing input 13, an air/fuel ratio input 16, an engine rpm input 17, and an engine air charge input 18. EX1006, 5:57-6:2. And Scherer discloses an engine control device operatively linked to a sensor system for detecting air flow rate, engine speed, and engine load. EX1007, 3:59-67, 4:8-38.

157. Combining the teachings of Takahashi, Suzuki, Cullen, and Scherer would have simply involved modifying the engine controller (e.g., reprogramming stored instructions in the microcomputer of Suzuki's control unit 20) to perform the steps taught in the references—a basic task for a POSA. EX1019, 102, 223 ("In a computer-based controller, however, the control law and system parameters are changed via program (i.e., software) control."). A POSA would have been motivated to combine the teachings of Suzuki, Cullen, Scherer, and Takahashi for at least the reasons discussed below and would have had a reasonable expectation of success in doing so.

158. The motivation to combine Suzuki, Cullen, and Scherer is discussed above in Section X.A. That motivation still applies here for claims 2, 3, 5, and 6. For example, a POSA would have been motivated to combine Cullen's routine for estimating torque output with Suzuki's control unit 20 to provide a more accurate estimation of the engine output torque, thereby allowing Suzuki's control unit 20 to

converge current torque output to the desired torque output more precisely. EX1006, 2:21-42; *see supra* Section X.A.1. And a POSA would have been motivated to combine Scherer's high-pass filter 4 with Suzuki's control unit 20 to allow Suzuki's torque correction section to correct the transient torque demand in a faster response time. EX1007, 4:40-45, 5:10-15, *see supra* Section X.A.2.

159. The motivation to combine Suzuki, Cullen, and Scherer is discussed above in Section X.A. Suzuki's control unit 20 includes a torque control section shown in Figure 1B ("air charge controller") for controlling the throttle valve to adjust the cylinder air charge. EX1005, 3:12-15, 4:33-38.



EX1005, FIG. 1B (annotated).

160. While Suzuki discloses an air charge controller, Suzuki does not expressly disclose that that the air charge controller produces an estimated air charge signal and receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature

signal. But these features are explicitly disclosed in Takahashi. EX1008, 3:13-27, 10:27-66, FIGS. 14 and 15.

161. Takahashi discloses specific implementation details of an air charge controller outputting an estimated air charge signal and receiving as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal. Particularly, Takahashi discloses a control unit having a throttle controller 144 ("air charge controller") that receives the demand air charge Q_{map0} ("air charge demand signal") from a target air mass flow rate deciding block 11 and estimates the current air mass flow rate Q_{map} ("estimated air charge signal") using a status estimating block 142. EX1008, 10:43-60, FIG. 14. The status estimating block 142 receives a current throttle angle signal θ_{th} from a throttle angle sensor ("throttle position signal"), an intake manifold pressure signal P_m from a pressure sensor ("manifold pressure signal"), an engine speed signal N from the crank angle sensor ("engine speed signal"), and an intake air temperature signal from the intake air temperature sensor ("air charge temperature signal"). *Id*. A POSA would have understood that the throttle angle signal θ_{th}, intake manifold pressure signal P_m, engine speed signal N, intake air temperature signal, and demand air charge Q_{map0} inputted into the combination of Takahashi's throttle controller 144 and status-estimating block 142 are the inputs recited in claims 2 and 5. And based on these inputs, the status estimating block 142

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of Takahashi calculates the estimated air charge, which is used by the control unit to adjust both the throttle valve position and the fuel injection quantity. *Id*. Takahashi further discloses that the air mass flow rate deciding block 11 receives a target torque signal T_o ("desired torque signal"), a target air/fuel ratio signal A/F_o ("desired air/fuel"), and a spark advance signal θ_{adv} ("desired spark angle signal") to determine the target mass flow rate Q_{map0} ("air charge demand signal"). EX1008, 3:28-51.

162. Because Suzuki is silent on this implementation detail of the air charge controller, a POSA would have sought out these details provided by Takahashi's analogous control unit. In my opinion, combining the teachings of Suzuki and Takahashi would have yielded predictable benefits and results—for example, precisely controlling the air mass flow rate at the inlet port of the engine cylinder. EX1008, 2:18-24 ("Since [using] a status estimating model … ensures a high precision estimation of the air flow status inside the intake manifold, the present invention further provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque at the target value."). A POSA would have understood that combining Takahashi's status estimating block technique with Suzuki's torque control section would have provided a more accurate estimation of the air mass entering the engine cylinder, thereby allowing Suzuki's control unit 20 to converge current torque output to the

desired torque output more precisely. *Id*. Furthermore, a POSA would have understood that incorporating Takahashi's target air mass flow rate deciding block 11 into Suzuki's torque correction section to output the demand air charge signal would have allowed Suzuki's torque control section to control cylinder air charge more precisely, ultimately allowing engine torque output to achieve the target torque. EX1008, 1:49-57, 3:24-51. As such, combining Takahashi's known status estimating block technique with Suzuki's known torque control section and incorporating Takahashi's target air mass flow rate deciding block 11 into Suzuki's torque correction section would have merely been applying a known technique in a similar, known device in the same way.

163. Moreover, a POSA would have had a reasonable expectation of success in combining Suzuki, as modified by Cullen and Scherer, with Takahashi. Indeed, a POSA would have recognized that the status estimating block technique in Takahashi would have been easily applied to Suzuki's torque control section to output the estimate air charge signal based on the detected engine speed, throttle position, manifold pressure, and air charge temperature. A POSA would have also understood how to combine the teachings of Takahashi with Suzuki, as modified by Cullen and Scherer. A POSA would have simply modified the software instructions stored in the microcomputer of Suzuki's control unit 20, such that the torque control section receives as inputs an air charge demand signal, a throttle position signal, an

engine speed signal, a manifold pressure signal, and an air charge temperature signal and generates an estimated air charge signal, as disclosed in Takahashi. Considering the similarities in Suzuki's and Takahashi's control systems, any necessary coding modifications to implement Takahashi's teachings into Suzuki's system would have been trivial and well within the skill level of a POSA.

164. In sum, Suzuki's control unit 20, Cullen's technique for estimating torque output, Scherer's high-pass filter, and Takahashi's technique for generating an estimated air charge signal were known elements that a POSA would have been motivated to and known how to combine in a known way to provide the predictable benefits disclosed in the references for providing precise, rapid correction of engine torque demand.

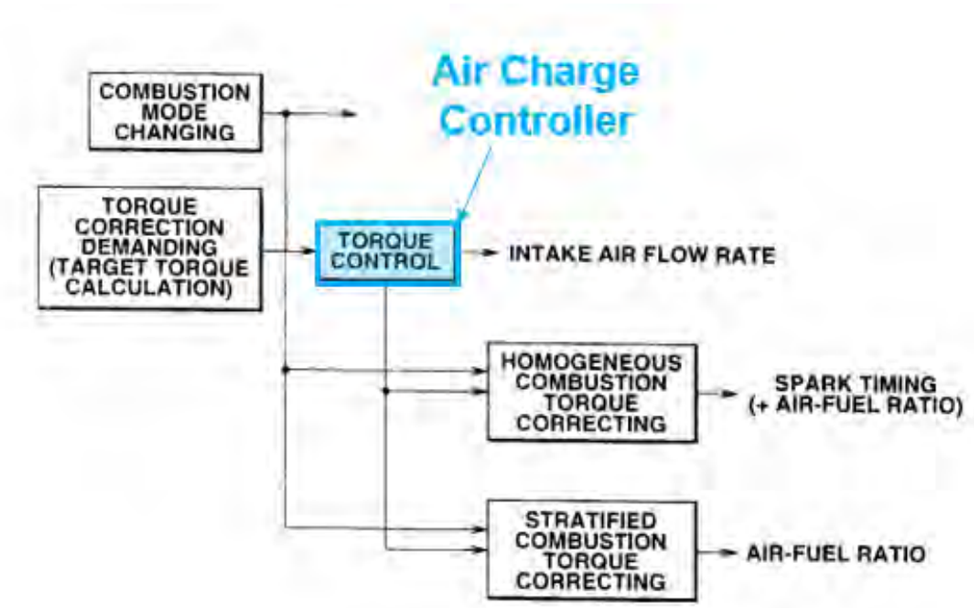
165. Accordingly, it would have been obvious to combine the teachings of Suzuki, Cullen, Scherer, and Takahashi.

B. Suzuki, Cullen, Scherer, and Takahashi render obvious claims 2 and 5.

166. Claims 2 and 5 depend from claims 1 and 4, respectively, and recite "wherein the estimated air charge signal is produced by an air charge controller which receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal and an air charge temperature signal." EX1001, 4:22-26, 4:44-48.

167. Suzuki, in combination with Cullen, Scherer, and Takahashi, renders obvious this limitation of claims 2 and 5.

168. As shown below in Figure 1B, Suzuki discloses that the torque correction section includes a torque control section (blue) that controls a throttle valve to adjust "the amount of air permitted to enter the engine in order to control the torque." EX1005, 3:12-15.



EX1005, FIG. 1B (annotated).

169. A POSA would have understood that Suzuki's torque control section is the "air charge controller," as recited in claims 2 and 5.[5] Suzuki's torque control

[5] Again, a POSA would have understood that different software or instruction modules of a control unit constitute different controllers, as the term "controller" is used in the '565 patent and asserted in the district court complaint. *See supra*

section adjusts the air charge inputted into the engine cylinders via actuating the throttle valve. EX1005, 3:27-31 ("Air intake is controlled by an electronic controlled throttle valve 4. The degree of opening of the electronic controlled throttle valve 4 is controlled by, for example, a step motor operable in response to a signal from a control unit 20."), 4:32-37, 8:43-47. And Suzuki's torque control section operates in the same manner as the air charge controller 29 disclosed by the '565 patent, which transmit a signal indicating the desired throttle position to the throttle actuator. EX1001, 3:19-22.

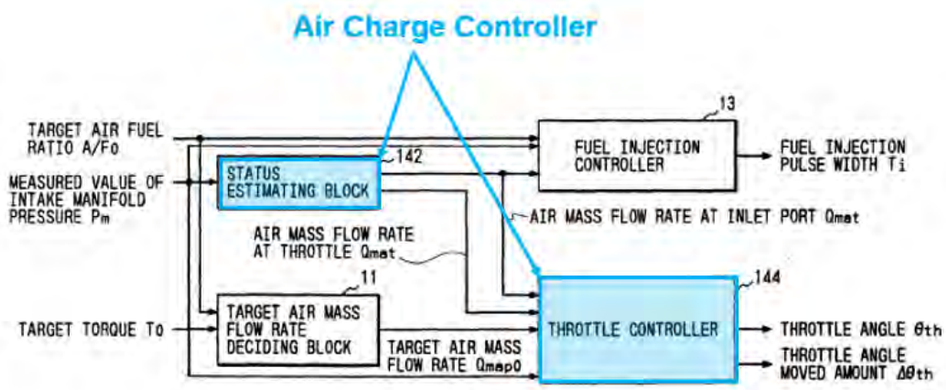
170. Suzuki does not expressly disclose that the torque control section produces an estimated air charge signal and receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal. However, Takahashi explicitly discloses this feature. EX1008, 3:13-27, 10:27-66, FIGS. 14, 15.

171. Takahashi discloses a control unit that controls torque output based on receiving inputs from a throttle angle sensor, an intake pressure sensor, an intake air temperature sensor, a crank angle sensor, an engine coolant sensor, and an exhaust oxygen sensor. EX1008, 3:10-13, FIG. 13. As shown below in Figure 14, the control unit includes a throttle controller 144 that calculates a desired throttle position for

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Footnote 4. Accordingly, a POSA would have understood that different modules of Suzuki's control unit 20 are each a controller as that term is used in the '565 patent.

the throttle valve to set the air flow into the engine cylinder at a desired air charge value, ultimately allowing the engine to achieve a target torque value. *Id.*, 3:20-27, 6:10-12, 7:50-58.



EX1008, FIG. 14 (annotated).

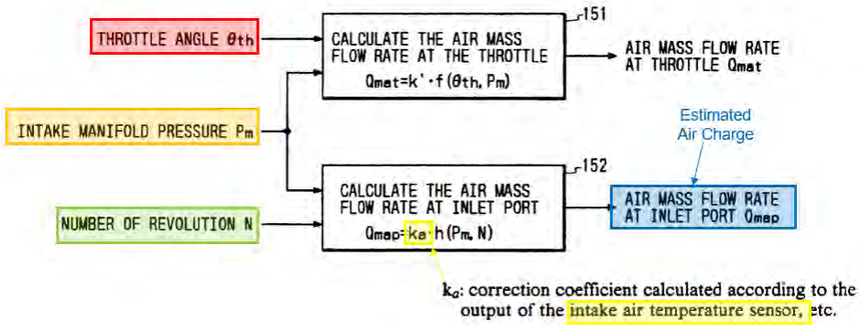
172. The throttle controller 144 determines the desired throttle position as a function of a target air mass flow rate Q_{map0} ("air charge demand signal") and an estimated air mass flow rate at the inlet port Q_{map} ("estimated air charge signal").[6]

[6] In Takahashi, there is a discrepancy between the reference symbols disclosed in the specification and the reference symbols shown in the figures regarding the element "air mass flow rate at the inlet port." In the specification and Figure 2, Takahashi refers to the "air mass flow rate at the inlet port" using the reference symbol Q_{map}. EX1008, 10:54-60. However, in Figure 14 of Takahashi, the "air mass flow rate at the inlet port" is represented by the reference symbol Q_{mat}.

EX1008, 10:42-47, FIG. 14. The throttle controller 144 receives the demand air charge Q_{map0} from a target air mass flow rate deciding block 11 and estimates the current air mass flow rate Q_{map} using a status estimating block 142. *Id.*, 10:42-60, FIG. 14.

173. As shown below in Figure 15, the status estimating block 142 receives a current throttle angle signal θ_{th} (red, "throttle position signal") from a throttle angle sensor, an intake manifold pressure signal P_m (orange, "manifold pressure signal") from a pressure sensor, and an engine speed signal N (green, "engine speed signal") from the crank angle sensor.[7] *Id.*, 10:54-66. The status estimating block 142 estimates the air charge value based on intake pressure P_m, engine speed N, and a correction coefficient k_a determined from current intake temperature sensor (yellow). *Id*. The estimated air charge value is used to adjust both the throttle valve position and the fuel injection quantity, which ultimately controls the torque output of the engine. *Id.*, 3:24-27, 5:53-67, 10:21-27.

[7] A POSA would have understood that the measured parameter number of revolutions N as disclosed in Takahashi represents engine speed.



EX1008, FIG. 15 (annotated).

174. Takahashi discloses an air charge controller as recited in claims 2 and 5. Takahashi's throttle controller 144 and status estimating block 142 collectively compose an "air charge controller," as recited in claims 2 and 5. Takahashi's status-estimating block 142 and throttle controller 144 operate in the same manner as the air charge controller 29 disclosed by the '565 patent, which receives an air charge demand signal and signals from throttle position sensor 6, engine speed sensor 3, manifold pressure sensor 110, and temperature meter 5. EX1001, 3:13-22.

175. And Takahashi's throttle controller 144 and status estimating block 142 receive as inputs an air charge demand signal (Takahashi's target air mass flow rate Q_{map0}), a throttle position signal (Takahashi's throttle angle signal θ_{th}), an engine speed signal (Takahashi's number of revolutions N), a manifold pressure signal (Takahashi's intake manifold pressure P_m), and an air charge temperature signal (Takahashi's intake air temperature). The combination of Takahashi's throttle controller 144 and status estimating block 142 produces an estimated air charge

signal (Takahashi's air mass flow rate at inlet port Q_{map}), which is ultimately used to adjust both the throttle angle position and fuel quantity. Accordingly, Takahashi discloses an air charge controller that produces an estimated air charge signal and that receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal, as recited in claims 2 and 5.

176. In view of Takahashi, it would have been obvious for a POSA to modify Suzuki's torque control section to receive as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal and to use these inputs to produce an estimated air charge signal so that Suzuki's control unit 20 may estimate the cylinder air charge more accurately. EX1008, 1:43-65, 2:18-24, 10:21-27. Indeed, Takahashi expressly discloses that this configuration "provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque at the target value." *Id.*, 2:18-24. Such modification would have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. Accordingly, a POSA would have been motivated to combine the teachings of Takahashi with Suzuki so that the control unit converges the engine output torque to the demand torque value with greater precision. *Id.*

177. Likewise, a POSA would have been able to easily implement the teaching in Takahashi by modifying the software instructions stored in the microcomputer of Suzuki's control unit 20 such that the torque control section receives as inputs an air charge demand signal, a throttle position signal, an engine speed signal, a manifold pressure signal, and an air charge temperature signal and produces an estimated air charge signal. Indeed, a POSA would have recognized to combine Takahashi's status estimating block technique with Suzuki's torque control section to output the estimated air charge signal based on the detected engine speed, throttle position, manifold pressure, and air charge temperature. Accordingly, a POSA would have had a reasonable expectation of success in combining Suzuki and Takahashi.

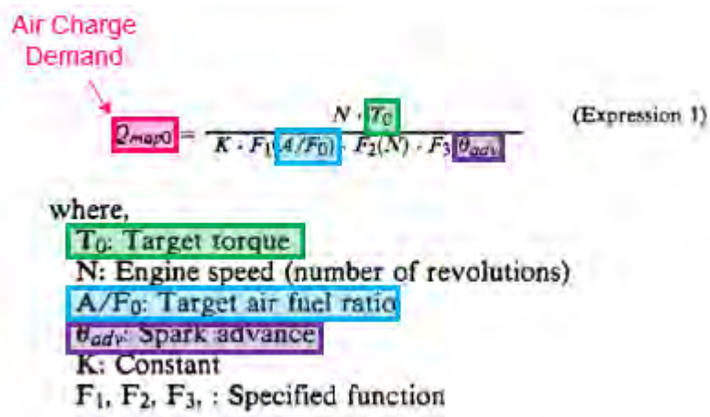
178. Thus, Suzuki, in combination with Cullen, Scherer, and Takahashi, renders obvious claims 2 and 5.

C. Suzuki, Cullen, Scherer, and Takahashi render obvious claims 3 and 6.

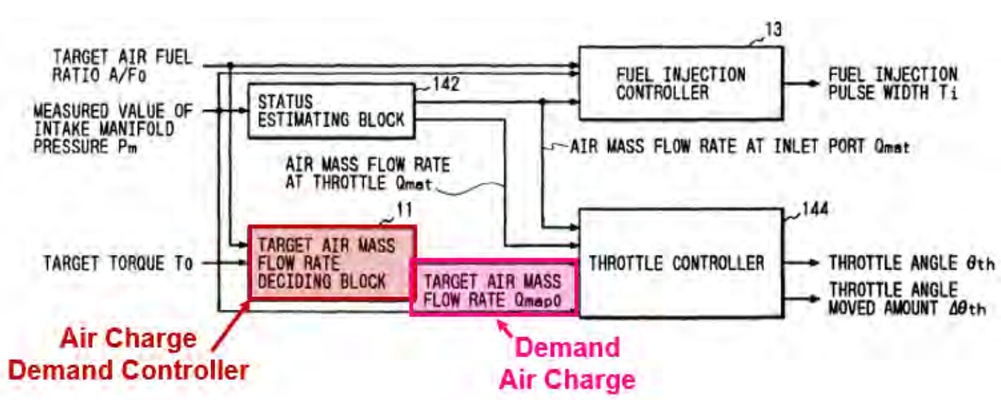
179. Claims 3 and 6 depend from claims 2 and 5, respectively, and recite "wherein the air charge demand signal is produced by an air charge demand controller which receives as inputs the desired torque signal, a desired spark angle signal and a desired air/fuel ratio."

180. Suzuki and Takahashi render obvious this limitation of claims 3 and 6. As described above, Takahashi discloses that the throttle controller 144 (which

composes the recited air charge controller) receives the demand air charge Q_{map0} from a target air mass flow rate deciding block 11. EX1008, 3:28-29, 10:42-50, FIG. 14. As shown below in Figure 14 and Expression 1 recited in column 3 of the specification, Takahashi further discloses that the air mass flow rate deciding block 11 receives a target torque signal T_o (i.e., green, "a desired torque signal"), a target air/fuel ratio signal A/F_o (i.e., blue, "a desired air/fuel"), and a spark advance signal θ_{adv} (i.e., purple "a desired spark angle signal") to determine the target mass flow rate Q_{map0} (pink, "air charge demand signal"). EX1008, 3:28-51.



EX1008, 3:30-41 (annotated).



EX1008, FIG. 14 (annotated).

181. Takahashi's target air mass flow rate deciding block 11 is an "air charge demand controller," as recited in claims 3 and 6. The target air mass flow rate deciding block 11 determines a demand air charge value for the throttle controller 144 based on receiving a desired torque signal, a desired spark angle signal, and a desired air/fuel ratio. Indeed, Takahashi's target air mass flow rate deciding block 11 operates in the same manner as the air charge demand controller 27 disclosed by the '565 patent, which receives a desired torque signal, a desired spark angle signal, and a desired air/fuel ratio and outputs a demand air charge signal to the air charge controller 29. EX1001, 3:6-12.

182. It would have been obvious for a POSA to incorporate Takahashi's target air mass flow rate deciding block 11 into Suzuki's torque correction section to output the demand air charge signal to Suzuki's torque control section. EX1008, 1:43-65, 2:17-23, 10:21-27. Indeed, Takahashi expressly discloses that determining the target air mass flow rate based on the target torque, target air/fuel ratio, and ignition (spark) advance provides precise control of cylinder air charge, ultimately allowing engine torque output to achieve the target torque. EX1008, 1:49-57, 2:17-24, 3:24-51 ("Since it uses a status estimating model which ensures a high precision estimation of the air flow status inside the intake manifold, the present invention … provides a high-precision control of the air mass flow rate at the inlet port and

ensures a high-precision maintenance of the engine-generated torque."). Such modification would have simply been applying a known technique to a known device to yield the predictable result of controlling cylinder air charge more precisely. Accordingly, a POSA would have been motivated to combine the teachings of Takahashi with Suzuki so that the control unit converges the engine output torque at the demand torque value with more precision. EX1008, 2:17-23.

183. Likewise, a POSA would have been able to easily implement the teaching in Takahashi by modifying the software instructions stored in the microcomputer of Suzuki's control unit 20 such that the demand air charge value is calculated according to Takahashi's Expression 1 equation. EX1008, 3:30-41. Indeed, a POSA would have recognized that the target air mass flow rate technique in Takahashi could be applied to Suzuki's torque control section to provide a demand air charge signal that would achieve the demand torque. Accordingly, a POSA would have had a reasonable expectation of success in combining Suzuki and Takahashi.

184. Thus, Suzuki, in combination with Cullen, Scherer, and Takahashi, renders obvious claims 3 and 6.

XII. Objective Indicia Do Not Support Patentability.

185. I understand that the obviousness analysis includes considering evidence of secondary indicia of nonobviousness (if available). I understand that any

secondary indicia of nonobviousness must have a nexus, or a close connection, to the novel aspects of the claimed invention. I understand that secondary indicia of nonobviousness include the following: commercial success, long-felt but unmet need, failure of others, copying, praise in the industry, and unexpectedly superior results as compared with the closest prior art.

186. Considering the information I have reviewed, my general knowledge of the field of engine control systems, and publications within that and related fields, I am not aware of any objective evidence that might support the patentability of the claims of the ’565 patent. Further, from my review of the file history (Exhibit 1002) of the ’565 patent, I did not see that the applicant raised any secondary indicia of nonobviousness during prosecution. I am not otherwise aware of any publicly available evidence of secondary indicia of nonobviousness. Should any alleged secondary indicia of nonobviousness be presented, I reserve the right to provide an opinion thereon.

XIII. Conclusion

In signing this Declaration, I recognize that this Declaration will be filed as evidence in an *inter partes* review before the Patent Trial and Appeal Board of the United States Patent and Trademark Office. I also recognize that I may be subject to cross-examination in the case and that cross-examination will take place within the United States. If cross-examination is required, I will appear for cross-examination within the United States during the time allotted.

I hereby declare that all statements made herein are made of my own knowledge and are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code.

Executed on this 30th day of January 2020.

C. Arthur MacCarley, Ph.D., P.E.

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Curriculum Vitae

C. Arthur (Art) MacCarley, Ph.D. PE.
amaccarl@calpoly.edu, art1@loragen.com, http://www.ee.calpoly.edu/faculty/amaccarl, http://www.loragen.com

Specializations: Automotive electronics and control systems, electric and alternative fuel vehicles.

Employment

California Polytechnic State University, San Luis Obispo (1988-present)

Professor and former Department Chair, Electrical Engineering

Professor and former Program Director, Computer Engineering

Professor and former Department Head, BioResource and Agricultural Engineering

Director, Cal Poly Transportation Electronics Laboratory

Munich University of Applied Science (Germany)

Adjunct Professor, Mechanical & Electrical Engineering (Summer 2014,16,18,19 and Winter semester 2017)

Registered Professional Engineer, Electrical and Mechanical (Colorado, 1981-present)

Education

Purdue University, West Lafayette, Indiana
Ph.D. Electrical Engineering (Computer Engineering Specialization), 1987. Thesis: Advanced Digital Control.
University of California, Los Angeles, California
M.S. Electrical Engineering, 1978. Thesis: Electronic Fuel Injection Techniques for Hydrogen IC Engines.
B.S. (Cum Laude) Engineering, Mechanical/Alternative Energy Specialization, 1976.

Employment

9/16-1/17 *Munich University of Applied Science (Germany), Adjunct Professor, Mechanical Engineering.* Teach and supervise projects in Electric and Alternative Fuel Vehicles, Solar PV Systems.

3/88 to present *California Polytechnic State University, Professor, Electrical Engineering.*
EE Department Chair 2007-2010, Computer Engineering Program Director 2000- 2003, Dept. Head BioResource and Agricultural Engineering 2014-2015.
Administrative and academic responsibilities, teaching undergraduate and graduate courses in control systems, computer engineering, automotive engineering and alternative energy.
Research funded by NSF, DOE, DOT, Caltrans, PG&E and five industrial firms on advanced highway monitoring and control systems, electric vehicles, electronic engine controls and alternative fuels.

1/11-5/11 *Franklin Olin College of Engineering (Mass), Adjunct Professor of ECE.* Taught multidisciplinary engineering lecture/lab and senior elective “Automotive Technologies for a Sustainable Future”.

6/97 to 6/14 *Loragen Corporation, Advanced Technology Group, Principal Engineer*
Automotive and highway safety electronics R&D for US DOE, Caltrans, UC Berkeley, Hughes SBRC.

1/84 to 12/87 *Purdue University, School of Electrical Engineering, David Ross Fellow*
Research in microprocessor-based control systems and advanced indirect sensing methods. Lead teaching assistant for digital laboratory; instructor for two undergrad laboratories; teaching asst. for two grad courses.

8/82 to 9/83 *American Bosch Division of United Technologies, Springfield, MA., Senior Engineer*
Design and optimization of electronic diesel engine controls. Lead engineer, controls group, responsible for development and testing of electronic engine control algorithms.

5/82 to 8/82 *Consulting Engineer in Private Practice, Denver, CO.*
Designed, constructed and tested electronic fuel injection and ignition control system for natural gas fueled engines, for CNG Vehicle Equipment Co., Fort Collins, Colorado.

5/79 to 5/82 *Denver Research Institute, University of Denver, CO., Research Engineer*
Principle investigator on three programs involving the development and testing of alternative fuel engines and vehicles. Designed electronic engine controls and on-board metal-hydride hydrogen fuel storage systems.

9/77 to 5/79 *Hughes Aircraft Co. Digital Communications Lab, El Segundo, CA., Member of Technical Staff*
Design, analysis and computer optimization of circuits for NASA Space Shuttle, GMS2 and GOES satellites.

6/75 to 9/77 *Research Assistant, UCLA School of Engineering and Applied Science*
Designed electronic fuel injection and cryogenic hydrogen fuel storage system under US DOT grant.

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Honors and Awards

Deans list, UCLA College of Engineering 1975 and 76.
Outstanding Thesis of the Year, College of Engineering Nominee for University Award 1978
Outstanding Research Paper of the Year, University of Denver Research Institute (1980)
Cal Poly Meritorious Promise and Professional Practice (MPPP) Award, 1990.
Award recipient, DOE/NIST New Invention Competition, 1992.
Most Inspirational Instructor Award, runner-up, 1989 and 1992.
Outstanding Faculty-Student Involvement Award, 1992 and 1993.
Outstanding Faculty Advisor, 1995, 1996, 1997, 1998.
Northrup-Grumman Excellence in Teaching and Applied Research Award, 1997.
Litton Industries Excellence in Research and Development Award, 1997.
SCCA/EVTC Electric Vehicle Racing Series, 4th and 2nd Place National Winner, Stock/modified Class, 1998, 99.
Society of Automotive Engineers "Best Oral Presentation" Award, SAE International Congress, 2000.
Computer Engineering Program Appreciation Plaque for service as Director of Computer Engr. 2000-2003.
Society of Women Engineers Team Tech Competition Project Advisor, Recognition Plaque, 2003.
Electrical Engineering Student Advising and Support Award, 2003.
Caltrans nomination for State of California Award for most cost-effective research of the year, 2004.
Society of Women Engineers Team Tech Competition Project Advisor, Recognition Plaques, 2004 and 2005.
Electrical Engineering Department Appreciation Award for service as Department Chair, 2007-2010
Cal Poly 20-year Service Award, 2008.
EE Student Award for “Best Stories”, EE Department Banquet, 2010.
Professional Recognition Plaque from Cal Poly Alumnus Astronaut Greg Chamitoff, 2009.
Recognition pin for service to the disabled community from Rory Cooper, Director of the Human Engineering Research Laboratories, University of Pittsburgh Medical Center, 2010.
BioResource & Agricultural Engineering Department Appreciation Award for service as Dept. Head, 2013-15
Faculty Fellow, Cal Poly College of Agriculture, Food and Environmental Science, AY 2015-16

Professional Society Memberships

Registered Professional Engineer (Electrical and Mechanical), Colorado, 1980-present.
Society of Automotive Engineers (SAE), Senior Member, 1976-present.
International Association for Hydrogen Energy (IAHE), founding member, 1977-1982.
Institute of Electrical and Electronic Engineers (IEEE), Senior Member, 1976-present.
Sigma Xi Scientific Research Society, 1980-present. Cal Poly Chapter President 1991/92.
American Society of Engineering Educators (ASEE), Senior Member, 1989-2010.
American Society of Agricultural and Biological Engineers (ASABE), 2013-2016.

Professional Service

Faculty advisor to 150+ senior projects, 20+ MS theses in electrical and computer engineering, 1988-present.
Faculty advisor of student or team winning the Hewlett Packard Senior Project of the Year Award, 1989, 90, 91, 92, 93, 95, 98, 99, 2000, 2002.
Deployed first EE Central UNIX computer system, using donated systems and components. 1988.
Produced first computer-typeset lab manual in College of Engineering, using UNIX TROFF/EQN, 1988.
Patent Disclosure “Indirect Sensing Method for Diesel Fuel Injection Quantity Control,” CP Foundation, 1989.
Specified, deployed and wrote practical users manuals for EE Dept. network of 15 UNIX Workstations, 1990.
Served as UNIX and network system administrator for the EE Dept., 1990-1999.
Presentations for Electrical Engineering Graduate Seminar almost every year since 1989.
Faculty Advisor and Branch Counselor to Cal Poly Student IEEE Chapter, 1990-97.
Cal Poly representative to Chancellor's Technology Transfer Task Force, 1993.
Cal Poly Academic Senator, 1993-95.
Principal Evaluator, US Dept of Transportation Federal Highway Administration Field Operational Test, “Evaluation of Video Intersection Detection System”, 1993-06.
Principal Evaluator, US Dept of Transportation Federal Highway Administration Field Operational Test, “Evaluation of Integrated Freeway Ramp Meter and Arterial Control System”, 1993-06.
Patent Disclosure “Rapid Battery Interchange,” Cal Poly Foundation, 1993.
Invited speaker for IEEE Central Coast Professional Section Meetings, 1995, 1999 and 2007.
Cal Poly Intellectual Property Committee, 1995-97.
Developed modern EE/CPE Embedded Systems Laboratory, teaching both Intel and Motorola MCs, 1996.

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Founder and Incorporator of Loragen Corp., San Luis Obispo, CA (consulting and independent evaluation team of Cal Poly faculty and students) 1997.
Interviewed by KSBY News for technical opinion on ordinance banning cell phone use at gas stations, 1998.
Co-author of Cal Poly College of Engineering Mission Statement document, 1998.
Academic Senate Research Committee, College of Engineering Representative, 1996-99.
College of Engineering Strategic Planning Committee, 1997-98.
College of Engineering Research and Professional Development Committee, Chair, 1997-99.
Founder and faculty adviser, Cal Poly Electric Vehicle Engineering Club and Electric Racing Team, national winner of 4th place 1998 and 2nd place 1999. 1996-2012.
Expert witness for California Department of Transportation Legal Division (1999-present).
Director of Cal Poly Computer Engineering Program 2000–03.
Spent June-August of 2000 fundraising for CPE and EE; traveled to 18 companies throughout California. Resultant contacts and donations provide continuing annual support of CPE, EE and CsC.
Designated by Advancement Office in 2000 as the official contact between the College of Engineering and Bert and Candace Forbes, helping to secure $3 million dollar donation to Cal Poly CPE, half to the EE Dept.
Organized and offered the first Computer Engineering Program Banquet, September 2001.
Created first Industrial Advisory Board for the Computer Engineering Program, December 2001.
Founder and permanent faculty co-advisor of Cal Poly Computer Engineering Honor Society, Fall 2001-present.
Created and advised three Computer Engineering Capstone team projects with industrial collaborators.
Appointee, Caltrans working group on telecommunications, meeting annually 2002-present.
Raytheon Excellence in Teaching Award Selection Committee, 2004, 05, 06.
Raytheon Excellence in Applied Research Award Selection Committee, 2004, 05, 06.
Northrup-Grumman Excellence in Teaching and Research Award Selection Committee, 1999, 2004, 05, 06.
Developed and continue to operate Caltrans Detector Testbed on I-405 in Irvine, 2002-present.
Faculty advisor to the SWE *Team Tech* National Competition Team, 2003 (2nd place) and 2004 (1st place)
Developed "SIBS Bill Analyzer" computer program for Caltrans. Program for auditing and controlling state telecommunications costs, attributed with saving over $4 million in first year of use, 2004.
Member and Inter-committee Liaison, TRB Committee on User Information Systems, 2005-present.
Faculty advisor, Cal Poly Advanced Autonomous Vehicle Club, 2005-present.
Faculty advisor to the Cal Poly DARPA Grand Challenge Team, (semifinalists) 2005-06.
Chair of Tenured and Probationary Faculty Committee, Tenured Faculty Committee, and Probationary Review Committee, Cal Poly Electrical Engineering Department, 2005-06.
Developed Cal Poly EE "Control Systems" educational web site http://telab.ee.calpoly.edu/~amaccarl
Invited participant in the "Baker Forum", focusing on sustainability issues, 2006.
Completed short "CDR Certification Course" conducted by Collision Safety Institute, (for qualification as automotive crash data expert witness), Vallejo, CA, July 2006.
Co-organizer of special session "Next Generation of Driver Information Systems" at 2007 TRB Annual Meeting.
College of Engineering Domain 5 (Professional Development) Advisory Committee, 2007.
Member of SurGE, Cal Poly Sustainable Initiatives Working Group.
Participant in US Congressional Caucus meeting on "Education in Simulation and Modeling," 2007.
College of Engineering RPT Committee. Co-author of draft CENG RPT Policy Document, 2007-2009.
Represented Cal Poly at International Engineering Education Symposium, Seoul, Korea, 2009.
College of Engineering Project-Based Learning Center Committee, representing CPE, 2006-present.
College of Engineering Computers and Networks Committee, representing EE and CPE, 2006-present.
Founder and faculty advisor to interdisciplinary Electric Vehicle Engineering Club, 2007.
Active in many forums as advocate for improvement of research environment at Cal Poly.
Published lecture notes and laboratory manuals for 18 Electrical and Computer Engineering courses at Cal Poly, San Luis Obispo.
Principal Investigator on 36 funded research projects involving various areas of advanced controls and transportation electronics 1989-present, totaling over $3.5 million in external funding. All projects have involved and provided employment for undergraduate and graduate students. Complete list on request.
Member, National Academy of Engineering Transportation Research Board User Information Committee, 2006-
Member, College of Engineering Committee to write new Retention, Probation and Tenure Document, 2006-08.
Invited Speaker, Cal Poly Focus the Nation campus-wide event. Co-presented "Global Warming: Problems and Solutions, An Engineering Approach", Jan 31, 2008.
Invited Speaker, Cal Poly Kennedy Library Science Café. "My Methanol Motorcycle", Jan 28, 2009.

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Department Chair, Electrical Engineering, 2007-2010. Among accomplishments were major fiscal restructuring, implementation of “Promise-keeping Policy” for assured student accommodation in required classes, and guidance of Department through ABET accreditation culminating in visit 2008.
EPIC Course instructor, 2008 and 2009 (solar-powered model car design and competition).
Volunteer GATE course teacher, Nipomo MESA Middle School, every year 2002-present.
Adjunct Professor of Electrical and Computer Engineering at Olin College of Engineering, Needham, MA, during Sabbatical leave 2011. Developed and taught new course on Sustainable Automotive Technologies. Co-developed and taught major revision of freshman introduction course “Real-World Measurements”.
Created “Electric Vehicle and Battery Safety Course” with certification examination for Cal Poly Electric Vehicle Engineering Club. Offered course and certification exam to all interested Cal Poly students, Dec. 2011.
Created and taught new Cal Poly multidisciplinary engineering course “Automotive Technologies for a Sustainable Future”, Winter quarter, 2012.
Recipient of Chevron Grant for support of student team projects in above course.
Co-recipient (with ME faculty) of Chevron Grant for support of Wind Energy Project.
Currently (2012) PI on Caltrans Division of Innovation and Research advanced detector testbed project.
Safety officer for Cal Poly electrical engineering department (2011-present).
Department Head, BioResources and Agricultural Engineering Department. Administrative duties, oversaw program accreditation 2005, served faculty and College as member of visioning enrollment committees, reactivated Industrial Advisory Board, created Annual Department News Magazine and weekly newsletters.
Assisted in securing the donation of 1060 advanced solar panels from Sunpower Inc, 2013.
Created Solar Photovoltaic System Engineering Course (BRAE 434) and installed Solar PV systems on BRAE office building and Rodeo Arena storage building as course projects, 2013-15.
Faculty Fellow and Technology Consultant to CAFES, 2015-16.
Preliminary design of 70kW Solar PV system for College of Agriculture Swanton Pacific Ranch, 2016.
First electrical engineering professor to exchange with Munich University of Applied Science, Fall 2016.

University Courses Developed

Major course revisions:
EE 342, Control Systems Laboratory. Designed lab, wrote new lab manual, 1988, 1994, 1996, 1998.
EE/CPE 319/359 Digital Design with Laboratory. Introduced PLDs, FPGAs, and CAD logic design methods.
BRAE 335, Internal Combustion Engines. Updated and redesigned Lecture and Laboratory, Winter 2016.
Created new courses:
EE 563 Graduate Seminar, 1989.
EE 514 Advanced Topics in Automatic Control, 1988.
EE/CPE 432 Digital Control Systems, 1989.
EE 434 Automotive Engineering for a Sustainable Future, 2013.
EE/CPE 472 Microprocessor Controls Laboratory, 1989.
EE/CPE 336 Microprocessor Embedded Systems Lecture and Laboratory, 1994.
CPE 350/450 Jointly created (2003), and instructor for CPE 350/450 capstone courses, 2006-2016.
EE470/471 “Automotive Technologies for a Sustainable Future”, Winter quarter, 2012, 2013.
BRAE 240-5 Solar Engineering Laboratory Spring 2014
EE/BRAE 434 Alternative Energy Vehicles, Spring 2014,15,16,17,18.
BRAE 470/471 Special Topics “Solar PV Engineering”. Fall 2014, 2015.
EE/BRAE 450 Solar Photovoltaic System Engineering, Winter/Spring 2016,17,18, 19.
Munich Univ of Applied Science: “Alternative Energies” Mechanical Engineering, Winter Semester 2016.
Course coordinator and major course redesign:
EE 436 and 336, Embedded Systems Laboratories, 1994-2004.
EE 342 Controls Laboratory 1993-2003, 1988-2000, 2006-2012.
EE/CPE 219,259,319,359 digital area lectures and labs, 1990-1998.
EE 432/472 Digital Control Systems lecture and laboratory. 1990-present.
EE 513, Linear Control Theory, 1988 – 2000.
EE 514, Advanced Topics in Automatic Controls, 1988 – present.
Created “Prof. MacCarley’s New Control Systems Web Site” http://amaccarl.ceng.calpoly.edu/ControlsSystems , web site for courses EE302, 342, 432, 472, 513 and 514. Continuously updated 1998-present.
Created "Alternative Energy Vehicles" Web Site http://amaccarl.ceng.calpoly.edu/AltFuels/ courseware and reference web site for course EE/BRAE 434.
Created "Solar Photovoltaic System Engineering", http://amaccarl.ceng.calpoly.edu/SolarEngineering/ , a public-access courseware and information web site on solar PV system technologies, science, design and permitting.

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Journal Publications and Book Chapters

"Development of a Sodium Borohydride Hydrogen Fuel Storage System for Vehicular Applications," Physica Status Solidi (A) Applied Research, pp. 315-321, 1976.
“Energy Primer”, contributed section “Hydrogen Energy”, published by Portola Institute, Santa Cruz, CA, 1976.
"Electronic Fuel Injection Techniques for Hydrogen Powered I.C. Engines,” International Journal of Hydrogen Energy, V5.2, Pergamon Press, Oxford, England, 1980. Co-author: W.D. VanVorst.
“Alternative Automotive Fuels Handbook,” Publication of National Science Foundation, under Grant No. ISP-8009001, administered by University of Denver Research Institute, 1981.
"State Feedback Control of Nonlinear Systems," International Journal of Control, V.43, No.5, 1986. Co-author: S. H. Zak.
"An Auxiliary Sensor Processor to Provide Real Time Fuel Delivery Feedback for a Microprocessor Based Diesel Engine Controller," chapter in SAE publication "Recent Advances in Electronic Diesel Engine Control" and 1987 SAE Transactions. Co-author: D. G. Meyer.
"A Study of Numeric Saturation Effects in Linear Digital Compensators," Electrical Engineering Technical Journal, Purdue University, School of Electrical Engineering, 1988. Co-author: D. G. Meyer (thesis advisor).
"An Indirect Sensing Technique for Closed-Loop Diesel Fuel Quantity Control," Society of Automotive Engineers Transactions, 1990. Co-authors: W. Clark and K. Nakae (students).
“Sample Rate Selection for Discrete Time Switching Controls”, IFAC Journal, International Assoc. for Mathematics and Computer Simulation and International Federation of Operational Research Societies, Pergamon Press, Inc. 1990
"Evaluation of Video Image Processing Systems for Traffic Detection," Transportation Research Record No. 1360, National Research Council, Wash. DC., 1992. Co-authors: S. Hockaday, D. Need, S. Taff.
"Video Cameras for Roadway Surveillance: Technology Review and Product Evaluation Results," Transportation Research Record No. 1410, National Research Council, Washington D.C., 1993. Co-authors: D. Need, R. Neiman (students).
"Video Technologies for Roadway Surveillance and Automated Detection," Society of Automated Engineers, Transactions, 1995. Co-author: L. Ponce (student).
“Advanced Imaging Techniques for Traffic Surveillance and Hazard Detection,” Intellimotion (journal), Vol 6 No.2, Partners for Advanced Transit and Highways, University of California, Berkeley, March 1997.
"Evaluation of Infrared and Millimeter-wave Imaging Technologies Applied to Traffic Management," Society of Automotive Engineers, Transactions, and chapter in SAE publication “Journal of Passenger Car Electronic and Electrical Systems”, 2001.
"Computer Vision Detection System for Network Model Validation," Transportation Research Record 01-3442, National Research Council, Washington D.C., 2001
“Technical Evaluation of the Anaheim Advanced Traffic Control System Field Operational Test,” Transportation Research Record, National Research Council, Washington D.C., March 2004. Co-authors: J. E. Moore II, S. P. Mattingly, M. G. McNally.
“Methods and Metrics of Evaluation of Evaluation of an Automated Real-Time Driver Warning System,” Transportation Research Record, No. 05-1423, National Research Council, Washington DC, January 2005.
“A Study of the Response of Highway Traffic to Dynamic Fog Warning and Speed Advisory Messages,” TRB 06-3086, Transportation Research Record, National Research Council, Washington, DC, Feb 2007.
“Automated Consensus-based Data Verification in the Caltrans Detector Testbed“ Transporatation Research Record, Vol. 1993, No. 1, pp. 124-130, 2007, National Research Council, Washington DC, January 2007.
“A Spy Under the Hood: Controlling Risk and Automotive EDR” Risk Management Magazine, Vol. 55, Issue: February 01, 2008. Co-author: Peter Thom

Conference Papers and Published Articles

"Development of a Sodium Borohydride Hydrogen Fuel Storage System for Vehicular Applications," American Society of Aeronautical Engineers Conference on Future Transportation Fuels, AIAA Proceedings, 1976.)
"Electronic Fuel Injection Techniques for Hydrogen Powered I.C. Engines," Proc. Second World Hydrogen Energy Conference, Zurich, Switzerland, International Association of Hydrogen Energy, Coral Gables, FL, 1978. Co-author: W.D. VanVorst.
"Hydrogen Fuel Applications for Urban Transit," Proc. AIAA Society and Aerospace Technology Workshop, Los Angeles, California, 1979.
"Development of a High Speed Injection Valve for Electronic Hydrogen Fuel Injection," Proc. Third World Hydrogen Energy Conference, Tokyo, Japan, International Association of Hydrogen Energy, Coral Gables, Florida, September, 1980.

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"A Study of Factors Influencing Thermally Induced Backfiring in Hydrogen Fueled Engines, and Methods for Backfire Control," Proc. Intersociety Energy Conversion Engineering Conference, American Society of Mechanical Engineers, Atlanta, GA, July, 1981.

"An Auxiliary Sensor Processor to Provide Real Time Fuel Delivery Feedback for a Microprocessor Based Diesel Engine Controller," SAE International Congress, Detroit, Mich., Feb. 1987. Co-author: D. G. Meyer.

"An Indirect Sensing Technique for Closed-Loop Diesel Fuel Quantity Control," Proc. Society of Automotive Engineers International Congress, Detroit, MI, 1990.

"Sample Rate Selection for Discrete Time Switching Controls", Proc. 11th Triennial World Congress of the the International Federation of Automatic Control, Tallinn, Estonia, USSR. International Assoc. for Mathematics and Computer Simulation and International Federation of Operational Research Societies, Pergamon Press, Aug. 13-17, 1990.

"Computer Image Processing Techniques for Highway Traffic Monitoring," Proc. AMSE Workshop on Computer Applications in Transportation, UC Berkeley, California, 1991. Co-author: E. Sullivan.

"Testing and Feasibility of VIPS for Traffic Detection," Proc. Second International Conference on Applications of Advanced Technologies in Transportation Engineering, Minneapolis, MN, American Society of Civil Engineers, August 18-21,1991.

"Dynamic Extension of Static Traffic Flow Models for Computer Simulation," Proc. IEEE Pittsburgh Simulation and Modeling Conference, Pittsburgh, PA, May 1992. Co-author: E. Sullivan

"Evaluation of Video Image Processing Systems for Traffic Detection," Transportation Research Board Annual Meeting, National Research Council, Washington, DC, 1991.

"Video Cameras for Roadway Surveillance: Technology Review and Product Evaluation Results," Transportation Research Board Annual Meeting, National Research Council, Washington, DC, 1992.

"Video Technologies for Roadway Surveillance and Automated Detection," Proc. Society of Automotive Engineers International Congress, Detroit, January, 1995.

"Economic Analysis of Electric Vehicle Configuration," 20th International Conference on Computers and Industrial Engineering, Kyongjo, Korea, 1996. Co-author: A. Seifoddini.

"Electric Vehicles – Promise and Reality", quoted and contributed several pages on the state of the art of battery electric vehicles to US DOE-sponsored Renewable Energy Institute web site (no longer avail) 1996.

"Assessment of an Automated Driver Warning Systems: CAWS", Presentation and published notes for California Department of Transportation, Stockton, California, June 14, 1998.

"EDSRS: Electronic Diesel Smoke Reduction System," Poster Session for the National Conference on Strategic Technologies, US Department of Energy, Office of Industrial Technology, Washington, DC., Jan 7, 1999.

"Infrared and Millimeter-wave Imaging for Traffic Surveillance and Detection," Proc. Transportation Research Board Annual Meeting, National Research Council, Washington D.C., January, 1999.

"Review and Assessment of Battery Interchange Methods for Electric Vehicles," Proc. SAE Future Car Conference 2000, Society of Automotive Engineers, Washington, DC. January 2000.

"Evaluation of Infrared and Millimeter-wave Imaging Technologies Applied to Traffic Management," Proc. SAE International Congress and Exhibition, Society of Automotive Engineers, Detroit, March 2000.

"Battery Interchange Alternatives to In-Vehicle Charging: Technical, Safety and Economic Considerations," Proc. FISITA 2000 World Automotive Congress, Seoul, Korea, June 2000.

"Lessons Learned from Irvine Integrated Freeway Ramp Metering/Arterial Adaptive Signal Control Field Operational Test," Transportation Research Board Annual Meeting, 01-3354, National Research Council, Washington D.C., Jan 2001. Co-authors: S.P. Mattingly (student), M.G. McNally, J.E. Moore

"Computer Vision Detection System for Network Model Validation," Transportation Research Board Annual Meeting, National Research Council, Washington, DC, 2000.

"Evaluation of Video Traffic Sensors for Intersection Signal Actuation: Methods and Metrics," Transportation Research Board Annual Meeting, No. 02-3920, National Research Council, Washington DC, January 2002.

"Technical Evaluation of the Anaheim Advanced Traffic Control System Field Operational Test," Transportation Research Board Annual Meeting, National Research Council, Washington, DC, March 2003. Co-authors: J. E. Moore II, S. P. Mattingly, M. G. McNally.

"Methods and Metrics of Evaluation of Evaluation of an Automated Real-Time Driver Warning System," Transportation Research Board Annual Meeting, National Research Council, Washington, DC, March 2004.

"A Study of the Response of Highway Traffic to Dynamic Fog Warning and Speed Advisory Messages," Proc. Transportation Research Board Annual Meeting, National Research Council, Washington DC, Jan 2006.

"A Data Fusion Approach to Automated Vehicle Detector Testing" IEEE Digital Signal Processing and DSP in Education Conference, Teton, WY, Sept 2006.

"Automated Consensus-based Data Verification in the Caltrans Detector Testbed," Proc. 2007 Transportation Research Board Annual Meeting, National Research Council, Washington DC, January 2006.

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“Global Warming: Problems and Solutions, An Engineering Approach”, Invited Published Presentation, Focus the Nation, National Academic Initiative for Global Awareness, Jan 31, 2008. Co-authors: Yarrow Nelson, Linda Vanasupa.

“Adaptive Automatic Ground Truth Generation for Testing of Vehicle Detectors”, 2009 Transportation Research Board Annual Meeting, National Research Council, Washington DC, January 2009.

“Teaching Sustainability in Cal Poly Electrical and Computer Engineering Programs”, Presentation at UC/CSU Conference on Sustainability in Curricula, UC Santa Barbara, June 22, 2009.

“Retention, Promotion and Tenure Policies in the College of Engineering, California Polytechnic State University, San Luis Obispo”, Televised presentation and proceedings publication, International Engineering Education Symposium, Seoul National Technical University, S. Korea, 2009. Co-author: M. L. Noori

“A Comparison of Real-time and Short-term Aggregated Metrics of Potential Accident Risk and Severity”, Published via Digital Commons, California Polytechnic State University, San Luis Obispo, http://digitalcommons.calpoly.edu August 2011.

“Traffic Ground Truth Estimation using a Multi-Sensor Consensus Filter”, accepted for publication and presentation at 2011 Transportation Research Board Annual Meeting, National Research Council, Washington DC, January 2012.

“Automotive Technologies for a Sustainable Future: Alternative Fuel Engineering Education with Emphasis on DME and Methanol as Transition Fuels,” Fifth International DME Conference, Ann Arbor MI, International DME Association, London, England, April 2013.

“The Cal Poly Rapid Battery Exchange Project: Automated Battery Exchange as an Alternative to Fast-Charging of Electric Vehicles.” IEEE Power and Energy Conference, California Polytechnic State University, San Luis Obispo, 2013.

Published Research Reports

"Development of a Multi-fuel Vehicle using Electronic Fuel Injection," Final Project Report, Regional Technology Advancement grant, US Department of Energy, Region 8, September, 1981.

“Acceleration of Automobiles Fueled by Natural Gas and Gasoline: A Comparison”, Report to the National Science Foundation, Published by Denver Urban Observatory and City of Denver, University of Denver Research Institute, 1982.

"Evaluation of Image Processing Technology for Application on Highway Operations," Final Report to the California Department of Transportation, TR 91-2, June 1991.

"Noise-Optimal Control of HEMT LNA's for Compensation of Temperature Deviations," The Telecommunications and Data Acquisition Progress Report, 42-109, NASA JPL/Caltech, May 1992.
Co-authors: J.J. Bautista, P.A. Willis.

"Evaluation of Closed-Circuit Television Technology for Application in Highway Operations," Final Project Report, Caltrans Contract 51J932, Caltrans Division of New Technology, San Luis Obispo, CA., 1992.

"Video Cameras for Roadway Surveillance: Technology Review and Product Evaluation Results," Report to the California Dept. of Transportation, Cal Poly Transportation Electronics Laboratory, 1992.

"Feasibility Study: Rapid Battery Interchange for Electric Vehicles," published study commissioned by Pacific Gas and Electric Co., Transportation Electronics Laboratory, Cal Poly EL/EE Dept. PR93-1, 1993.

"Rapid Battery Interchange Electric Transit Bus Demonstration, Phase I," final project report (published) to Pacific Gas and Electric Co. Transportation Electronics Laboratory, Cal Poly EE Dept. PR95-5, 1995.

"Design and Deployment Planning (Phase II), Rapid Battery Interchange Electric Transit Bus" Project report published by California Energy Commission. Cal Poly Transportation Electronics Laboratory PR96-1,1996.

"Design Considerations for Automated Electric Vehicle Battery Interchange," Transportation Electronics Laboratory, California Polytechnic State University, SLO, Report published by sponsor Pacific Gas and Electric Company, No. TEL4881a97, January 1997.

“City of Anaheim / Caltrans / FHWA Advanced Traffic Control System Field Operational Test Evaluation Task C, Video Detection System,” final project report, US Dept. of Transportation FHWA and Caltrans agreement No. SA 1272-18286, Partners for Advanced Transit and Highways, UC Berkeley, April 18, 1998.

“Video-based Vehicle Signature Analysis and Tracking, Phase 1: Verification of Concept and Preliminary Testing,” PATH publication based on final project report, Caltrans MOU 262, Cal Poly Transportation Electronics Laboratory Report No. TEL5881a97. Partners for Advanced Transit and Highways, University of California, Berkeley, January 10, 1998.

"Evaluation of Caltrans District 10 Automated Warning System, First Year Report," Cal Poly Transportation Electronics Laboratory Document TEL5881B98R, published by Partners for Advanced Transit and Highways (PATH), University of California, Berkeley, July 6, 1998.

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“Video-based Vehicle Signature Analysis and Tracking, Phase 2: Algorithm Development and Field Testing,” final project report, Partners for Advanced Transit and Highways, University of California, Berkeley, 1999.
"Evaluation of Caltrans District 10 Automated Warning System, Second Year Report," Cal Poly Transportation Electronics Laboratory Document TEL5881B99, Published by Partners for Advanced Transit and Highways (PATH), Univ of California, Berkeley, March 4, 1999.
"An Indirect Sensing Technique for Diesel Fuel Quantity Control," Final Report, U.S. Department of Energy, ERIP Project 583 Contract No. DE-FG01-94CE15583 May, 1999.
"Evaluation of SCOOT Performance in the Anaheim Advanced Traffic Control System Field Operational Test," Intellimotion, Published by Partners for Advanced Transit and Highways, University of California, Berkeley, November 1999. Co-authors: J. Moore, R. Jayakrishnan, M. McNally
"Evaluation of Infrared and Millimeter-wave Imaging Technologies," Project Final Report, Partners for Advanced Transportation and Highways, Feb. 2001.
"Documentation of the Irvine Integrated Corridor Freeway Ramp Metering and Arterial Adaptive Control Field Operational Test," California Partnership for Advanced Transit and Highways (PATH) Research Report UCB-ITS-PRR-2001-02, Report for MOU RTA 65V313-5, California Department of Transportation, Office of New Technology, Jan. 2001. Co-authors: M. McNally and J.E. Moore II.
“V2SAT Operators Manual“ published project deliverable under University of California Contract No. T01-65A0071-4122-L, California Department of Transportation, August 2002, with major addendum 2003.
“Calnet/SIBS Bill Analyzer Operators Manual”, deliverable under contract to Caltrans Division of Research and Innovation Contract, March 2004.
“Caltrans Detector Testbed / V2SAT Technical Report, 2004”, deliverable under University of California Purchase Order 0031 P 00 681648, California Department of Transportation, August 2004.
“Instrumentation and Evaluation of District 10 Caltrans Automated Warning System (CAWS)” Volumes 1-5, Document Nos. L-D10-FR-01 though -05, California Office of Traffic Safety (OTS) Grant RS0034, Caltrans Contract 51A0050, distributed by California Office of Traffic Safety, Sacramento, CA., Sept. 2005.
“Video Vehicle Detector Verification System Operators Manual,” Project deliverable to California Dept. of Transportation and Univ. of California, Berkeley under Task Order 5327, 2006, and supplement 2007.
“Caltrans Traffic Detection Plan”, Published report for the California Dept of Transportation under contract to Cambridge Systemetrics, Washington DC. 2008. Co-authors: Daniel Krechmer, Lawrence Klein.
“My Methanol Motorcycle”, web site on my self-designed multi-fuel motorcycle, 1998-present.
“What Your Car Knows About You that You Don’t Know – Data Retention in Automotive Electronics”. Invited presentation at over ten academic, professional and public forums and events, 2007-10.
“Electric Vehicle Safety”, online tutorial at http://evec.calpoly.edu/ElectricVehicleSafety.pdf , sponsored by Cal Poly Electric Vehicle Engineering Club, November 2011.
“Methanol Fuel Safety – a Practical Guide”, Available online through the Cal Poly State University Digital Commons, http://digitalcommons.calpoly.edu/cgi/viewcontent.cgi?article=1345&context=eeng_fac , 2013.

Unpublished Project Reports (list on request)

Author or co-author of over 150 unpublished research reports for DOE, NSF, DOT/ FHWA, Caltrans, California Office of Traffic Safety, Hughes Electronics, UC Berkeley, UC Irvine, Raytheon, Northrup Grumman, and other corporate sponsors,1979-present.

Proposals Submitted

Author, co-author or major contributor to over 110 research proposals to state, federal and industrial sponsors. Approximately 50% funding success rate. List on request from Cal Poly Sponsored Programs Office.

Journal, Conference and Proposal Reviewer (lists of individual titles on request)

California Partner for Advanced Transportation and Highways, annual reviewer, 1991-present.
Prentice Hall, Academic Publishing Division, contract textbook review, 1995-2000.
Society of Automotive Engineers World Congress and Transactions, annual reviewer, 1995-2003.
Society of Automotive Engineers, Transactions on Automotive Electronics, Associate Editor, 2009-present.
Transportation Research Board, National Academies. Reviewer for committees: Intelligent Transportation Systems, Visibility, Motorcycles and Vulnerable Vehicles, and User Information Systems, 1999-present.
IEEE Transaction on Intelligent Transportation Systems, annual reviewer, 2001-present.
Intelligent Transportation Journal, Pergamon Press, 1998, 99, 2003.
METRANS (Los Angeles Metropolitan Transit), annual reviewer, 2002, 04, 05.
Cal Poly C3RP proposal reviewer, 2005, 2006.

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US Patents

"Consensus-based Vehicle Detector Verification System." issued 2012, Assignee Cal Poly Corp.
"Geometric Tactile Information Delivery System for the Visually Impaired." issued 2013, Assignee Cal Poly Corp.

Other Relevant Qualifications

Caltrans-appointed evaluator for HOV-lane enforcement system manufactured by Vehicle Occupancy Detection Systems, (7/13-6/14)
Operator of Cal Poly Alternative Fuel Facility dispensing methanol, DME and SVO (2005-).
Certified Crash Data Recorder (CDR) Analyst, training by Vetronix Div of Robert Bosch (6/06).
Owner/builder of two battery-electric vehicles, used for transportation and education (1998-).
Commute daily with self-constructed methanol-fueled ultra-low-emission vehicle (1988-).
Designer/installer of 4 residential and one commercial solar PV and thermal systems (1988/14).

Expert Witness Experience

Expert witness under three-year contract to the California Department of Transportation. Forensic electronics in highway applications, 1999-2002.
Federal evaluator for FHWA Field Operational Test of Advanced Integrated Traffic Management System for City or Irvine, California, 1995-98.
Federal evaluator for FHWA Field Operational Test of Computer Vision based Intersection Traffic Detection System for City of Anaheim, California, 1995-98.
Evaluator/operator of Caltrans Detector Testbed, Irvine, CA. California Department of Transportation Division of Innovation and Research, for Evaluation of Intersection Video Traffic Detection Systems, 2004-2011.
Shackelford v United Stereo (expert for defendant). Fatality crash allegedly related to cruise control. Litigation against client dropped following my inspection report, 2005.
Savagian v Advantage Ford, et, al. (expert for defendant). Multiple fatality crash allegedly related to vehicle stability enhancement system. Settled, for defendant, 2006-07.
Backe v Mercendes of Nanuet, Massachusetts and Daimler Chrysler Corp. (expert for defendant). Single fatality crash allegedly related to engine management electronics failure. Litigation against client dropped following my inspection, 2007.
Misc. analysis, vehicle inspections and report preparation on multiple cases as subcontractor to Peter Thom and Associates, Orinda, CA., 1990-2008.
Lyon v. Hybrid Technologies Inc./EVii (expert for plaintiff). One of the first electric vehicle Lemon-Law cases litigated in California. Proved multiple defects and FMVSS violations by manufacturer. Settled in full following inspection report, 2009.
Romero v Stowasser et. al. (expert for defendant, engaged by Murchison Cumming LLP). Automotive electrical system failure and resultant vehicle disablement. Lawsuit dropped following my inspection report, 2010.
Combustion Controls Inc. v. Harley-Davidson Corp., Milwaukee, WI. (expert for defendant). Patent infringement case related to electronic fuel injection. Token settlement paid by defendant. 2010 - 2011.
HTI LLC and Network Fleet Inc v. DriveOK, Webtech Wireless Inc, Procon Inc., and Xirgo Technologies LLC. (expert for defendants). Patent infringement related to vehicular wireless technologies. Case settled prior to significant action, 2011.
Vehicle Occupancy Detection Co. USA / Laser Optical Engineering Ltd England. Independent evaluation of HOV lane enforcement detection system. Study/report completed. June 2012 – January 2014.
Zavalla v Randell Equipment & Danfoss Power Solutions (expert for defendant, engaged by Youngerman McNutt LLP), injury accident, electrical system in specialized vehicle. 2013-15, settled favorably 2015.
UUSI/Nartron v. Brose GmbH and Robert Bosch GmbH (expert for defendants, engaged by Kirkland Ellis LLP), patent infringement case related to automotive electric window closure safety technology. Our clients sought IPR invalidation of two patents. 2013-15. Case resolved July 2015 with all contested claims invalidated.
Campana v. Rally Auto Group and State of California (expert for defendants, engaged by Murchison Cumming LLP), automotive fatality case. Found tampered airbag and SRS. Trial testimony. Client exonerated on tampering charges, but settled due to failure to disclose vehicle history. 2013-2016.
Lee/Baldwin v. Volkswagen Group of America, Inc. et. al. (expert for defendants, engaged by Murchison Cumming LLP) – failure of airbag to deploy. Litigation dropped following my inspection report, Jan 2015.
Fountain v. Hyundai Motor Company (expert for plaintiff, engaged by Taylor and English LLP.) Wrongful death, alleged defects of Electronic Power Steering system. Litigation dropped upon my recommendation following vehicle inspection. April 2015-Dec 2016.

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Robinson v Taylor-Dunn (expert for defense, engaged by Meyers McConnell Reisz Siderman LLP.) Wrongful death allegations related to electric vehicle control systems. Case in progress, Nov. 2015-present.

Signal LLP v. Mazda Motor Corporation (expert for defendant, engaged by DLA Piper LLP). Patent infringement and IPR case related to RADAR-based Blind Spot Detection System. Summary judgement in client's favor following my deposition, January 2016.

Chen v Soibatian (expert for plaintiff, engaged by Schwabe, Williamson & Wyatt LLP). Representing inventor of popular "Hoverboard" in infringement suit against multiple Chinese manufacturers. Case currently under stay of proceedings pending ruling by the International Trade Commission, March 2016.

UUSI LLC v AM General LLC (expert for defendant, engaged by Ropes and Gray LLP). Patent infringement defense and IPR related to electronic diesel engine control and starting assist systems. Declarations and IPR petition filed. Awaiting depositions, June, 2016.

Signal LLP v. Fiat-Chrysler Automobiles (expert for defendant, engaged by Venable LLP). Patent infringement defense and IPR related to Radar anti-collision warning system and Passenger classification system for air-bag control. Declarations and IPR petition filed. Depositions completed. Awaiting trial. Sept 2016 - present.

Frac Shack v Atlas Oil. (expert for defense, engaged by Carlson, Gaskey & Olds, P.C.) Patent infringement and IPR related to automated refueling system for wellsite hydrofracturing equipment. IPR unsuccessful, infringement trial pending. January 2017 – present.

Doebeck v Cobra Engineering (for plaintiff, engaged by Frisenda, Quinton & Nicholson LLC). Patent infringement and IPR related to motorcycle fuel injection tuning technology. Infringing product evaluation and claim charts completed, declaration in progress. January 2017 – present.

Signal LLP v Denso (expert for defense, engaged by DLA Piper LLP). Infringement and IPR related to collision avoidance system technology. IPR declarations, deposition completed, awaiting PTO decision. May 2017.

Electrojet v Stihl GmBH (expert for defense, engaged by McGuire Woods, LLP). Infringement and IPR related to automotive electronic fuel injection IP. IPR declarations filed, deposition scheduled. Sept 2017 – present.

Avila v General Motors, (expert for plaintiff, engaged by Cobin Weiss, LLP.) Wrongful death, product defect - , transmission interlock. Complaint filing in progress, possible class action status, March 2018 – present.

Faraday Future, Inc. v. EVelozcity, Inc. (expert for plaintiff, engaged by Quinn Emanuel Urquhart & Sullivan, LLP.) Corporate theft of electric vehicle trade secrets. Case status indefinite following departure of CEO and financial issues with Faraday Future. April – September 2018.

Ivey v Volkswagen AG. (expert for plaintiff, engaged by Anapolweiss LLC). Product defect/liability SRS failure to deploy resulting in fatality. In discovery and deposition phases, June 2018 – present.

Fitzmaurice v Polaris Industries, Inc. (expert for plaintiff, engaged by Anapolweiss LLC). Product defect resulting in fatalities, involving vehicle control and active safety systems of off-road vehicle. Nov. 2018 – present.

Continental Automotive GmbH v. Atmel Corp. USA and Atmel Sari Switzerland, (expert for defense, engaged by Arnold & Porter Kaye Scholer LLP.) Alleged product defect, airbag control modules used by co-litigants Daimler, Volkswagen, Honda, Fiat Chrysler, Volvo, and Hyundai, causing failure to deploy or inadvertent deployment of airbags. January 2019 – present.

Oribital Engine Company Pty Ltd. v Robert Bosch LLC and Daimler AG, (expert for defendant Robert Bosch). IPR and infringement defense against asserted patent related to electronic throttle control. Case has been in progress since 2016. My engagement in August 2019 followed a previously unsuccessful IPR petition. I will support invalidation case in Federal Court.

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

US006006717A

United States Patent [19]

Suzuki et al.

[11] **Patent Number: 6,006,717**

[45] **Date of Patent: Dec. 28, 1999**

[54] **DIRECT-INJECTION SPARK-IGNITION TYPE ENGINE CONTROL APPARATUS**

[75] Inventors: **Keisuke Suzuki**, Kanagawa; **Yuki Nakajima**; **Nobutaka Takahashi**, both of Yokohama, all of Japan

[73] Assignee: **Nissan Motor Co., Ltd.**, Yokohama, Japan

[21] Appl. No.: **09/104,359**

[22] Filed: **Jun. 25, 1998**

[30] **Foreign Application Priority Data**

Jun. 25, 1997 [JP] Japan 9-168419

[51] **Int. Cl.**[6] **F02B 17/00**; F02D 43/04

[52] **U.S. Cl.** **123/295**; 123/406.45; 123/430

[58] **Field of Search** 123/295, 299, 123/300, 305, 406.45, 430

[56] **References Cited**

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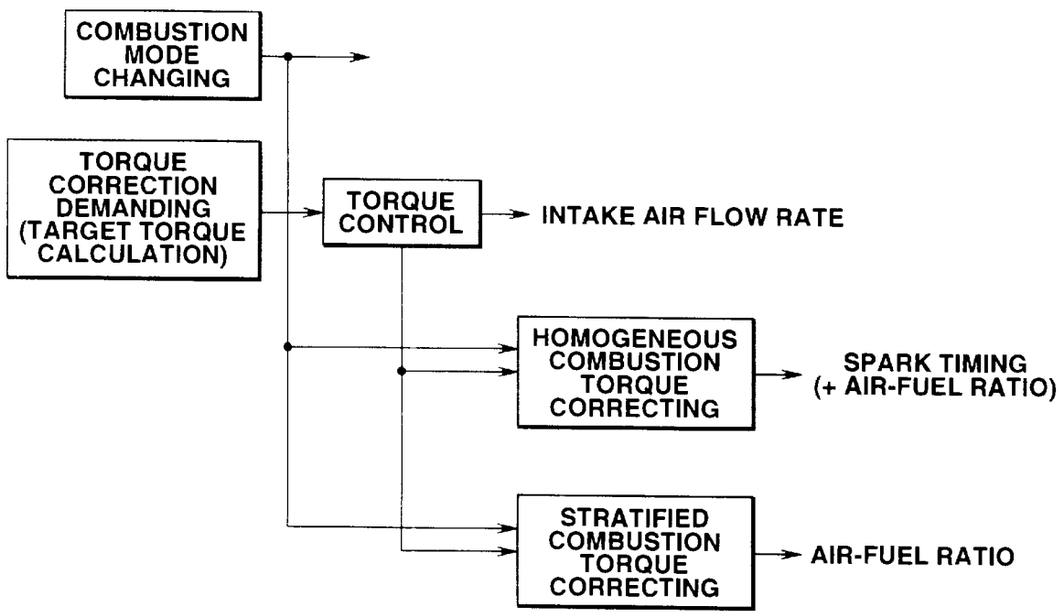
Nissan Direct–Injection Engine, NEODi–Gasoline Engine Diesel Engine.

Primary Examiner—Tony M. Argenbright
Attorney, Agent, or Firm—Foley & Lardner

[57] **ABSTRACT**

The invention provides torque correction during both homogeneous combustion and stratified combustion. Torque correction is made in response to a torque correction demand (produced when, for example, a gear shift is effected, the air conditioner is turned on, or fuel cut recovery is effected) by correcting the spark timing (or the spark timing and air-fuel ratio) during homogeneous combustion and by correcting the air-fuel ratio during stratified combustion.

10 Claims, 25 Drawing Sheets



VW EX1005
U.S. Patent No. 6,581,565

PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

FIG.1(A)

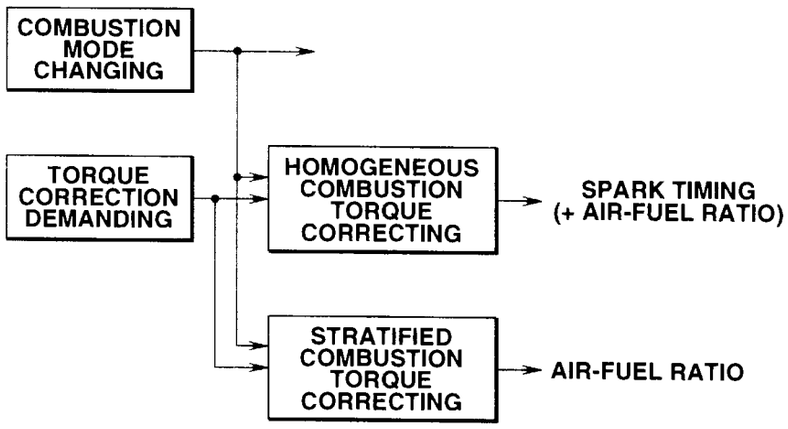
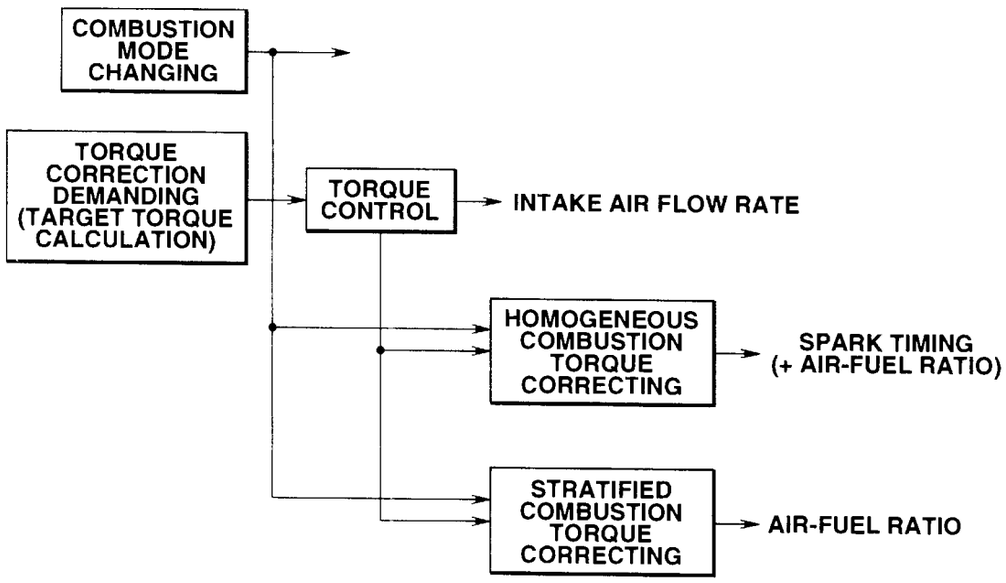


FIG.1(B)



PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

FIG.2

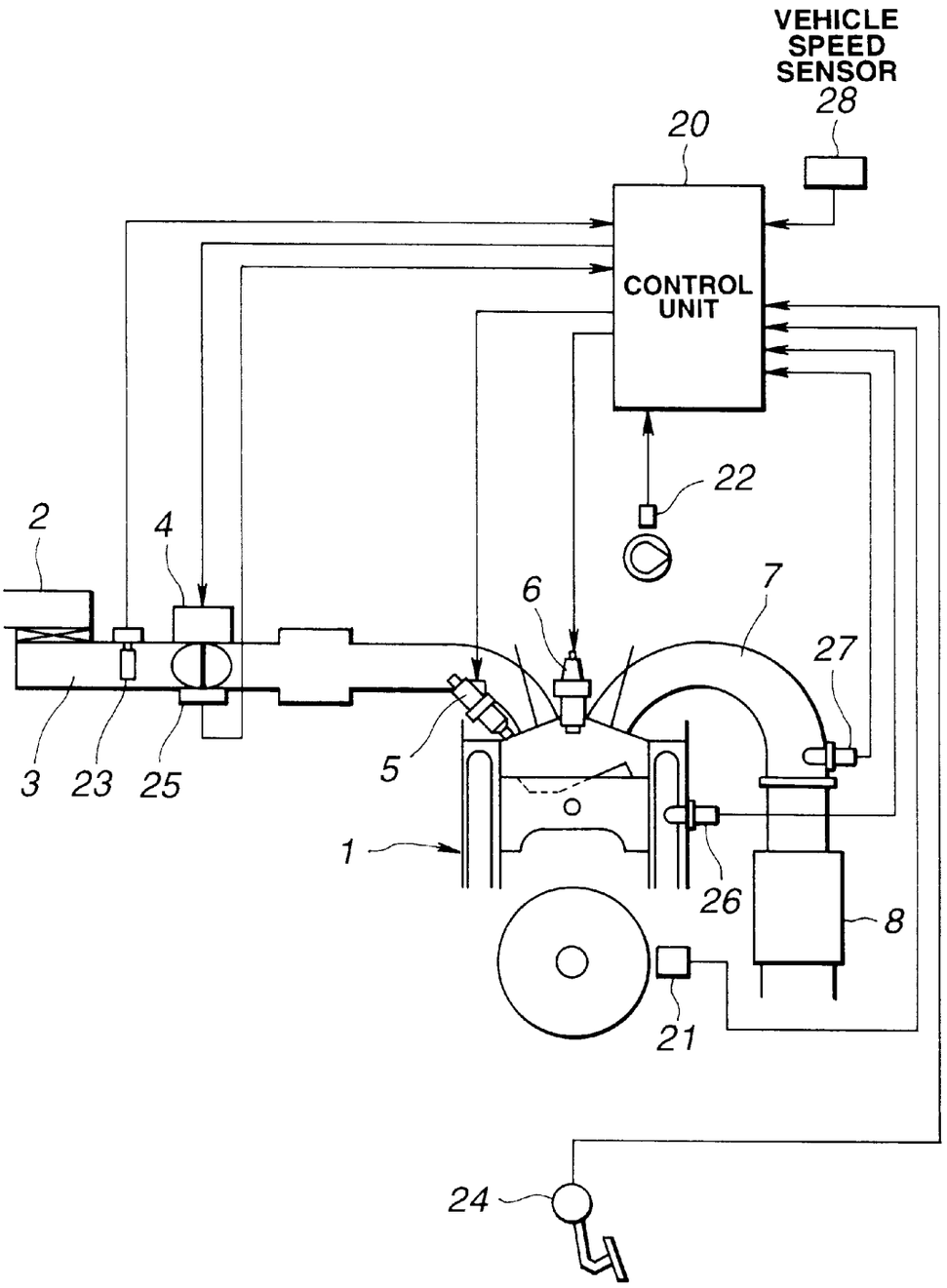
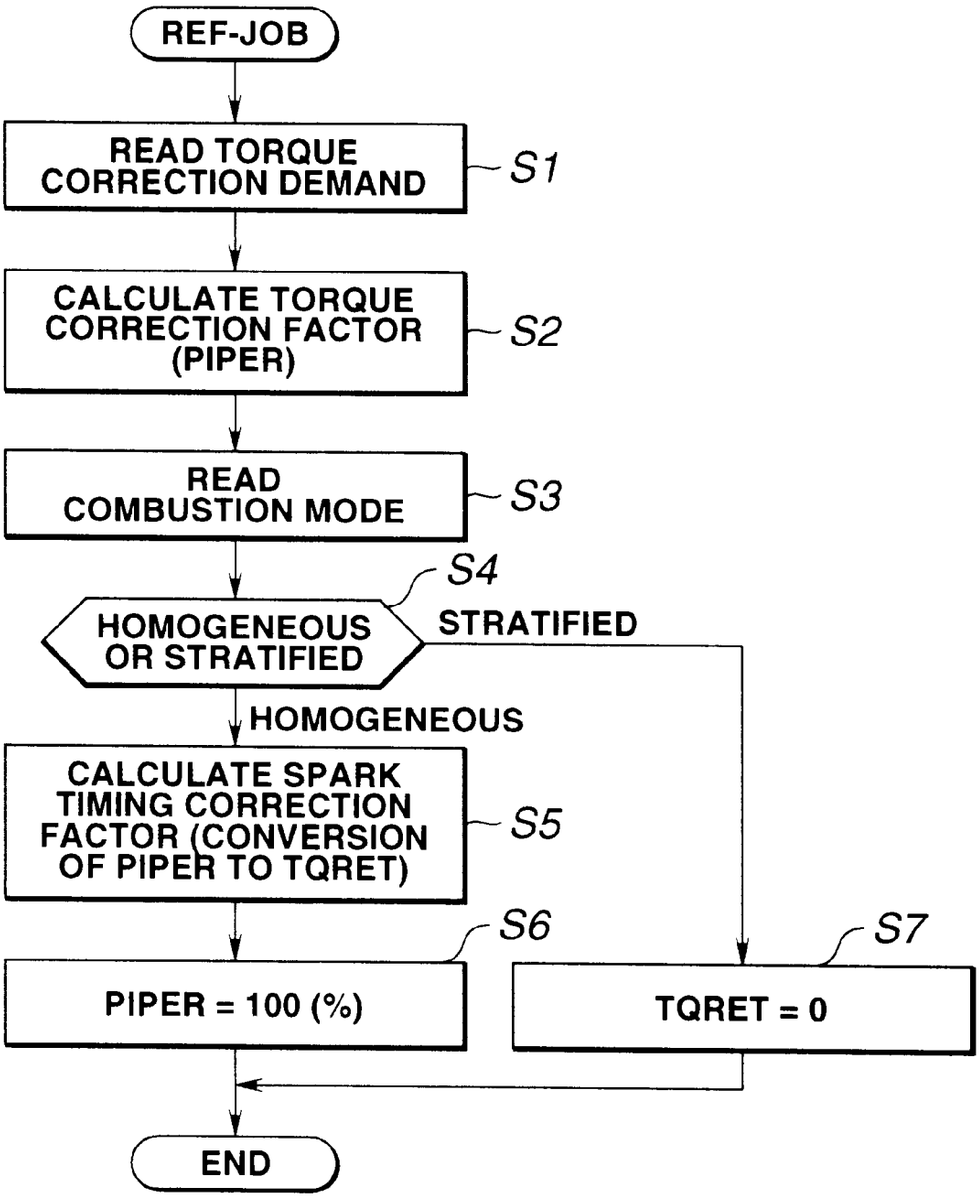
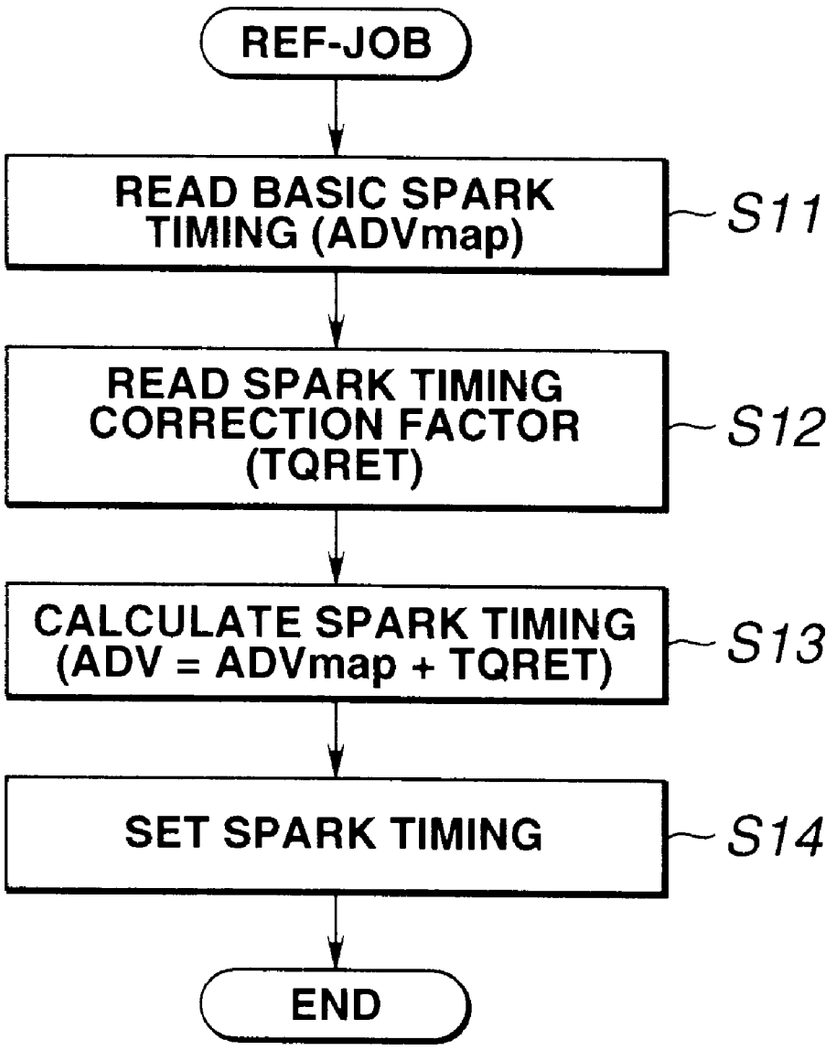

VEHICLE
SPEED
SENSOR
28
20
CONTROL
UNIT
22
2
4
6
7
27
3
23
25
5
1
26
8
21
24

FIG.3



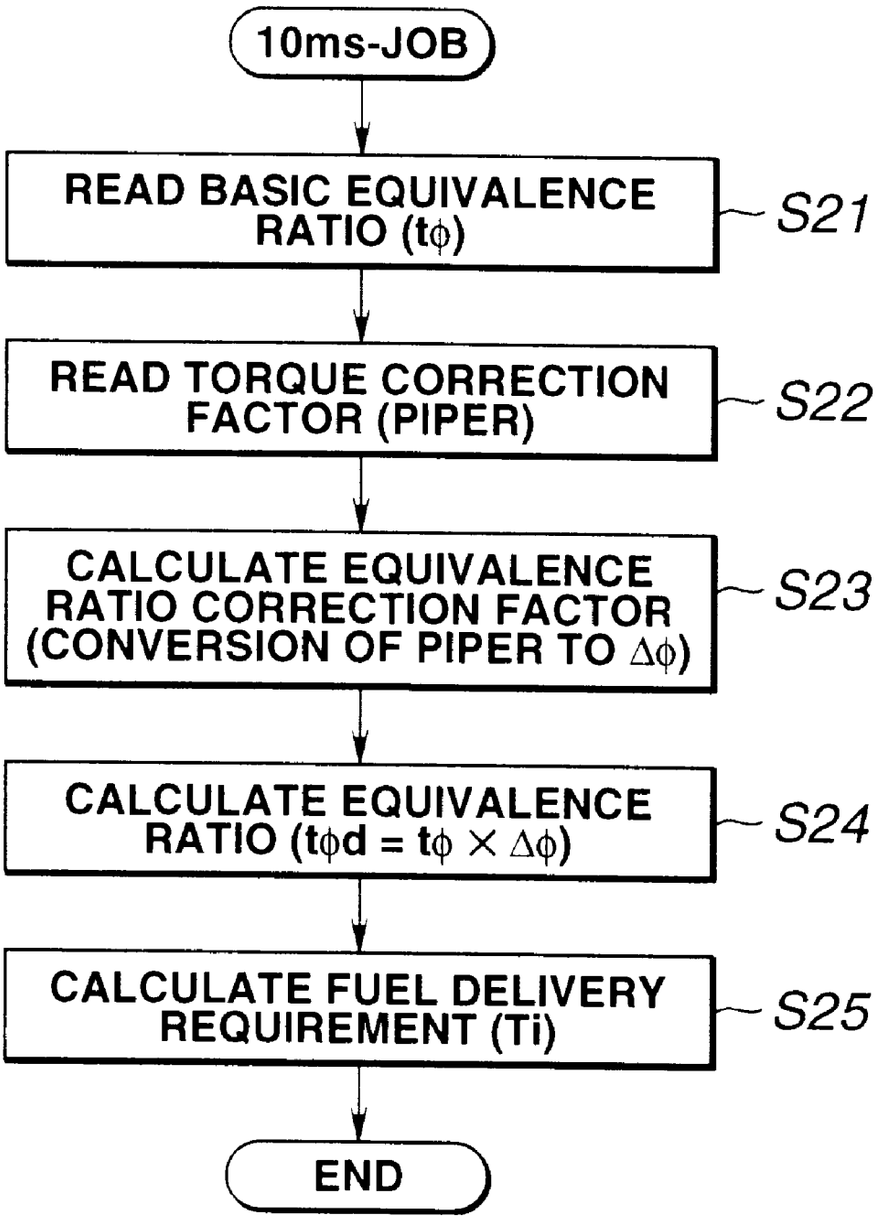
PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

FIG.4



PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

FIG.5



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US PATENT NO. 6,581,565

FIG.6

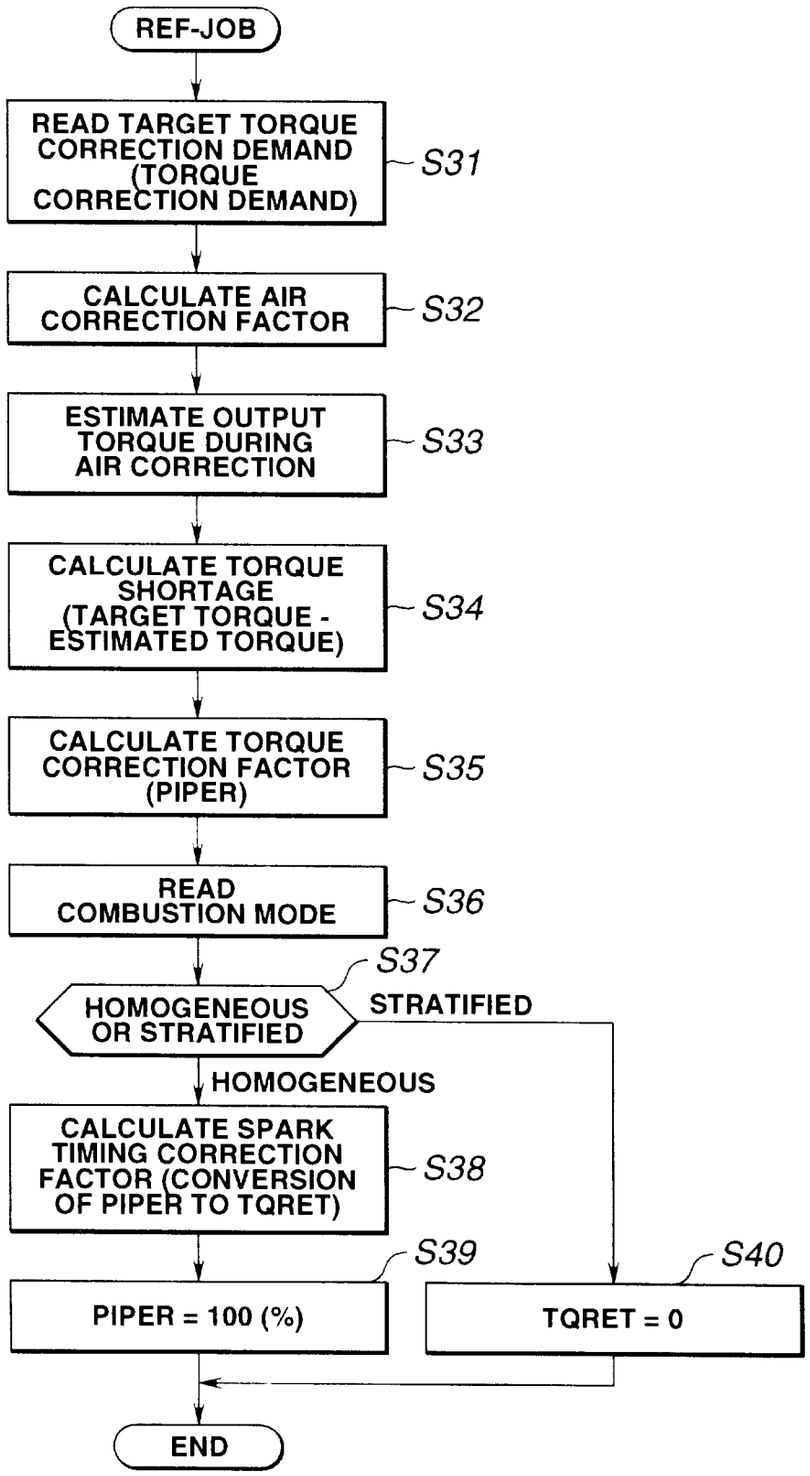

REF-JOB
READ TARGET TORQUE CORRECTION DEMAND (TORQUE CORRECTION DEMAND)
S31
CALCULATE AIR CORRECTION FACTOR
S32
ESTIMATE OUTPUT TORQUE DURING AIR CORRECTION
S33
CALCULATE TORQUE SHORTAGE (TARGET TORQUE - ESTIMATED TORQUE)
S34
CALCULATE TORQUE CORRECTION FACTOR (PIPER)
S35
READ COMBUSTION MODE
S36
S37
HOMOGENEOUS OR STRATIFIED
STRATIFIED
HOMOGENEOUS
CALCULATE SPARK TIMING CORRECTION FACTOR (CONVERSION OF PIPER TO TQRET)
S38
S39
PIPER = 100 (%)
S40
TQRET = 0
END

FIG.7

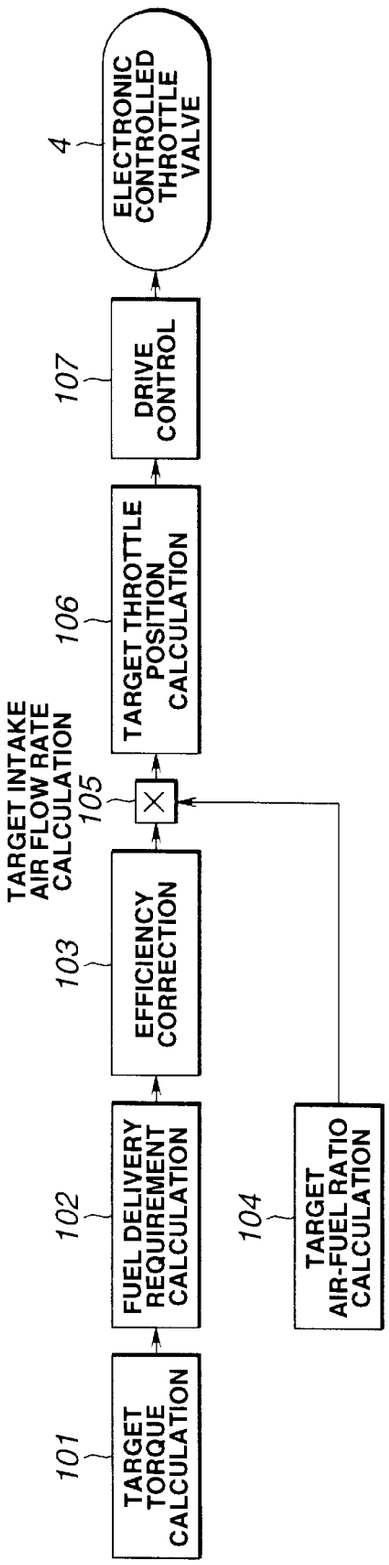

101
TARGET TORQUE CALCULATION
102
FUEL DELIVERY REQUIREMENT CALCULATION
103
EFFICIENCY CORRECTION
104
TARGET AIR-FUEL RATIO CALCULATION
105
TARGET INTAKE AIR FLOW RATE CALCULATION
106
TARGET THROTTLE POSITION CALCULATION
107
DRIVE CONTROL
4
ELECTRONIC CONTROLLED THROTTLE VALVE

FIG.8

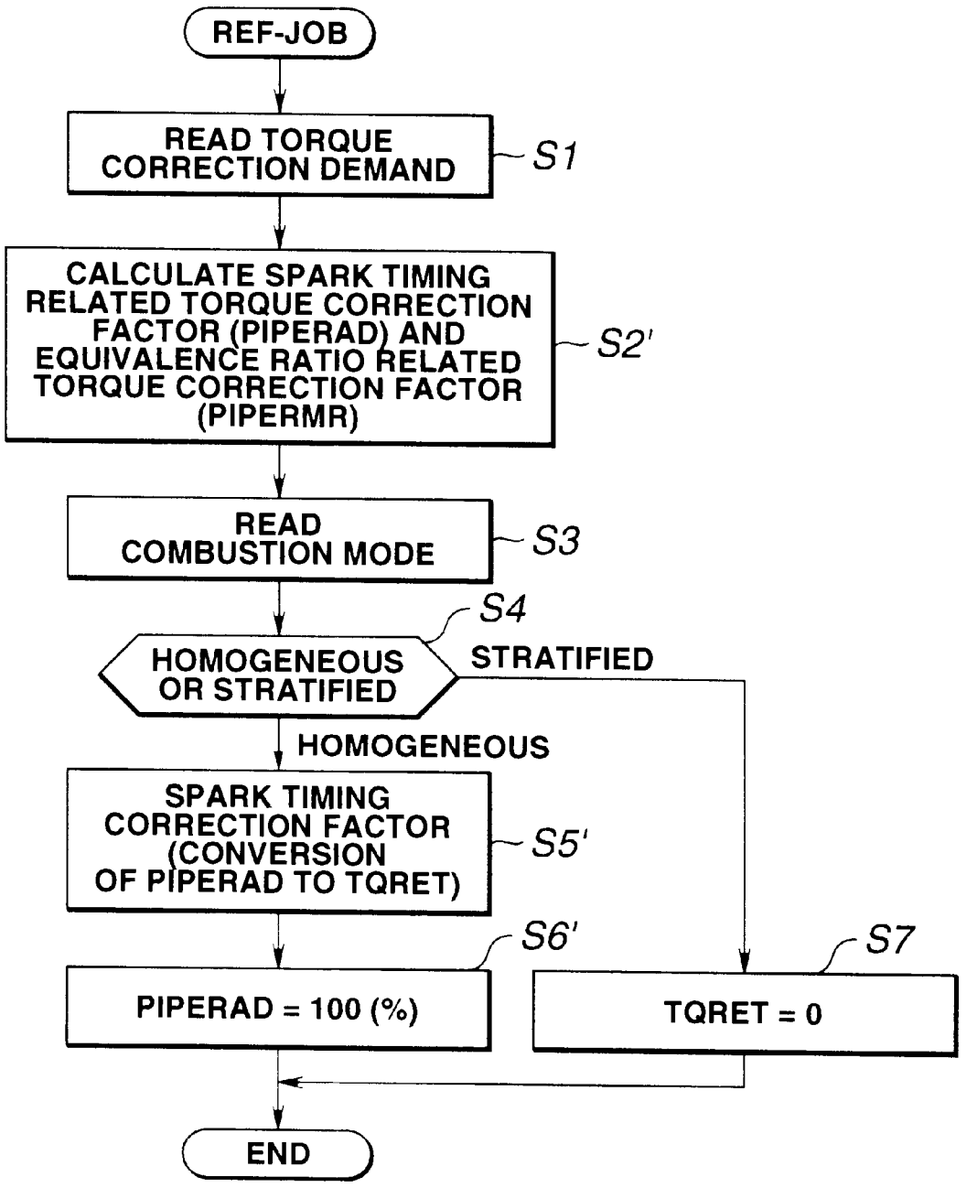
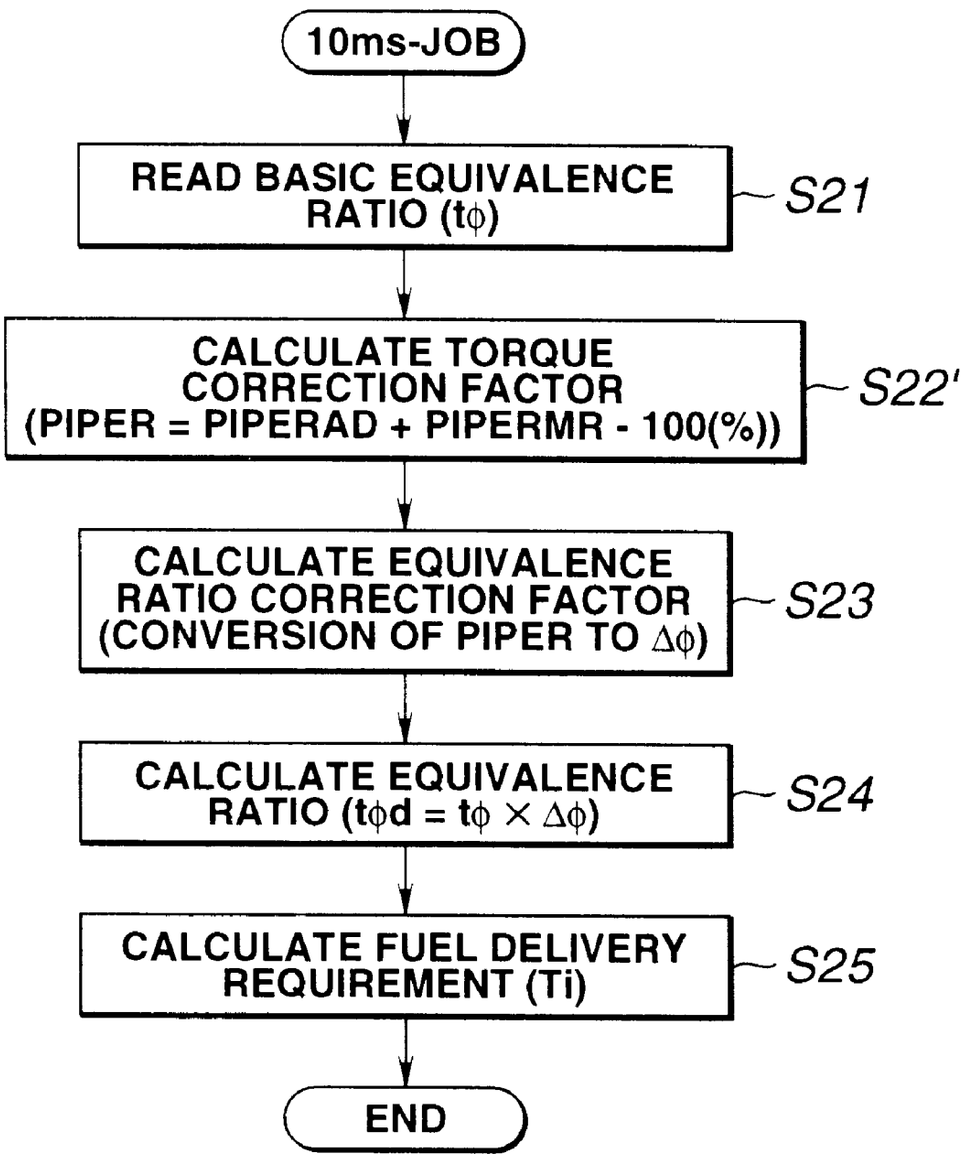

REF-JOB
READ TORQUE CORRECTION DEMAND
S1
CALCULATE SPARK TIMING RELATED TORQUE CORRECTION FACTOR (PIPERAD) AND EQUIVALENCE RATIO RELATED TORQUE CORRECTION FACTOR (PIPERMR)
S2'
READ COMBUSTION MODE
S3
S4
HOMOGENEOUS OR STRATIFIED
STRATIFIED
HOMOGENEOUS
SPARK TIMING CORRECTION FACTOR (CONVERSION OF PIPERAD TO TQRET)
S5'
S6'
S7
PIPERAD = 100 (%)
TQRET = 0
END

FIG.9



PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

FIG.10

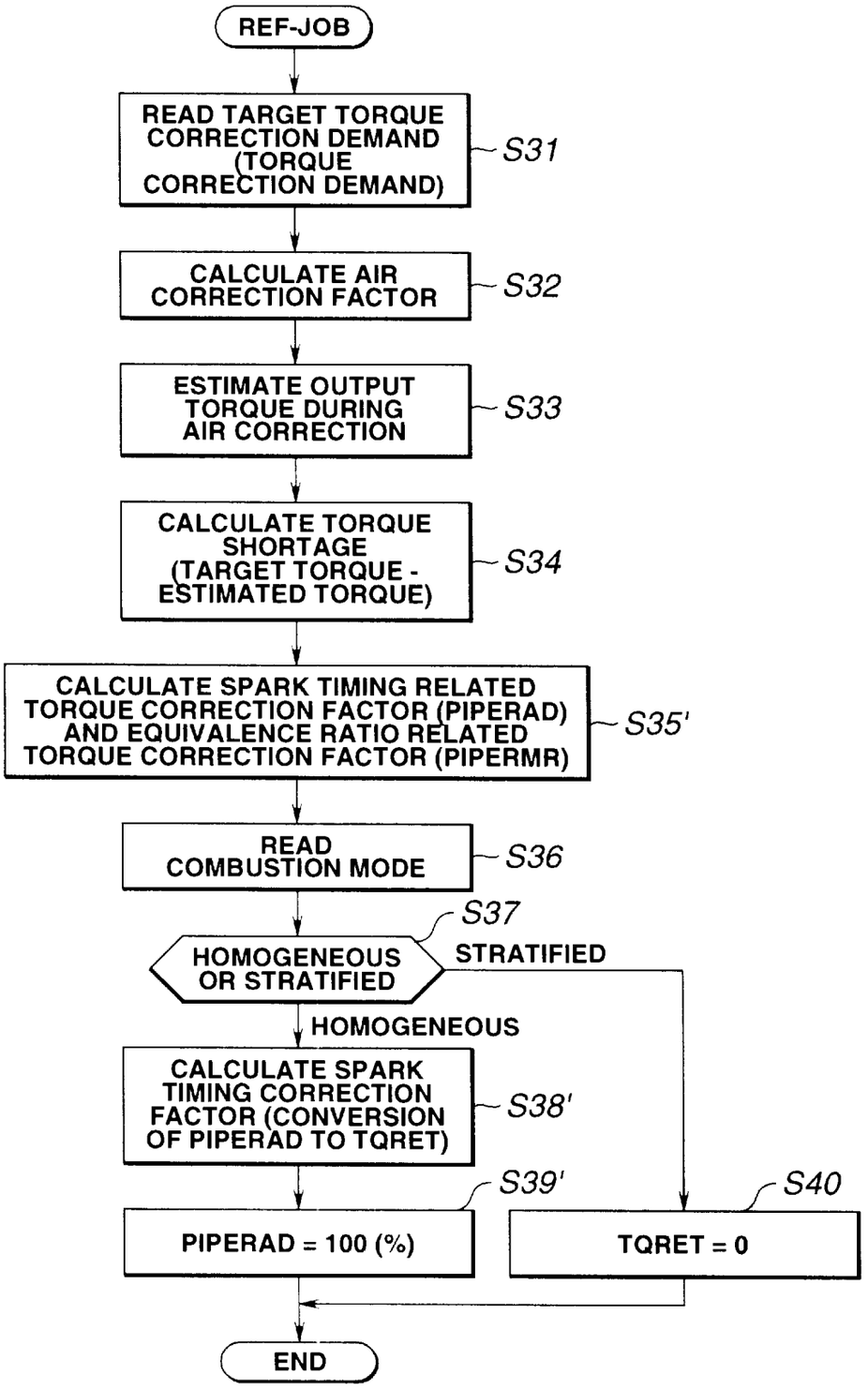
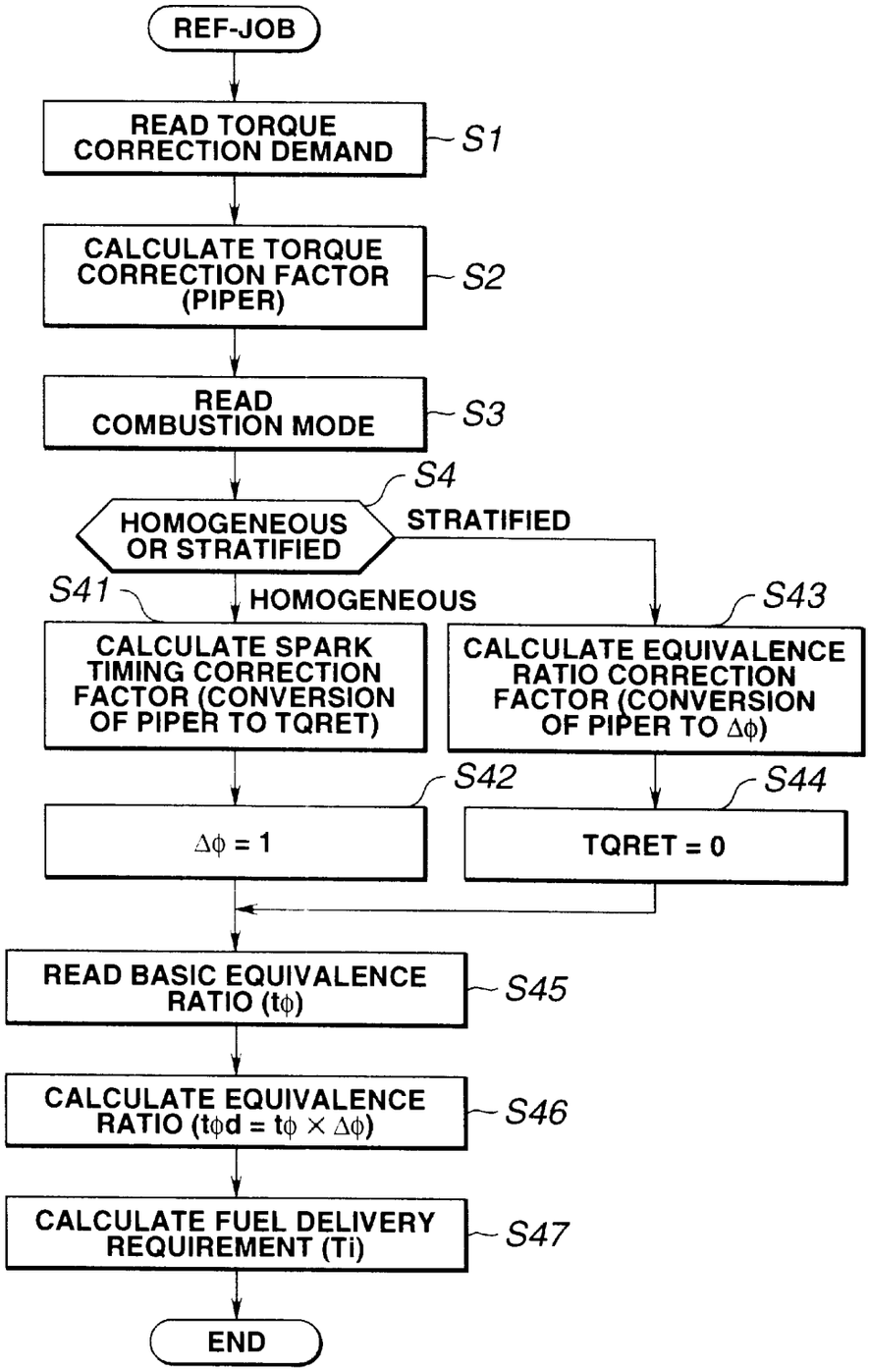

REF-JOB
READ TARGET TORQUE CORRECTION DEMAND (TORQUE CORRECTION DEMAND)
S31
CALCULATE AIR CORRECTION FACTOR
S32
ESTIMATE OUTPUT TORQUE DURING AIR CORRECTION
S33
CALCULATE TORQUE SHORTAGE (TARGET TORQUE - ESTIMATED TORQUE)
S34
CALCULATE SPARK TIMING RELATED TORQUE CORRECTION FACTOR (PIPERAD) AND EQUIVALENCE RATIO RELATED TORQUE CORRECTION FACTOR (PIPERMR)
S35'
READ COMBUSTION MODE
S36
S37
HOMOGENEOUS OR STRATIFIED
STRATIFIED
HOMOGENEOUS
CALCULATE SPARK TIMING CORRECTION FACTOR (CONVERSION OF PIPERAD TO TQRET)
S38'
S39'
S40
PIPERAD = 100 (%)
TQRET = 0
END

FIG.11



PETITIONER'S EXHIBIT 1002
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FIG.12

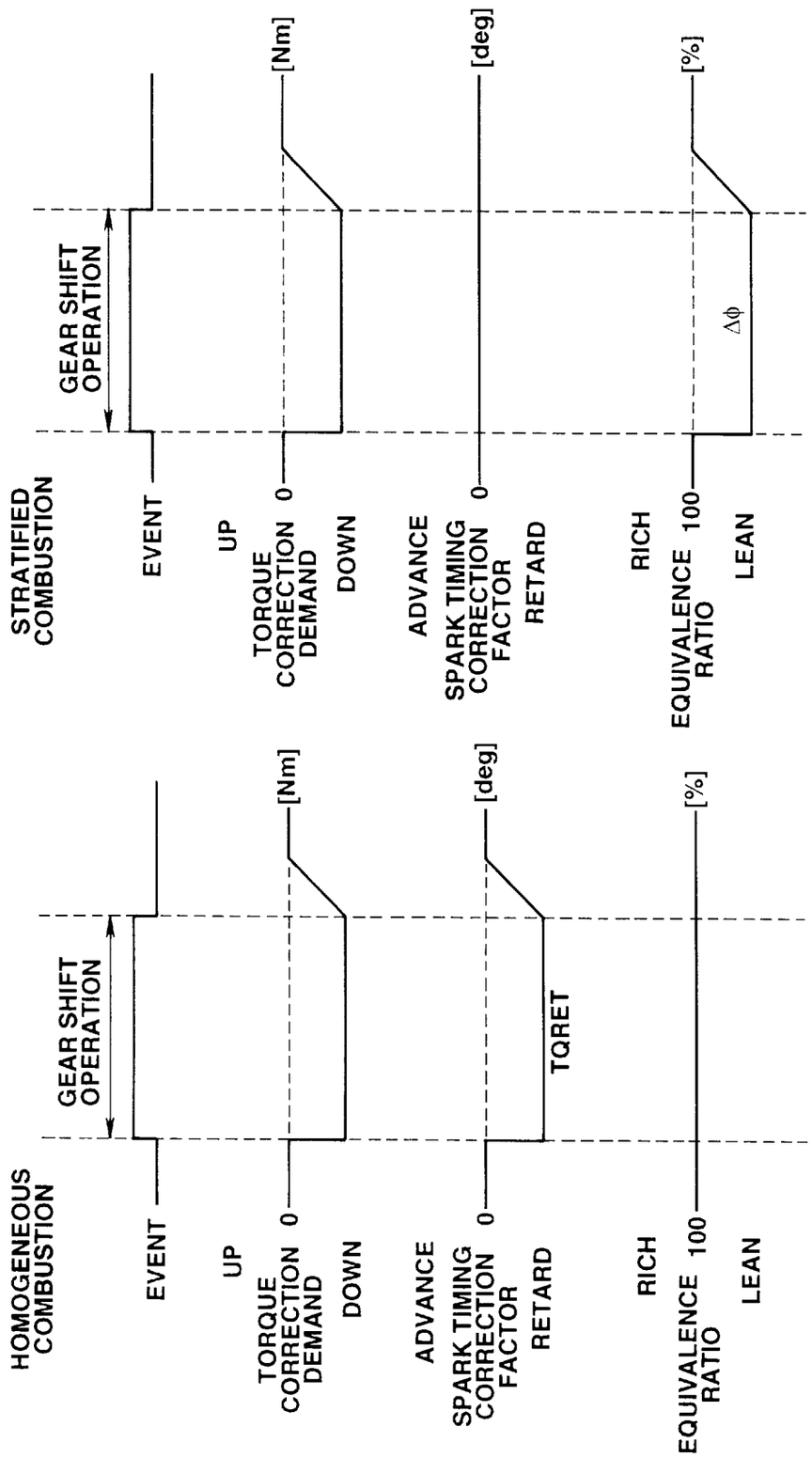

STRATIFIED COMBUSTION
HOMOGENEOUS COMBUSTION
EVENT
GEAR SHIFT OPERATION
TORQUE CORRECTION DEMAND
UP
DOWN
0
[Nm]
SPARK TIMING CORRECTION FACTOR
ADVANCE
RETARD
[deg]
TQRET
EQUIVALENCE RATIO
RICH
LEAN
100
[%]
Δφ

FIG.13

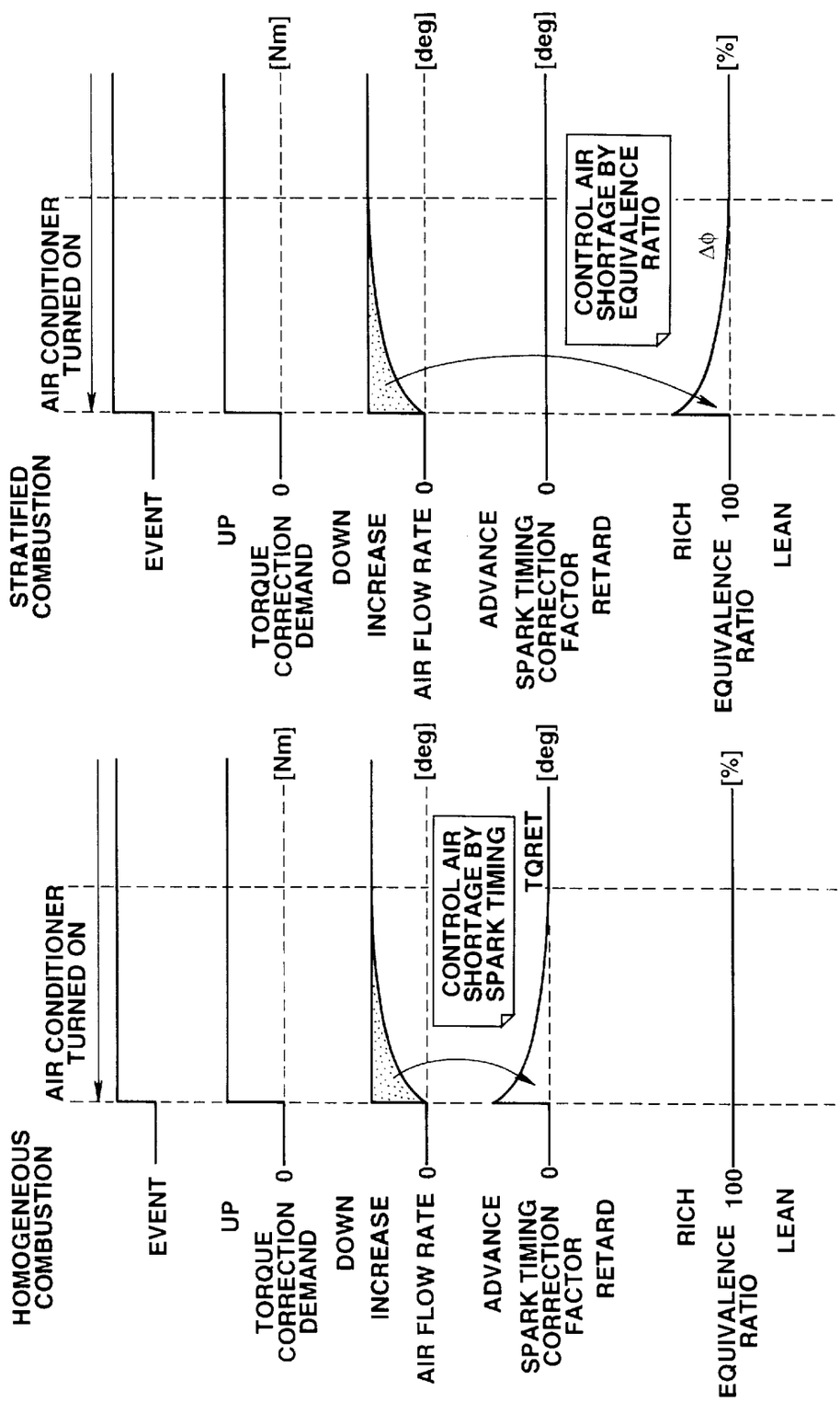

STRATIFIED COMBUSTION
AIR CONDITIONER TURNED ON
EVENT
UP
TORQUE CORRECTION DEMAND
0
[Nm]
DOWN
INCREASE
AIR FLOW RATE
0
[deg]
ADVANCE
SPARK TIMING CORRECTION FACTOR
0
[deg]
RETARD
CONTROL AIR SHORTAGE BY EQUIVALENCE RATIO
Δφ
RICH
EQUIVALENCE RATIO
100
[%]
LEAN
HOMOGENEOUS COMBUSTION
AIR CONDITIONER TURNED ON
EVENT
UP
TORQUE CORRECTION DEMAND
0
[Nm]
DOWN
INCREASE
AIR FLOW RATE
0
[deg]
CONTROL AIR SHORTAGE BY SPARK TIMING
ADVANCE
SPARK TIMING CORRECTION FACTOR
TQRET
0
[deg]
RETARD
RICH
EQUIVALENCE RATIO
100
[%]
LEAN

FIG.14

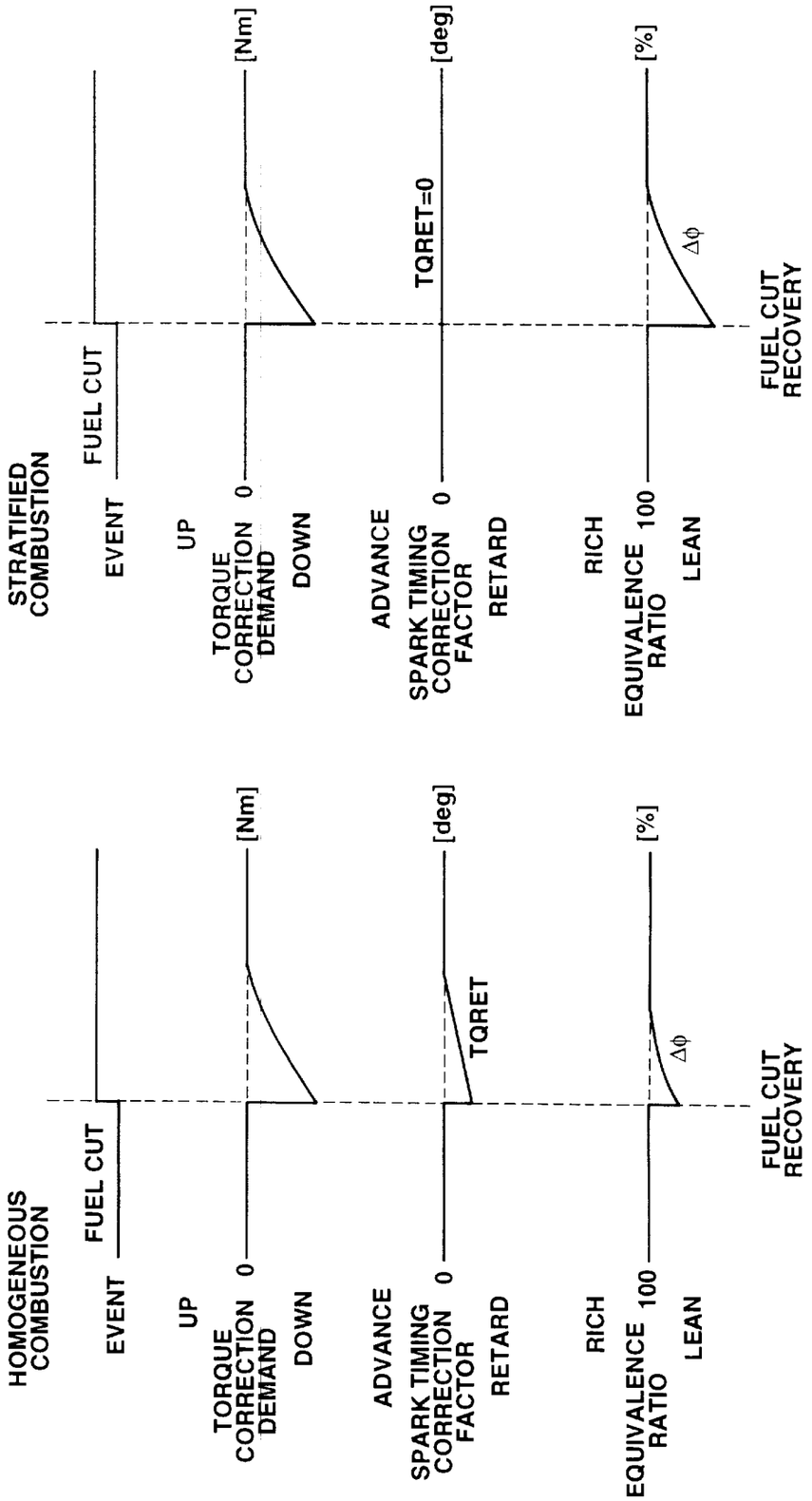

STRATIFIED COMBUSTION
HOMOGENEOUS COMBUSTION
EVENT
FUEL CUT
FUEL CUT RECOVERY
TORQUE CORRECTION DEMAND
UP
DOWN
0
[Nm]
SPARK TIMING CORRECTION FACTOR
ADVANCE
RETARD
TQRET=0
TQRET
[deg]
EQUIVALENCE RATIO
RICH
LEAN
100
[%]
Δφ

FIG.15

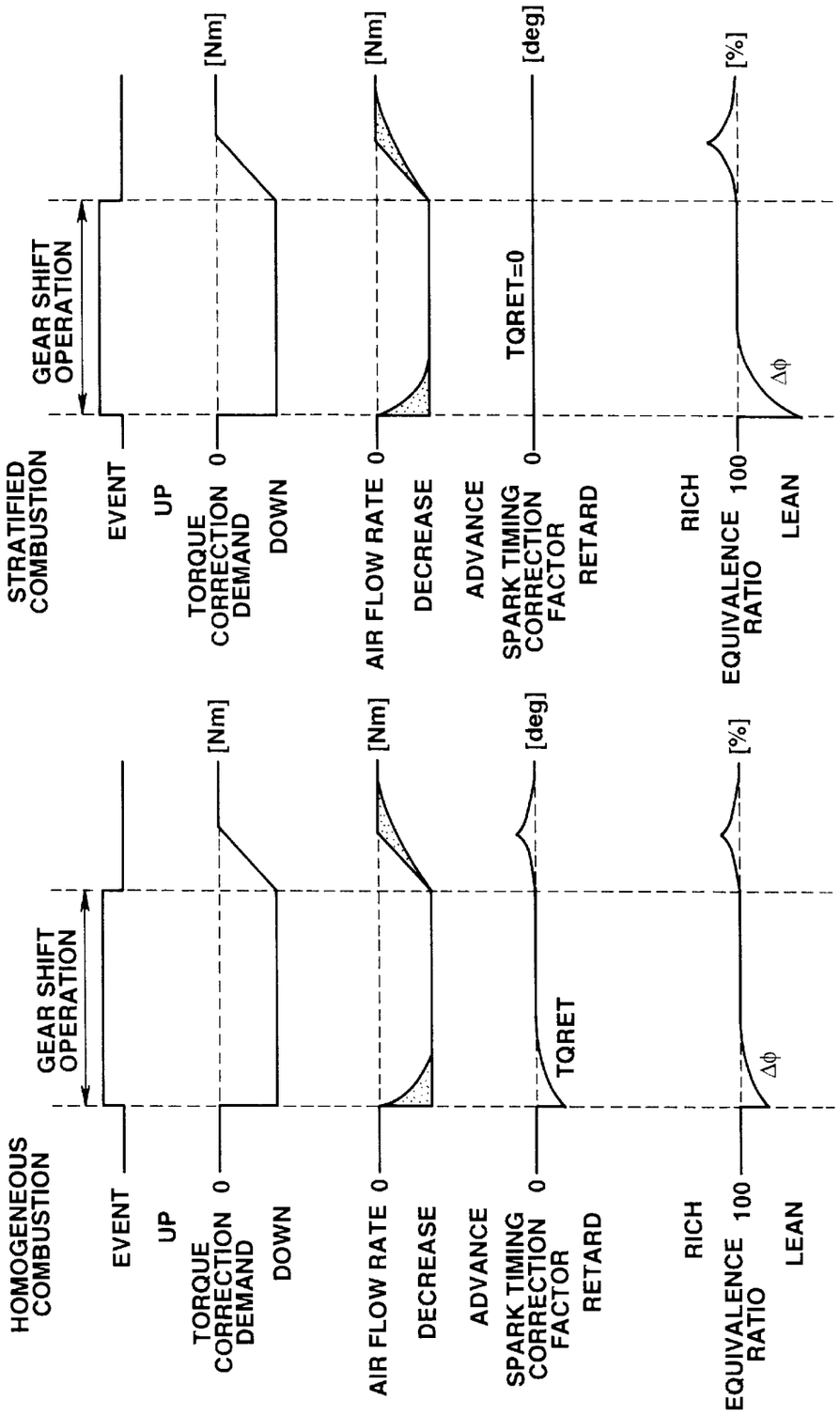

STRATIFIED COMBUSTION
HOMOGENEOUS COMBUSTION
GEAR SHIFT OPERATION
EVENT
TORQUE CORRECTION DEMAND
UP
DOWN
0
[Nm]
AIR FLOW RATE
DECREASE
ADVANCE
SPARK TIMING CORRECTION FACTOR
RETARD
TQRET=0
TQRET
[deg]
EQUIVALENCE RATIO
RICH
LEAN
100
[%]
Δφ

FIG.16

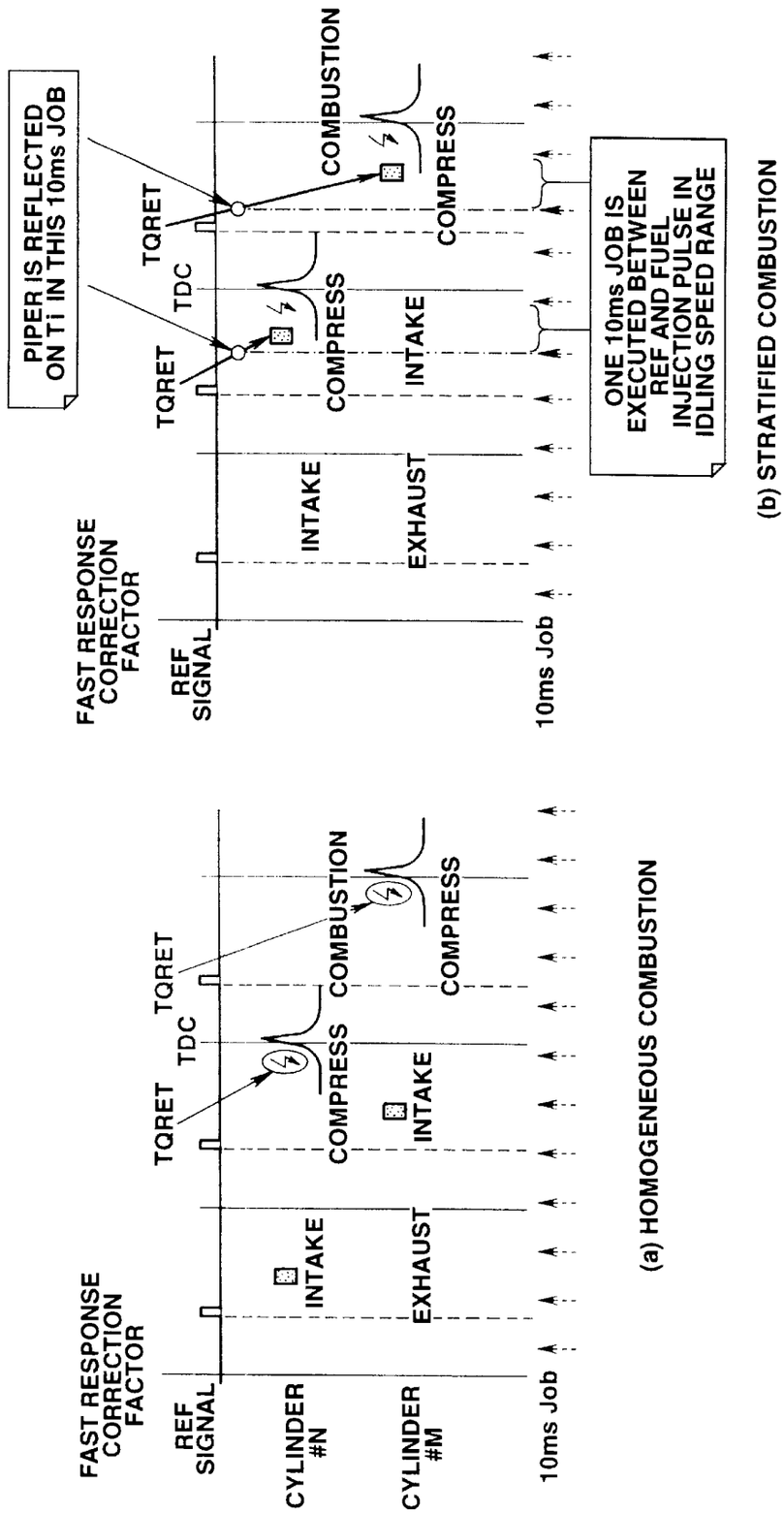

FAST RESPONSE CORRECTION FACTOR
REF SIGNAL
CYLINDER #N
CYLINDER #M
10ms Job
INTAKE
EXHAUST
COMPRESS
COMBUSTION
TDC
TQRET
(a) HOMOGENEOUS COMBUSTION
PIPER IS REFLECTED ON Ti IN THIS 10ms JOB
ONE 10ms JOB IS EXECUTED BETWEEN REF AND FUEL INJECTION PULSE IN IDLING SPEED RANGE
(b) STRATIFIED COMBUSTION
IDLING SPEED RANGE

FIG.17

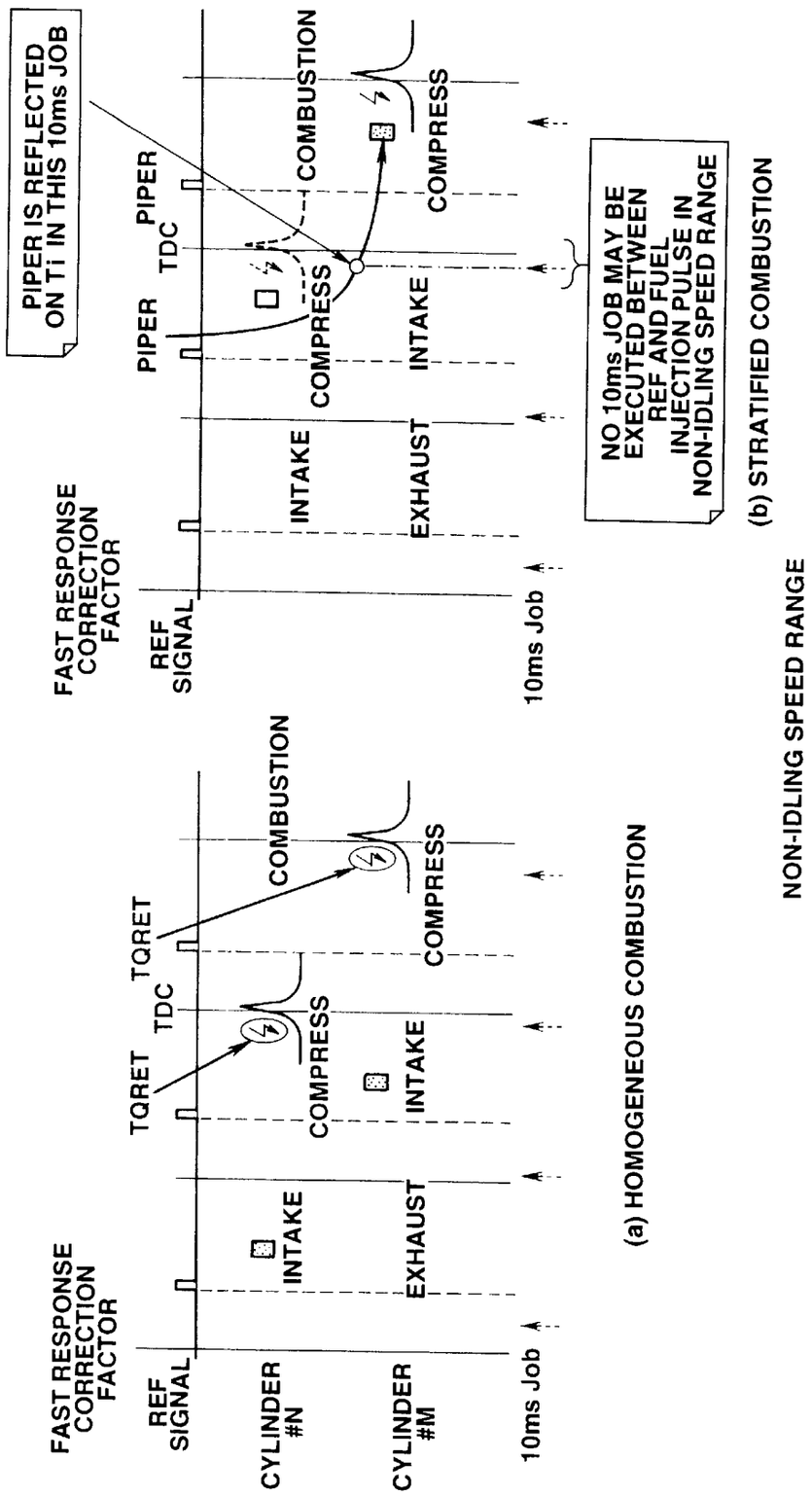

FAST RESPONSE CORRECTION FACTOR
REF SIGNAL
CYLINDER #N
CYLINDER #M
INTAKE
EXHAUST
TQRET
TDC
COMPRESS
COMBUSTION
10ms Job
(a) HOMOGENEOUS COMBUSTION
PIPER IS REFLECTED ON Ti IN THIS 10ms JOB
PIPER
NO 10ms JOB MAY BE EXECUTED BETWEEN REF AND FUEL INJECTION PULSE IN NON-IDLING SPEED RANGE
(b) STRATIFIED COMBUSTION
NON-IDLING SPEED RANGE

FIG.18

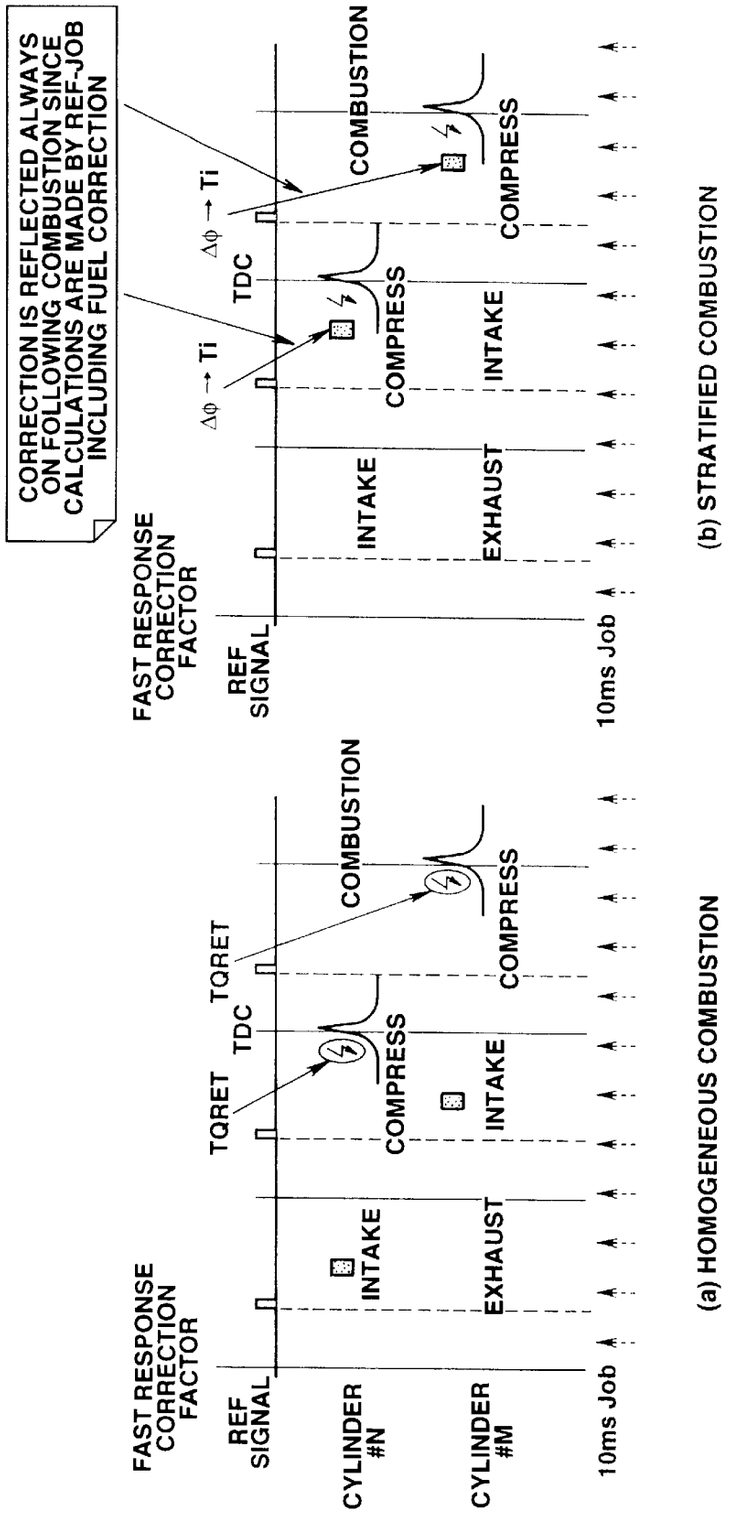

CORRECTION IS REFLECTED ALWAYS ON FOLLOWING COMBUSTION SINCE CALCULATIONS ARE MADE BY REF-JOB INCLUDING FUEL CORRECTION
FAST RESPONSE CORRECTION FACTOR
REF SIGNAL
CYLINDER #N
CYLINDER #M
INTAKE
EXHAUST
COMPRESS
COMBUSTION
TDC
TQRET
Δφ → Ti
10ms Job
(a) HOMOGENEOUS COMBUSTION
(b) STRATIFIED COMBUSTION

FIG.19

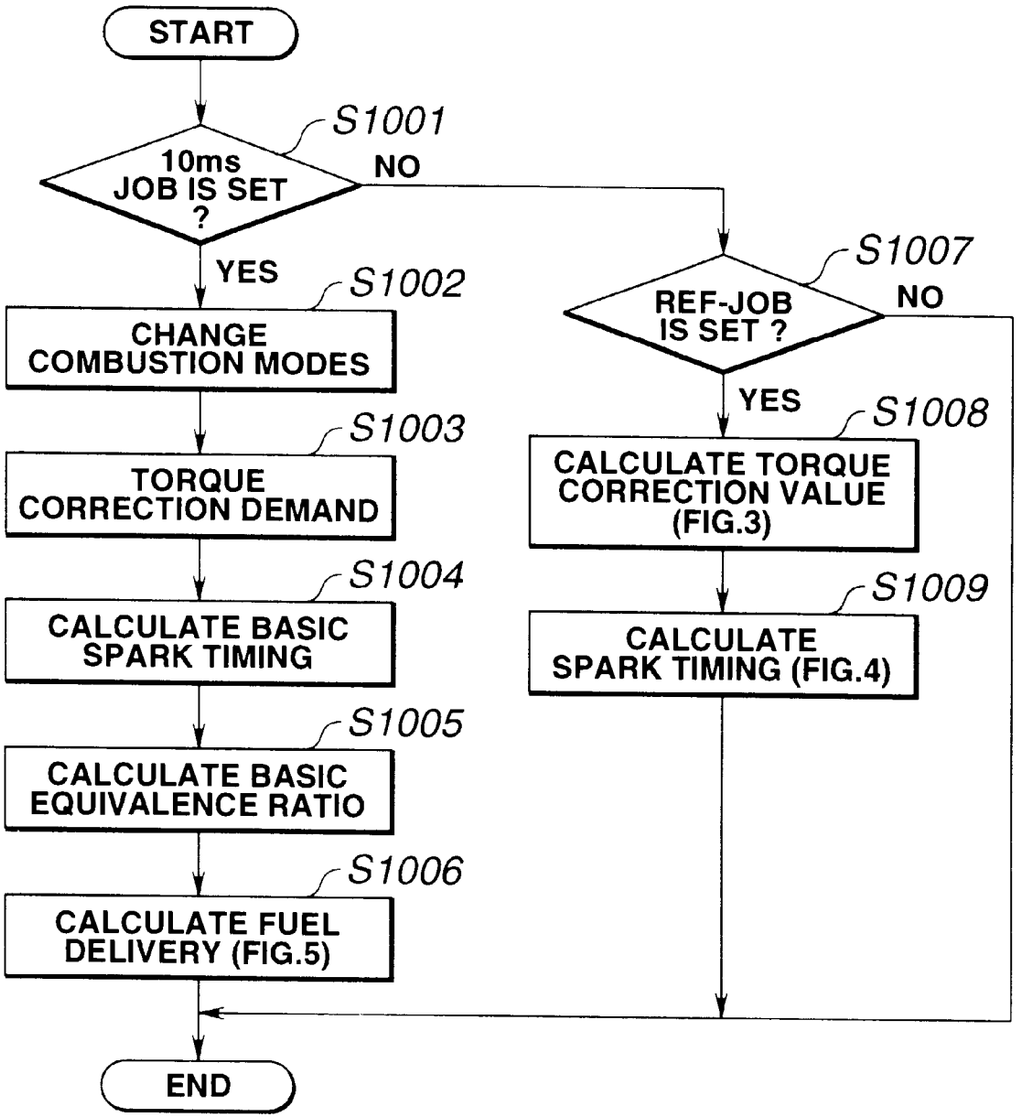
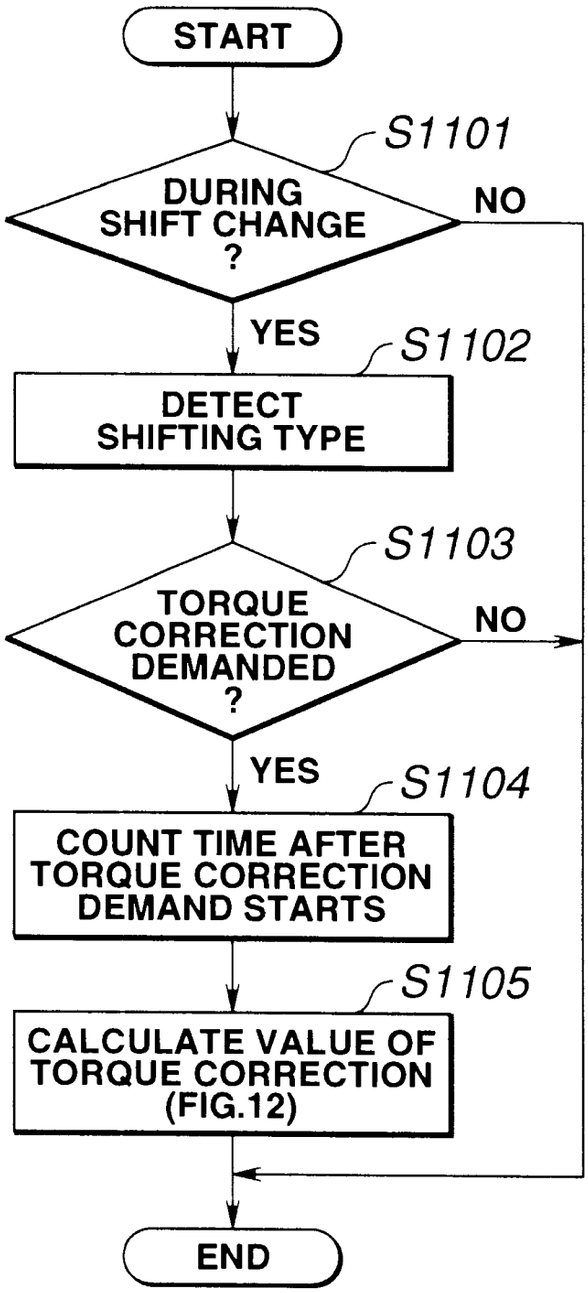
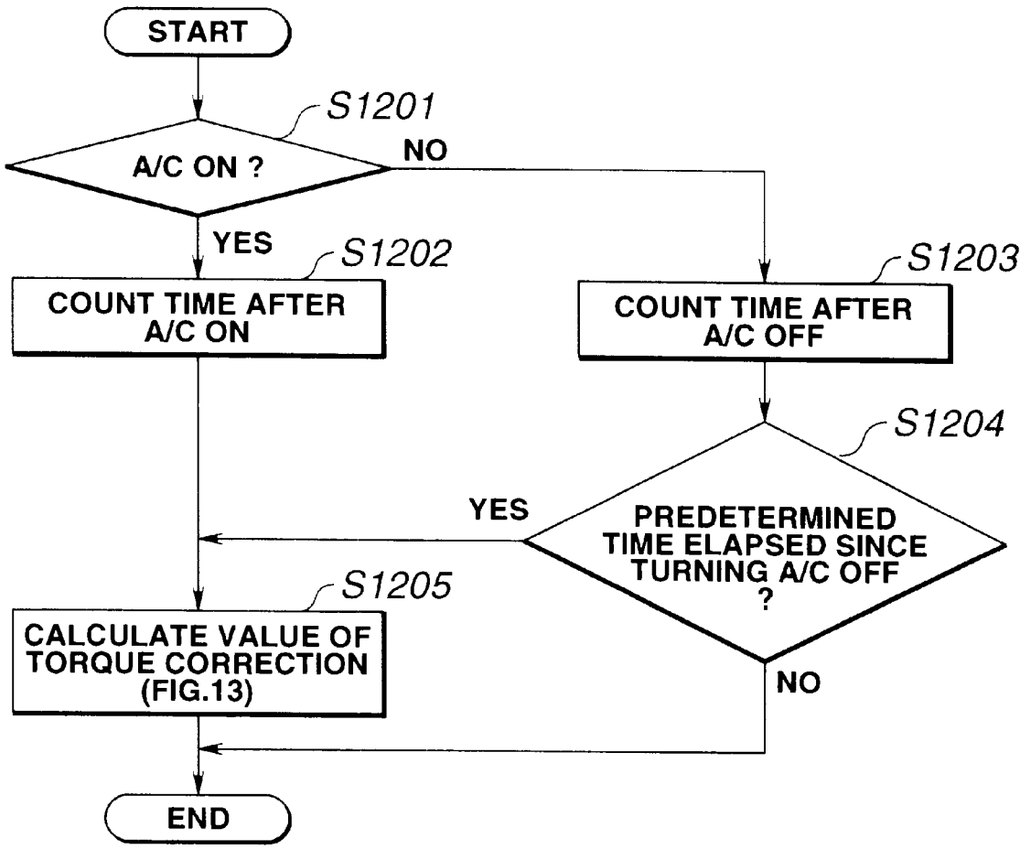

START
S1001
10ms JOB IS SET ?
NO
YES
S1002
CHANGE COMBUSTION MODES
S1003
TORQUE CORRECTION DEMAND
S1004
CALCULATE BASIC SPARK TIMING
S1005
CALCULATE BASIC EQUIVALENCE RATIO
S1006
CALCULATE FUEL DELIVERY (FIG.5)
END
S1007
REF-JOB IS SET ?
NO
YES
S1008
CALCULATE TORQUE CORRECTION VALUE (FIG.3)
S1009
CALCULATE SPARK TIMING (FIG.4)

FIG.20



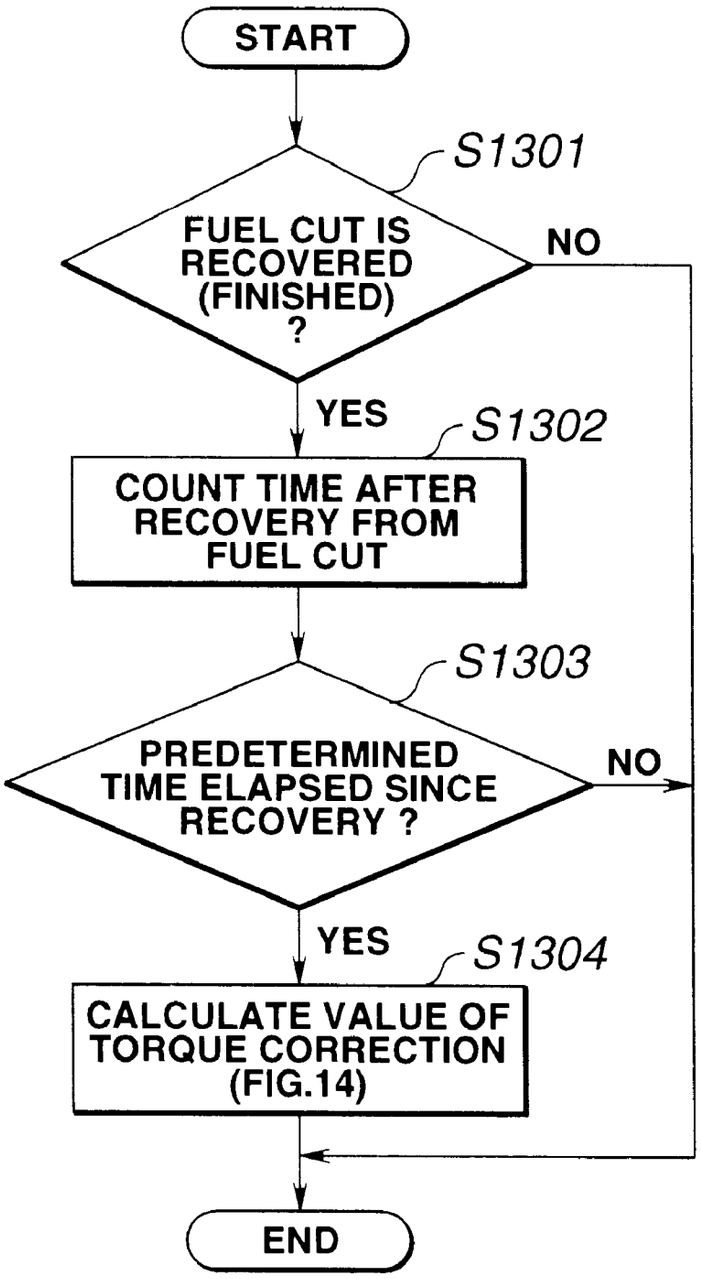
PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

FIG.21



PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

FIG.22



PETITIONER'S EXHIBIT 1002
US PATENT NO. 6,581,565

FIG.23

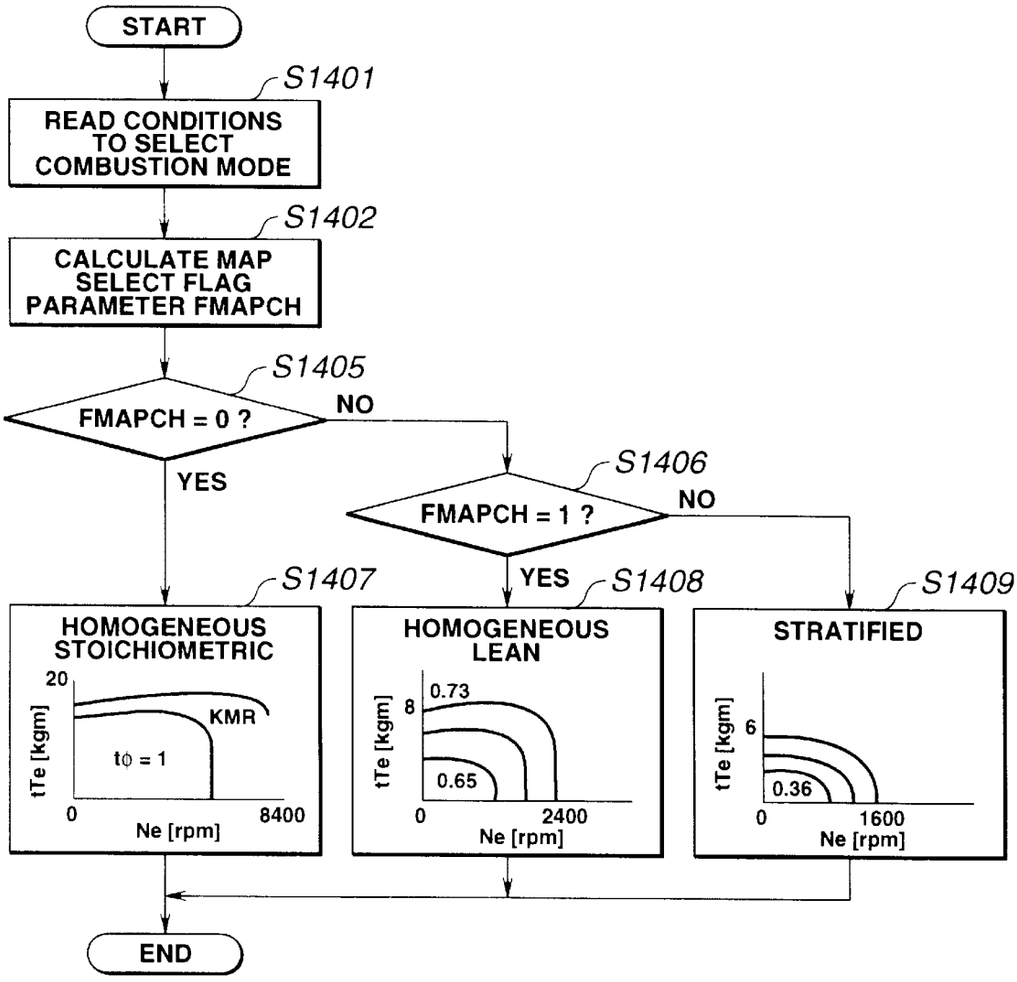

START
S1401
READ CONDITIONS TO SELECT COMBUSTION MODE
S1402
CALCULATE MAP SELECT FLAG PARAMETER FMAPCH
S1405
FMAPCH = 0 ?
NO
YES
S1406
FMAPCH = 1 ?
NO
YES
S1407
HOMOGENEOUS STOICHIOMETRIC
20
KMR
tϕ = 1
tTe [kgm]
0
8400
Ne [rpm]
S1408
HOMOGENEOUS LEAN
0.73
8
0.65
tTe [kgm]
0
2400
Ne [rpm]
S1409
STRATIFIED
6
0.36
tTe [kgm]
0
1600
Ne [rpm]
END

FIG.24

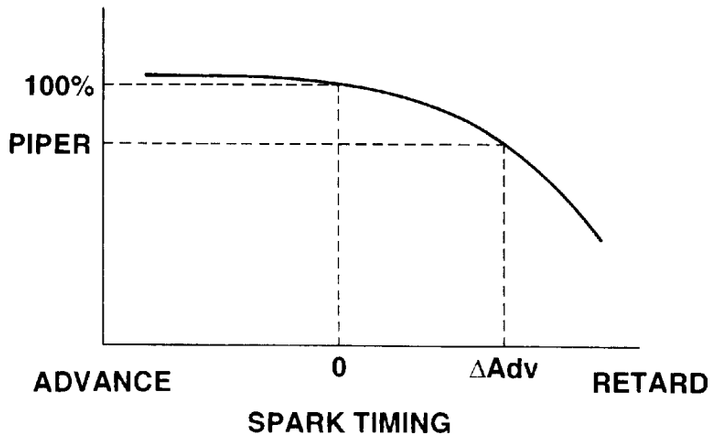


FIG.25

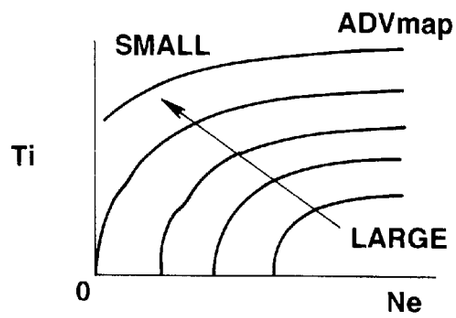


FIG.26

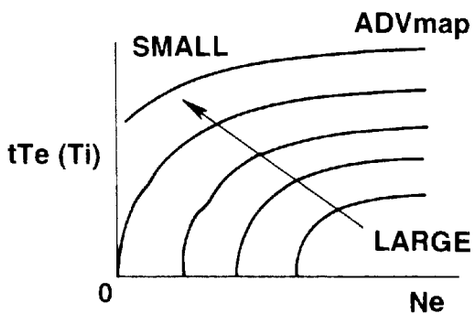
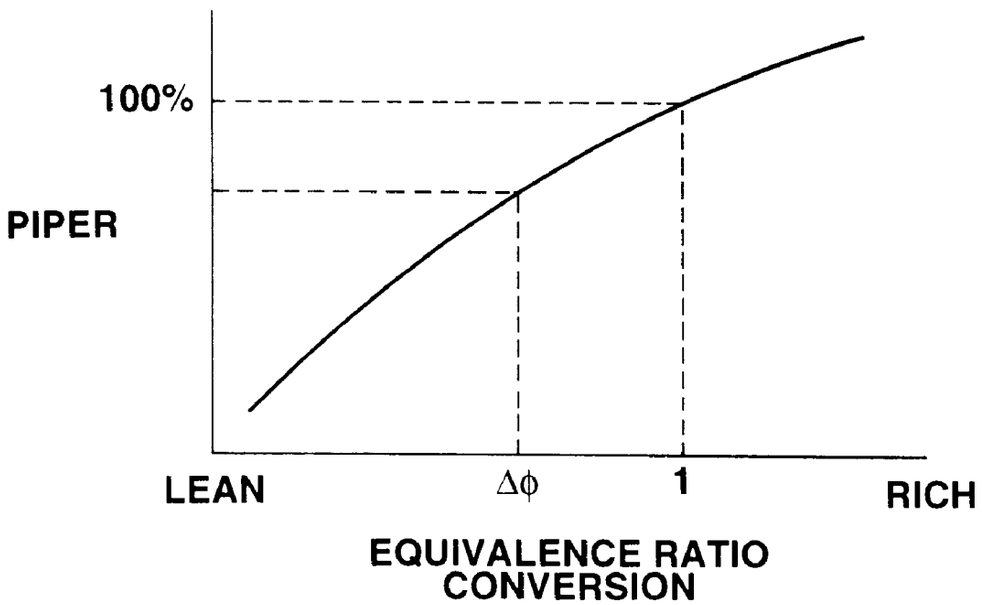


FIG.27



DIRECT-INJECTION SPARK-IGNITION TYPE ENGINE CONTROL APPARATUS

BACKGROUND OF THE INVENTION

This invention is directed to a direct-injection spark-ignition type engine control apparatus for correcting engine torque based on engine operating conditions.

It is conventional practice to realize a desired target torque (for example, during a gear shift operation made in an automatic transmission) using feedback control of the intake air flow rate in a manner to converge the engine torque to the target torque while correcting the spark timing according to a difference between the engine torque and the target torque. In order to achieve the target torque, the torque control (torque correction), which requires a faster response than intake air flow rate control can provide, is made by correcting spark timing, as discussed in Japanese Patent Kokai No. 5-163996.

In recent years, direct-injection spark-ignition type engines have attracted special interest. In such a direct-injection spark-ignition type engine, it is the current practice to make a combustion mode change, according to engine operating conditions, between homogeneous combustion (wherein fuel is injected during an intake stroke to diffuse the injected fuel so as to form a homogeneous mixture in the combustion chamber) and stratified combustion (wherein fuel is injected during a compression stroke to form a stratified fuel mixture around the spark plug) as discussed in Japanese Patent Kokai No. 59-37236.

With such a direct-injection spark-ignition type engine, sparks must be produced at a time when the mixture is close to the spark plug if torque correction is to be made by the use of spark timing during stratified combustion. However, the range over which spark timing can be corrected is too narrow to permit sufficient torque correction during stratified combustion. An attempt to correct spark timing to an excessive extent will cause degraded combustion performance and eventually misfire.

SUMMARY OF THE INVENTION

In view of these considerations, the invention has for an object providing a direct-injection spark-ignition type engine control apparatus which can ensure optimum torque correction when the combustion mode is either homogeneous combustion or stratified combustion.

The invention provides desired torque correction regardless of the combustion mode by controlling at least the spark timing to correct torque during homogeneous combustion and by controlling at least the air-fuel ratio to correct torque during stratified combustion. Torque correction is provided with a fast response to a torque correction demand that cannot be followed by intake air flow rate control, regardless of the combustion mode. High speed torque correction is provided when torque demand control (such as the control described in connection with FIG. **7**) is used to control the throttle position. Also, the invention widens the range (dynamic range) over which torque can be controlled during homogeneous combustion. It is possible to realize a response during stratified combustion that is about as fast as the response during homogeneous combustion, without increasing the processing load required for calculations during high speed operations. Also, the same response characteristics for operations with stratified and homogeneous combustion can be used over the entire range of engine speed.

BRIEF DESCRIPTION OF THE DRAWINGS

FIGS. **1**(A) and **1**(B) illustrate block diagrams showing the overall arrangement of the invention.

FIG. **2** is a system diagram of an engine embodying the invention.

FIG. **3** is a flow diagram showing a torque correction factor calculating routine used in a first embodiment.

FIG. **4** is a flow diagram showing a spark timing calculating routine used in the first embodiment.

FIG. **5** is a flow diagram showing a fuel delivery requirement calculating routine used in the first embodiment.

FIG. **6** is a flow diagram showing a torque correction factor calculating routine used in a second embodiment.

FIG. **7** is a block diagram showing torque demand control used in the second embodiment.

FIG. **8** is a flow diagram showing a torque correction factor calculating routine used in a third embodiment.

FIG. **9** is a flow diagram showing a fuel delivery requirement calculating routine used in the third embodiment.

FIG. **10** is a flow diagram showing a torque correction factor calculating routine used in a fourth embodiment.

FIG. **11** is a flow diagram showing a torque correction factor and fuel delivery calculating routine used in a fifth embodiment.

FIG. **12** shows response waveforms for the first embodiment.

FIG. **13** shows response waveforms for the second embodiment.

FIG. **14** shows response waveforms for the third embodiment.

FIG. **15** shows response waveforms for the fourth embodiment.

FIG. **16** shows time synchronous calculation of the fuel delivery requirement during idling.

FIG. **17** shows time synchronous calculation of the fuel delivery requirement above idling speed.

FIG. **18** shows rotation synchronous calculation of the fuel delivery requirement (fifth embodiment).

FIG. **19** illustrates one arrangement of overall processing.

FIGS. **20** to **22** illustrate torque correction demand processing under various conditions.

FIG. **23** illustrates processing to select a combustion mode and basic equivalence ratio.

FIGS. **24** to **27** are examples of maps employed in the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

FIGS. **1**(A) and **1**(B) will be used to explain the overall design of the invention.

The invention is directed to a control apparatus, or controller, for a direct-injection spark-ignition type engine. As shown in FIG. **1**(A), the invention includes a combustion mode changing section for making a combustion change between homogenous combustion (wherein fuel is injected during an intake stroke to diffuse the injected fuel so as to form a homogeneous mixture in the combustion chamber) and stratified combustion (wherein fuel is injected during a compression stroke to form a stratified fuel mixture around the spark plug). The invention includes a torque correction demanding section for producing a torque correction demand in accordance with engine operating conditions. The controller also includes a homogenous combustion torque correcting section, which is responsive to the torque correction demand, for correcting at least the spark timing in order to make a torque correction during homogenous

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combustion. A stratified combustion torque correcting section is responsive to a torque correction demand and corrects at least the air-fuel ratio in order to make a torque correction during stratified combustion.

FIG. **1**(B) shows another overall arrangement of the invention. This arrangement is also directed to a controller for a direct-injection spark-ignition type engine. This design also includes a combustion mode changing section for making a combustion mode change between homogenous combustion and stratified combustion. A torque correction demanding section produces a torque correction demand based on engine operating conditions. A torque control section is responsive to the torque correction demand and controls the amount of air permitted to enter the engine in order to control the torque. Because air intake cannot be changed rapidly, a homogenous combustion torque correcting section corrects at least the spark timing in order to make a torque correction with a fast response (compared with the delay associated with intake air flow rate control) during homogenous combustion. A stratified combustion torque correcting section corrects at least the air-fuel ratio to make torque correction during stratified combustion.

FIG. **2** is a system diagram showing a direct-injection spark-ignition engine embodying the invention. Air is introduced through an air cleaner **2** into an intake passage **3** and hence into each of the combustion chambers of engine **1** (installed in a vehicle). Air intake is controlled by an electronic controlled throttle valve **4**. The degree of opening of the electronic controlled throttle valve **4** is controlled by, for example, a step motor operable in response to a signal from a control unit **20**.

An electro-magnetic fuel injector **5** is provided for direct injection of fuel (gasoline) into the combustion chamber. The fuel injector **5** opens to inject fuel adjusted at a predetermined pressure when its solenoid receives a fuel injection pulse signal outputted from the control unit **20** during an intake or compression stroke, in synchronism with engine rotation, to inject fuel. In the case where the fuel is injected during the intake stroke, the injected fuel diffuses into the combustion chamber to form a homogeneous mixture. In the case where the fuel is injected during the compression stroke, a stratified mixture is formed around a spark plug **6**. The spark plug **6** produces a spark to ignite the mixture for combustion (homogeneous combustion or stratified combustion). The combustion modes include homogeneous stoichiometric combustion (at an air-fuel ratio of about 14.6), homogeneous lean combustion (at air-fuel ratios ranging from about 20 to 30), and stratified lean combustion (at air-fuel ratios of about 40), in accordance with air-fuel ratio control. Additional discussion regarding homogeneous combustion and stratified combustion and regarding how the air-fuel ratio can be adjusted for various engine operating conditions is set forth in U.S. patent application Ser. No. 08/901,963, filed Jul. 29, 1997 entitled "Control System for Internal Combustion Engine," and a U.S. Patent Application entitled "Direct Injection Gasoline Engine with Stratified Charge Combustion and Homogeneous Charge Combustion" filed under Attorney Docket No. 040679/625. The entire contents of these applications are incorporated herein by reference.

The exhaust gases discharge from the engine **1** into exhaust passage **7**. The exhaust passage **7** has a catalytic converter **8** for purifying the exhaust gases.

The control unit, or controller, **20** includes a microcomputer comprised of a CPU, a ROM, a RAM, an A/D converter and an input/output interface and receives signals from various sensors. One suitable control unit is, for example, a Hitachi SH70 series processor, programmed in C and/or machine language. The sections described herein are implemented in hardware, software, or a combination of both, in the control unit **20**.

These sensors include angle sensors **21** and **22** for detecting the rotation of the crankshaft or camshaft of the engine **1**. The sensors **21** and **22** produce a reference pulse signal REF for each 720°/n of rotation of the shaft (where n is the number of cylinders) at a predetermined shaft position (at a predetermined crankshaft angular position before the compression top dead center of each of the cylinders) and also a unit pulse signal POS at a predetermined number of degrees (1 to 2°) of rotation of the shaft. The engine speed Ne is calculated based on the period of the reference pulse signal REF.

The sensors also include an airflow meter **23** provided in the intake passage **3** at a position upstream of the throttle valve **4** for detecting the intake air flow rate Qa (the amount of air permitted to enter the engine); an accelerator sensor **24** for detecting the accelerator position ACC (the degree to which the accelerator is depressed); a throttle valve sensor **25** (including an idle switch positioned to be turned on when the throttle valve **4** is fully closed) for detecting the degree TVO of opening of the throttle valve **4**; a coolant temperature sensor **26** for detecting the temperature Tw of the coolant of the engine **1**; an O_2 sensor **27** positioned in the exhaust passage **7** for producing a signal corresponding to the rich/lean composition of the exhaust gas for actual air-fuel ratio determination; and a vehicle speed sensor **28** for detecting the vehicle speed VSP.

The control unit **20** receives the signals fed thereto from the various sensors and includes a microcomputer built therein for making the calculations described herein to control the degree of opening of the electronic controlled throttle valve **4**, the amount of fuel injected to the engine by the fuel injector **5**, and the spark timing of the spark plug **6**.

Torque control (torque correction) will be described with reference to the flow diagrams.

First Embodiment

A first embodiment will be described with reference to the flow diagrams of FIGS. **3** to **5**.

FIG. **3** shows a torque correction factor calculating routine executed in synchronism with the reference pulse signal REF (REF-JOB).

In step **S1**, a torque correction demand (that is, a demand for an increase or decrease in engine torque), which can result from, for example, a gear shift operation, air conditioner turning on operation, or fuel cut recovery, is read. For example, a torque decreasing demand is produced during a gear shift operation; a torque increasing demand is produced when the air conditioner is turned on; and a torque decreasing demand is produced upon fuel cut recovery. Examples of torque correction demand will be described in further detail below in connection with FIGS. **20** to **22**.

In step **S2**, a torque correction factor PIPER (100±α%) is calculated in accordance with the torque correction demand. More specifically:

$$PIPER = \frac{tTeO + \Delta tTe}{tTeO}$$

wherein tTeO is basic target engine torque and ΔtTe is the torque correction value. No correction is made when

PIPER=100%. A torque increasing demand is when PIPER>100% and a torque decreasing demand is when PIPER<100%.

In step **S3**, the combustion mode is read. The combustion mode is changed based on engine operating conditions using combustion mode changing maps such as a map which defines the combustion mode (and basic equivalence ratio tφ or air-fuel ratio) as a function of engine speed Ne and the target engine torque tTe. Maps are prepared for each engine operating condition as defined by, for example, coolant temperature Tw, the time elapsed after the engine starts, and the like. One of homogeneous stoichiometric combustion, homogeneous lean combustion, and stratified lean combustion is set based on the actual engine operating conditions from the map selected according to these conditions. An example of this process will be described below in connection with FIG. **23**.

In step **S4**, a determination is made as to whether the combustion mode is homogeneous combustion (homogeneous stoichiometric combustion or homogeneous lean combustion) or stratified combustion (stratified lean combustion).

If the combustion mode is homogeneous combustion, then the program proceeds to step **S5** where the torque correction factor PIPER is converted into a spark timing correction factor TQRET according to, for example, a map such as shown in FIG. **24** (TQRET=ΔAdv). As shown in FIG. **24**, since advancing the spark timing increases the torque little, the basic spark timing is set retarded in order to obtain a enough torque increase when the spark timing is advanced. The spark timing correction factor TQRET has a positive sign when the spark timing is to be retarded and a negative sign when the spark timing is to be advanced. In step **S6**, the torque correction factor PIPER is returned to 100% and this routine is ended.

If the combustion mode is stratified combustion, then the program proceeds to step **S7** wherein the spark timing correction factor TQRET is set at zero (TQRET=0) and this program is ended. In this case, the torque correction factor PIPER is held at the value calculated in step **S2**. In one embodiment, the calculations in FIG. **3** take several microseconds.

FIG. **4** shows a spark timing calculating routine executed in synchronism with the reference pulse signal REF (REF-JOB).

In step **S11**, the basic spark timing ADVmap is obtained. The basic spark timing ADVmap for homogeneous combustion [both stoichiometric and lean] is calculated in accordance with MBT control such as disclosed in U.S. Pat. No. 5,070,842. The basic spark timing ADVmap for stratified charge combustion is calculated from a prepared map. FIG. **25** shows an ADVmap for stratified charge combustion which defines the basic spark timing ADVmap as a function of engine speed Ne and fuel delivery, more particularly pulse width for fuel delivery Ti. In FIG. **25**, the target torque tTe can also be used instead of fuel delivery Ti.

The spark timing ADVmap for homogeneous combustion can be calculated in accordance with a map as a function of engine speed Ne and one the target torque tTe and fuel delivery Ti (see FIG. **26**)

In step **S12**, the spark timing correction factor TQRET (from the FIG. **3** processing) is read. In step **S13**, the spark timing correction factor TQRET is added to the basic spark timing ADVmap to calculate the eventual spark timing ADV:

$$ADV=ADVmap+TQRET$$

Since the torque correction factor PIPER is converted to the spark timing correction factor TQRET during homogeneous combustion, this torque correction reflects on the spark timing ADV, and the torque is corrected by adjusting the spark timing. Since the spark timing correction factor TQRET is zero during stratified combustion, no torque correction is made via the spark timing during stratified combustion.

In step **S14**, the spark timing ADV is set in a predetermined register and a command is produced to generate a spark at the spark timing ADV.

FIG. **5** shows a fuel delivery requirement calculating routine executed at uniform intervals of time, for example, 10 ms (10 ms-JOB).

In step **S21**, a basic equivalence ratio tφ (set during execution of another routine for air-fuel ratio control) is read. The basic equivalence ratio tφ is set according to the combustion mode, as discussed above. The term "equivalence ratio" means a fuel-air ratio represented as 14.6/AFR, where AFR is the air-fuel ratio. An example of this processing will be described in connection with FIG. **23**.

In step **S22**, the torque correction factor PIPER is read.

In step **S23**, the torque correction factor PIPER is converted to an equivalence ratio correction factor Δφ. Since the torque correction factor PIPER is 100% during homogeneous combustion (in this embodiment), the equivalence ratio correction factor Δφ is 1 in this case. Since the torque correction factor PIPER is 100±α% during stratified combustion, the equivalence ratio correction factor Δφ is 1±β. FIG. **27** shows one suitable map for converting PIPER to Δφ.

In step **S24**, the target equivalence ratio tφd is calculated by multiplying the basic equivalence ratio tφ by the equivalence ratio correction factor Δφ:

$$t\phi d=t\phi\times\Delta\phi$$

In step **S25**, the basic fuel delivery requirement Tp is corrected for the target equivalence ratio tφd and the like to calculate the eventual fuel delivery requirement Ti as follows:

$$Ti=Tp\times t\phi d\times K\alpha+Ts$$

Tp is the basic fuel delivery requirement corresponding to the stoichiometric air-fuel ratio, Tp=K1×Qa/Ne (K1 is a constant).

Kα is an air-fuel ratio feedback correction factor calculated based on the O_2 sensor signal (the correction factor Kα is clamped at **1** during lean combustion).

Ts is an ineffective injection time correction factor dependent on the battery voltage.

The fuel delivery requirement Ti calculated in such a manner is set in a predetermined register. An injection pulse signal having a pulse width corresponding to the fuel delivery requirement Ti is outputted to each of the fuel injectors **5** for fuel injection in the intake stroke of the corresponding cylinder (during homogeneous combustion) and in the compression stroke of the corresponding cylinder (during stratified combustion).

Thus, the steps **S1** to **S4**, **S5**, **S6**, **S12** and **S13** perform a homogeneous combustion torque correcting function and the steps **S1** to **S4**, **S7**, and **S22** to **S25** perform a stratified combustion torque correcting function.

FIG. **12** shows response waveforms for the first embodiment of the invention. Assuming that a demand for torque correction (torque down demand) is produced in the presence of a gear shift, the spark timing is corrected to correct the torque during homogeneous combustion, whereas the equivalence ratio (air-fuel ratio) is corrected, without cor-

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recting the spark timing, to correct the torque during stratified combustion.

In this embodiment, the electronic controlled throttle valve **4** is controlled according to the accelerator position ACC.

Second Embodiment

In the second embodiment, torque correction is made as shown in FIG. **6**, and spark timing and fuel delivery requirement calculations are made as described above in connection with FIGS. **4** and **5**.

FIG. **6** shows a torque correcting routine executed in synchronism with the reference pulse signal REF (REFJOB).

At step **S31**, a target torque tTRQ calculated by torque demand control is retrieved. The parameter tTRQ includes a torque correction demand (demand for increasing or decreasing the torque) resulting from gear shifting of the transmission, turning on the air conditioner, recovery from a fuel cut, or the like.

The target torque is represented by the following formula:

$$\text{Target torque } tTE \ (= tTRQ) = \text{basic target engine torque } (tTeO) + \text{torque correction for intake air } (\Delta tTe\_air)$$

In the second and fourth embodiments, torque correction entails correction for the intake air amount. This torque correction is indicated by ΔtTe_air.

In step **S32**, an air correction factor to obtain the target torque (the torque correction demand) is calculated to control the degree of opening of the electronic controlled throttle valve **4**.

In step **S33**, the output torque during intake air correction is estimated.

In step **S34**, the estimated torque is subtracted from the target torque (which is based on the torque demand control target torque or the torque correction demand calculated at step **S31**) to calculate the torque shortage due to the delay involved with changing the amount of intake air.

In step **S35**, a torque correction factor PIPER (100±α%) is calculated in accordance with the torque shortage. In this case, PIPER=100% indicates no correction. PIPER>100% indicates a torque increase demand, and PIPER<100% indicates a torque decrease demand.

In step **S36**, the combustion mode is read.

In step **S37**, a determination is made as to whether the combustion mode is homogeneous combustion (homogeneous stoichiometric combustion or homogeneous lean combustion) or stratified combustion (stratified lean combustion).

If the combustion mode is homogeneous combustion, then the program proceeds to step **S38** wherein the torque correction factor PIPER is converted to a spark timing correction factor TQRET, as discussed above. The spark timing correction factor TQRET has a positive sign when the spark timing is to be retarded and a negative sign when the spark timing is to be advanced. In step **S39**, the torque correction factor PIPER is returned to 100% and this program is ended.

If the combustion mode is stratified combustion, then the program proceeds to step **S40** wherein the spark timing correction factor TQRET is set at 0 and this program is ended. In this case, the torque correction factor is held at the value calculated in step **S35**.

Thereafter, control is made according to the spark timing calculation routine of FIG. **4** and the fuel delivery requirement calculation routine of FIG. **5**.

The steps **S31** to **S37**, **S38**, **S39**, **S12** and **S13** perform a homogeneous combustion torque correcting function and the steps **S31** to **S37**, **S40** and **S22** to **S25** perform a stratified combustion torque correcting function.

FIG. **7** is a control block diagram for torque demand control.

A target torque calculation section **101** receives the accelerator position ACC and the engine speed Ne, and outputs a driver demand torque based on a predetermined map which defines the driver demand torque as a function of accelerator position and engine speed. A torque correction demand factor resulting from a gear shift, air conditioner on, fuel cut recovery, or the like is added to the driver demand torque to calculate a target torque tTRQ.

A basic fuel delivery requirement calculation section **102** receives the target torque tTRQ and the engine speed Ne and it outputs a basic fuel delivery requirement tQf based on a predetermined map which specifies the basic fuel delivery requirement tQf as a function of target torque and engine speed.

The combustion efficiency varies when the air-fuel ratio changes over a wide range during operation with homogeneous and stratified combustion. An efficiency correction section **103** corrects the basic fuel delivery requirement tQf based on combustion efficiency. The basic fuel delivery is corrected less as the air/fuel ratio increases (leaner). Under lean conditions, the pumping loss is lower and efficiency is higher; thus less fuel is needed to get a certain torque when the air fuel ratio is leaner.

A target air-fuel ratio calculation section **104** receives the target torque tTRQ and the engine speed Ne and outputs a target air-fuel ratio tAFR from a predetermined map which defines the target air-fuel ratio tAFR as a function of target torque and engine speed.

A target intake air flow rate calculation section **105** includes a multiplier which multiplies the basic fuel delivery requirement tQf by the target air-fuel ratio tAFR to calculate a target intake air flow rate tQcyl=tQf×tAFR.

A target throttle position calculation section **106** receives the target intake air flow rate tQcyl and the engine speed Ne and outputs a target throttle position tTVO from a predetermined map which specifies the target throttle position tTVO as a function of tQcyl and Ne.

A throttle valve drive control section **107** drives, for example, a step motor in a stepped manner in response to a command signal corresponding to the target throttle position tTVO so as to bring the throttle valve **4** to the target throttle position tTVO. Examples of maps referred to above in connection with FIG. **7** are shown in a U.S. Patent Application entitled "Engine Throttle Control Apparatus" and filed under Attorney Docket No. 040679/0629.

FIG. **13** shows response waveforms for the second embodiment. Assuming that a torque correction (torque up) demand is produced when the air conditioner is turned on, the amount of air to the engine increases; however, a torque shortage occurs because of the delay in increasing the actual amount of air to the engine. The spark timing is corrected to correct the torque shortage during homogeneous combustion and the equivalence ratio (air-fuel ratio) is corrected, without correcting the spark timing, to correct the torque shortage during stratified combustion.

Third Embodiment

In the third embodiment, the torque correction factor calculation is made as shown in FIG. **8**, the spark timing calculation is made as described above in connection with FIG. **4**, and the fuel delivery requirement calculation is made as shown in FIG. **9**.

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FIG. **8** shows a torque correction factor calculating routine executed in synchronism with the reference pulse signal REF (REF-JOB). FIG. **8** is different from FIG. **3** in steps S**2**', S**5**' and S**6**'.

In step S**1**, a torque correction demand (increase or decrease demand) resulting from a gear shift, air conditioner on, fuel cut recovery, or the like, is read.

In step S**2**, a torque correction factor is calculated in accordance with the torque correction demand. The torque correction factor is divided into a spark timing related torque correction factor PIPERAD and an air-fuel ratio related torque correction factor PIPERMR, which are independently calculated. When each correction factor is ΔtTe_AD, ΔtTe_MR:

$$PIPERAD = \frac{tTeO + \Delta tTe_{AD}}{tTeO}$$

In this case, 100% indicates no correction, greater than 100% indicates a torque increase demand, and less than 100% indicates a torque decrease demand.

In step S**3**, the combustion mode is read.

In step S**4**, a determination is made as to whether the combustion mode is homogeneous combustion (homogeneous stoichiometric combustion or homogeneous lean combustion) or s t ratified combustion (stratified lean combustion).

If the combustion mode is homogeneous combustion, then the program proceeds to the step S**5**' wherein the spark timing related torque correction factor PIPERAD is converted to a spark timing correction factor TQRET in accordance with FIG. **24**. (TQRET=ΔAdv). The spark timing correction factor TQRET has a positive sign when the spark timing is to be retarded and a negative sign when the spark timing is to be advanced. In step S**6**', the spark timing related torque correction factor PIPERAD is returned to 100% and this program is ended.

If the combustion mode is stratified combustion, then the program proceeds to step S**7**, where the spark timing correction factor TQRET is set at 0. In this case, the spark timing related torque correction factor PIPERAD is held at the value calculated in step S**2**'.

Thereafter, control is made according to the spark timing calculation routine of FIG. **4**.

FIG. **9** shows a fuel injection requirement calculating routine executed at uniform intervals of time, for example, 10 ms (10 ms-JOB). FIG. **9** is different from FIG. **5** in step S**22**'.

In step S**21**, a basic equivalence ratio tϕ for air-fuel ratio control is read.

In step S**22**', the spark timing related torque correction factor PIPERAD and the equivalence ratio related torque correction factor PIPERMR are read and added to calculate a total torque correction factor PIPER as follows:

$$PIPER=PIPERAD+PIPERMR-100(\%)$$

Since the spark timing related torque correction factor PIPERAD 100% during homogeneous combustion (after execution of FIG. **8**), PIPER=PIPERMR during homogeneous combustion.

In step S**23**, the torque correction factor PIPER is converted to an equivalence ratio correction factor Δϕ.

In step S**24**, the equivalence ratio correction factor Δϕ is multiplied by the basic equivalence ratio tϕ to calculate a target equivalence ratio tϕd as follows:

$$t\phi d=t\phi\times\Delta\phi$$

In step S**25**, the basic fuel delivery requirement Tp is corrected based on the target equivalence ratio tϕd to calculate an eventual fuel delivery requirement Ti:

$$Ti=Tp\times t\phi d\times K\alpha+Ts$$

The fuel delivery requirement Ti calculated in such a manner is set in a predetermined register. An injection pulse signal having a pulse width corresponding to the fuel delivery requirement Ti is outputted to each of the fuel injectors **5** for fuel injection in the intake stroke of the corresponding cylinder during homogeneous combustion and in the compression stroke of the corresponding cylinder during stratified combustion.

FIG. **14** shows response waveforms for the third embodiment. Assuming that a demand for torque correction (torque down demand) is produced in the presence of a fuel cut, the spark timing and equivalence ratio (air-fuel ratio) are corrected to correct the torque during homogeneous combustion, whereas the equivalence ratio (air-fuel ratio) is corrected to a greater extent, without correcting the spark timing, to correct the torque during stratified combustion.

Fourth Embodiment

In the fourth embodiment, the torque correction is made as shown in FIG. **10**, the spark timing calculation is made as described above in connection with FIG. **4**, and the fuel delivery requirement calculation is made as described above in connection with FIG. **9**.

FIG. **10** shows a torque correcting routine executed in synchronism with the reference pulse signal REF (REF-JOB). FIG. **10** is different from FIG. **6** in steps S**35**', S**38**' and S**39**'.

In step S**31**, a torque correction demand (increase or decrease demand) resulting from the target torque for torque demand control, a gear shift, the air conditioner being turned on, fuel cut recovery, or the like is read.

In step S**32**, an air correction factor for the target torque or the torque correction demand is calculated to control the degree of opening of the electronic controlled throttle valve **4**.

In step S**33**, the output torque during air correction is estimated.

In step S**34**, the estimated torque is subtracted from the target torque (based on the torque demand control target torque or the torque correction demand) to calculate a torque shortage.

In step S**35**', a torque correction factor is calculated in accordance with the torque shortage. The torque correction factor is divided into a spark timing related torque correction factor PIPERAD and an air-fuel ratio related torque correction factor PIPERMR. The spark timing related torque correction factor and the air-fuel ratio related torque correction factor are calculated based on the torque shortage from step S**34** in the following manner:

under stratified combustion:

$$PIPERAD : PIPERMR = 0 : 100$$

under homogeneous combustion:

$$PIPERAD : PIPERMR = x : (100 - x)$$

a value retrieved from a map based on the driving condition (engine speed, torque). In this case, 100% indicates no correction, more than 100% indicates a torque increase demand and less than 100% indicates a torque decrease demand.

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In step S36, the combustion mode is read.

In step S37, a determination is made as to whether the combustion mode is homogeneous combustion (homogeneous stoichiometric combustion or homogeneous lean combustion) or stratified combustion (stratified lean combustion).

If the combustion mode is homogeneous combustion, then the program proceeds to step S38' wherein the spark timing related torque correction factor PIPERAD is converted to a spark timing correction factor TQRET. In step S39', the spark timing related torque correction factor PIPERAD is returned to 100% and this program is ended.

If the combustion mode is stratified combustion, then the program proceeds to step S40 wherein the spark timing correction factor TQRET is set at 0 and this program is ended. In this case, the spark timing related torque correction factor PIPERAD is held at the value calculated in step S35'.

Thereafter, control is made according to the spark timing calculation routine of FIG. 4 and the fuel delivery requirement calculation routine of FIG. 9.

FIG. 15 shows response waveforms for the fourth embodiment. Assuming that a demand for torque correction (torque down demand) is produced in the presence of a gear shift, the amount of air to the engine is decreased; however, too much torque occurs because of the delay in air flow rate control. In order to correct the torque excess, the spark timing and equivalence ratio (air-fuel ratio) are corrected to correct the torque during homogeneous combustion. The equivalence ratio (air-fuel ratio) is corrected to a greater extent, without correcting the spark timing, to correct the torque during stratified combustion.

Fifth Embodiment

In the fifth embodiment, calculations for the torque correction factor and fuel delivery requirement are made as shown in FIG. 11, and the spark timing calculation is made as described above in connection with FIG. 4.

In step S1, the torque correction demand (demand for increase or decrease) which can result from a gear shift operation, air conditioner turning on operation, or fuel cut recovery, or the like, is read.

In step S2, a torque correction factor PIPER (100±α%) is calculated in accordance with the torque correction demand. In this case, no correction is made when PIPER=100%, a torque increasing demand correction is made when PIPER>100%, and a torque decreasing demand correction is made when PIPER<100%.

In step S3, the combustion mode is read.

In step S4, a determination is made as to whether the combustion mode is homogeneous combustion (homogeneous stoichiometric combustion or homogeneous lean combustion) or stratified combustion (stratified lean combustion).

If the combustion mode is homogeneous combustion, then the program proceeds to step S41 wherein the torque correction factor PIPER is converted to the spark timing correction factor TQRET. In step S42, the equivalence ratio correction factor Δφ is set to 1. Following this, the program proceeds to steps S45 to S47.

If the combustion mode is stratified combustion, then the program proceeds to step S43 wherein the torque correction factor PIPER is converted to a n equivalence ratio correction factor Δφ, and then to step S44 wherein the spark timing correction factor TQRET is set to 0. Following this, the program proceeds to steps S45 to S47.

In step S45, the basic equivalence ratio tφ (set in another routine) is read for air-fuel ratio control.

In step S46, the target equivalence ratio tφd is calculated by multiplying the basic equivalence ratio by the equivalence ratio correction factor Δφ as follows:

$$t\phi d = t\phi \times \Delta\phi$$

In step S47, the basic fuel delivery requirement Tp is corrected for the target equivalence ratio tφd and the like to calculate the eventual fuel delivery requirement Ti according to the following equation

$$Ti = Tp \times t\phi d \times K\alpha + Ts$$

The fuel delivery requirement Ti calculated in such a manner is set in a predetermined register. An injection pulse signal having a pulse width corresponding to Ti is outputted to each of the fuel injectors 5 to inject fuel in the intake stroke of the corresponding cylinder during homogeneous combustion and in the compression stroke of the corresponding cylinder during stratified combustion.

Control of spark timing is made according to the spark timing calculation routine of FIG. 4.

In the fifth embodiment, the fuel delivery requirement calculation is made in synchronism with engine rotation (REF-JOB) like the torque correction factor calculation.

Differences between fuel delivery requirement calculation made in synchronism with time (10 ms-JOB) as described above in connection with the first to fourth embodiments and fuel delivery requirement calculation made in synchronism with engine rotation (REF-JOB) as described in connection with the fifth embodiment will now be described.

Assuming that calculations made in synchronism with rotation (REF-JOB) are for a four-cylinder engine, the period of the reference pulse signal REF produced for each 180° of crankshaft rotation will change with engine speed approximately as follows:

1000 rpm . . . 30 ms
3000 rpm . . . 10 ms
5000 rpm . . . 6 ms
6000 rpm . . . 5 ms

Thus, the processing load required for the calculations is as great as compared to the ms-JOB at 3000 rpm or more and double the 10 ms-JOB at 6000 rpm. This tendency increases for 6 and 8 cylinder engines.

For this reason, the processing load required for the calculations is decreased, in the first to fourth embodiments, by executing the fuel delivery requirement calculation in synchronism with time (10 ms-JOB). The reason why the response speed during stratified combustion is not degraded by making the calculations in synchronism with time is as follows.

At low loads (1200 rpm or less) during stratified combustion, 10 ms-JOB is executed between the time at which the torque correction factor is calculated (in synchronism with rotation) and the time at which fuel is injected. Thus, it is possible to realize the same response characteristic as realized with spark timing adjustment during homogeneous combustion.

The reflection of the torque correction factor on the fuel delivery requirement is made in synchronism with time (10 ms-JOB) even at greater engine speeds, and the control is made at uniform intervals of 10 ms. However, sufficient control can be made for torque correction demands on such a time scale.

FIGS. 16 to 18 show the timing chart of the operation as to two cylinders of the engine. A Z-shape arrow represents

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a spark timing, a shaded rectangle shows a fuel delivery, and a triangular wave shows a pressure in the cylinder raised by the combustion.

Referring to FIG. **16**, the influence on performance is dependent on whether the reflection of the correction factor is delayed one combustion at low engine speeds, for example, at idling speeds. Since the correction factor (TQRET) is calculated by REF-JOB during homogeneous combustion and reflected immediately on spark timing set by the REF signal during homogeneous combustion (when the correction factors (TQRET, PIPER) are calculated by REF-JOB and the reflection on the fuel delivery requirement is made by 10 ms-JOB), it is possible to reflect the correction factor on the combustion just after the REF signal. Homogeneous combustion might be used while idling if, for example, accessory loads are high and the engine is cold. Although the correction factor (PIPER) is calculated by REF-JOB during stratified combustion, at least one 10 ms-JOB is executed between the time at which a REF signal is produced and the time at which a fuel injection pulse is produced at low engine speeds. Thus, the correction factor can be reflected on the combustion just after the REF signal, like operation with homogeneous combustion.

It is, therefore, possible to make torque corrections with the same response characteristics for both stratified combustion and homogeneous combustion in the low engine speed range, such as the idling speed range.

As shown in FIG. **17**, at engine speeds above idling speeds, if the correction factors (TQRET, PIPER) are calculated by REF-JOB and the reflection on the fuel delivery requirement is made by 10 ms-JOB, the correction factor (TQRET) is calculated by REF-JOB and reflected immediately on the spark timing set by the REF signal during homogeneous combustion so that the correction factor is reflected on the combustion just after the REF signal.

Although the correction factor (PIPER) is calculated by REF-JOB during stratified combustion, no 10 ms-JOB routine can be executed between the time at which the REF signal is produced and the time at which a fuel injection pulse is produced, in this engine speed range. In this case, the calculated correction factor is reflected on the next combustion.

Thus, the time at which the correction factor is reflected may be delayed during stratified combustion as compared to homogeneous combustion. However, this manner of calculation can reduce the processing load required for the calculations of REF-JOB and can prevent an increase in the processing load required for calculations made in synchronism with rotation when the engine speed is increasing.

Since it is sufficient for a greater part of the correction demand values to be handled in synchronism with time, and the reflection timing is not severe at engine speeds except for idling speeds, there is no performance reduction problem if the corrected fuel delivery values are reflected at time intervals of 10 ms.

It is, therefore, possible to correct the torque with sufficient response regardless of whether homogeneous or stratified combustion is occurring, while also preventing an increase in the processing load required for calculations made in synchronism with rotation at engine speeds above idling speeds.

FIG. **18** illustrates the effect of the fifth embodiment. Both the correction factor TQRET and the fuel delivery requirement Ti can be calculated by REF-JOB when the control unit has a sufficiently great processing ability. The correction of the amount of fuel to the engine during stratified combustion is reflected on the combustion just after the REF signal, like the correction to spark timing made during homogeneous combustion.

It is thus possible to realize torque correction with a sufficient response regardless of whether the combustion mode is homogeneous combustion or stratified combustion, over the entire engine speed range.

FIG. **19** illustrates one arrangement for overall processing. This processing includes the torque correction calculations of FIG. **3**, the spark timing calculations of FIG. **4**, and the fuel delivery calculations of FIG. **5**. This processing also includes torque correction demand processing, change of combustion mode processing, basic spark timing calculation processing and processing for calculating basic equivalence ratio $t\phi$.

In step **S1001**, a determination is made as to whether a 10 ms job is set. A counter in the control unit **20** outputs a clock signal every 10 ms. If the clock signal was output between the last process and the current process, a "YES" determination is made and the processing proceeds on to step **S1002**. The general flow of FIG. **19** itself is processed under a 1 or 2 ms job.

In step **S1002**, the combustion mode is changed. For example, stratified charge combustion or homogenous charge combustion can be selected. Selection of the combustion mode based on various conditions is described, for example, in a U.S. Patent Application entitled "Direct Injection Gasoline Engine with Stratified Charge Combustion and Homogeneous Charge Combustion" filed under Attorney Docket Number 040679/0625. In step **S1003**, torque correction demand processing is performed and in step **S1004** basic spark timing is calculated.

In step **S1005**, the basic equivalence ratio is calculated, as discussed above. In step **S1006**, fuel delivery is calculated as discussed above in connection with FIG. **5**.

In step **S1007**, a determination is made as to whether REF-JOB is set. If the REF signal is output between the last process and the current process, "YES" is obtained and the processing proceeds to step **S1008**. In step **S1008**, a torque correction value is calculated, as discussed above in connection with FIG. **3**. In step **S1009**, spark timing is calculated, as discussed above in connection with FIG. **4**.

FIGS. **20–22** show torque correction demand processing under various conditions. FIG. **20** shows the processing for a shift change. FIG. **21** shows the processing for the air conditioner compressor being turned on/off. FIG. **22** shows the processing for fuel cut recovery.

In FIG. **22**, a determination is made in step **S1101** as to whether a shift change is occurring. If yes, the processing proceeds to step **S1102**. Otherwise, the processing proceeds to the end. In step **S1102**, the shifting type is detected. In step **S1103**, a determination is made as to whether torque correction is demanded. If yes, the processing proceeds to step **S1104**. Otherwise, the processing proceeds to the end.

In step **S1104**, the time after the torque correction demand starts is counted. In step **S1105**, the value of torque correction is calculated and torque is corrected as shown in FIG. **12**.

In FIG. **21**, step **S1201**, a determination is made as to whether the air conditioner is on. If the air conditioner is on, the processing proceeds to step **S1202**. Otherwise, the processing proceeds to step **S1203**. In step **S1202**, the time after the air conditioner has been turned on is counted. In step **S1203**, the time after the air conditioner has been turned off is counted. After step **S1203**, the processing proceeds to step **S1204**. In step **S1204**, a determination is made as to whether a predetermined time has elapsed since turning the air conditioner off. If yes, the processing proceeds to step **S1205**. Otherwise, the processing proceeds to the end. In step **S1205**, the value of the torque correction is calculated and torque is corrected as shown in FIG. **13**.

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In FIG. **22**, step **S1301** makes a determination as to whether a fuel cut is recovered (finished). If no, the processing proceeds to the end. Otherwise, the processing proceeds to step **S1302**. In step **S1302**, the time after the recovery from the fuel cut is counted. In step **S1303**, a determination is made as to whether a predetermined time has elapsed since recovery. If no, the processing proceeds to the end. Otherwise, the processing proceeds to step **S1304**. In step **S1304**, the value of torque correction is calculated and torque is corrected as shown in FIG. **14**.

FIG. **23** is a flowchart which shows an example of processing to select the combustion mode and basic equivalence ratio tφ. As discussed above, this processing is employed in connection with step **S3** of FIG. **3**, and step **S21** of FIG. **5**.

In step **S1401**, the conditions to select a combustion mode are read. These conditions can include, for example, water temperature, the time from engine starting, driving conditions such as engine revolution speed Ne and target torque, and the like.

In step **S1402**, a map select flag parameter FMAPCH is calculated in accordance with a combustion mode selected. Steps **S1405** and **1406** select the appropriate map based on the combustion mode, according to FMAPCH. The processing proceeds to step **S1407** for the homogeneous stoichiometric combustion condition. The processing proceeds to step **S1408** for the homogeneous lean condition. The processing proceeds to step **S1409** for the stratified combustion condition. In each of steps **S1407** to **S1409**, the basic equivalence ratio tφ is selected from a map based on engine speed Ne and target torque (tTe=tTeO).

The entire contents of Japanese patent application No. 9-168419 (filed Jun. 25, 1997) and Press Information entitled "Nissan Direct-Injection Engine" (Document E1-2200-9709 of Nissan Motor Co., Ltd., Tokyo, Japan) are incorporated herein by reference.

Although the invention has been described above by reference to certain embodiments of the invention, the invention is not limited to the embodiments described above. Modifications and variations of the embodiments described above will occur to those skilled in the art, in light of the above teachings. For example, the characteristic curves shown in the Figures are merely examples and other curves and techniques can be employed. The scope of the invention is defined with reference to the following claims.

What is claimed is:

1. A controller for an engine which operates in a homogeneous combustion mode and a stratified combustion mode, the controller comprising:

a detector to detect whether the engine is operating in a homogeneous combustion mode or a stratified combustion mode; and

a torque correction section, coupled to the detector, which receives a torque correction demand and produces a torque correction output in response to the torque correction demand, the torque correction output varying spark timing when the detector detects that the engine is in the homogeneous combustion mode and varying a ratio of air and fuel when the detector detects that the engine is in the stratified combustion mode.

2. A controller as set forth in claim **1**, wherein the torque correction output varies a ratio of air and fuel but not spark timing when the detector detects that the engine is in the stratified combustion mode.

3. A controller as set forth in claim **1**, wherein the torque correction output varies spark timing and a ratio of air and fuel when the detector detects that the engine is in the homogeneous combustion mode.

4. A controller as set forth in claim **1**, wherein the torque correction section calculates an intake air flow amount to satisfy the torque correction demand and produces an air flow amount output corresponding thereto, and wherein the torque correction section varies spark timing when the detector detects that the engine is in a homogeneous combustion mode to compensate for a delay in actual air flow reaching air flow specified by the air flow amount output, and varies the ratio of air and fuel when the detector detects that the engine is in a stratified combustion mode to compensate for a delay in actual air flow reaching air flow specified by the air flow amount output.

5. A controller as set forth in claim **4**, wherein the torque correction section varies spark timing and a ratio of air and fuel when the detector detects that the engine is in a homogeneous combustion mode to compensate for the delay in actual air flow reaching air flow specified by the air flow amount output.

6. A controller as set forth in claim **1**, further comprising a fuel delivery calculation section, wherein the fuel delivery calculation section performs fuel delivery calculations in a loop having a constant repetition time, and wherein the torque correction section performs its calculations in a loop whose repetition time varies with engine speed.

7. A controller as set forth in claim **1**, wherein the torque correction section calculates an intake air flow amount to satisfy the torque correction demand and produces an air flow amount output corresponding thereto, and wherein the torque correction section varies spark timing when the detector detects that the engine is in a homogeneous combustion mode to compensate for a delay in actual air flow reaching air flow specified by the air flow amount output.

8. A controller as set forth in claim **2**, wherein the torque correction output varies spark timing and a ratio of air and fuel when the detector detects that the engine is in the homogeneous combustion mode.

9. A controller as set forth in claim **4**, wherein the torque correction section varies a ratio of air and fuel but not spark timing when the detector detects that the engine is in the stratified combustion mode.

10. A controller as set forth in claim **1**, further comprising a fuel delivery calculation section performing fuel delivery calculations, and wherein the fuel delivery calculation section and the torque correction section perform the calculations in loops, each having repetition time varying with engine speed, respectively.

* * * * *

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US005241855A

United States Patent [19]

Cullen et al.

[11] **Patent Number: 5,241,855**

[45] **Date of Patent: Sep. 7, 1993**

[54] **METHOD AND APPARATUS FOR INFERRING ENGINE TORQUE**

[75] Inventors: **Michael J. Cullen**, Dearborn; **James M. Kindree**; **Bruce J. Palansky**, both of Livonia; **Rocco Bellino**, Canton; **Joseph N. Ulrey**, Dearborn, all of Mich.

[73] Assignee: **Ford Motor Company**, Dearborn, Mich.

[21] Appl. No.: **786,229**

[22] Filed: **Oct. 31, 1991**

[51] **Int. Cl.**[5] **G01M 15/00**

[52] **U.S. Cl.** **73/117.3**

[58] **Field of Search** 73/116, 117.3; 364/431.03, 431.04

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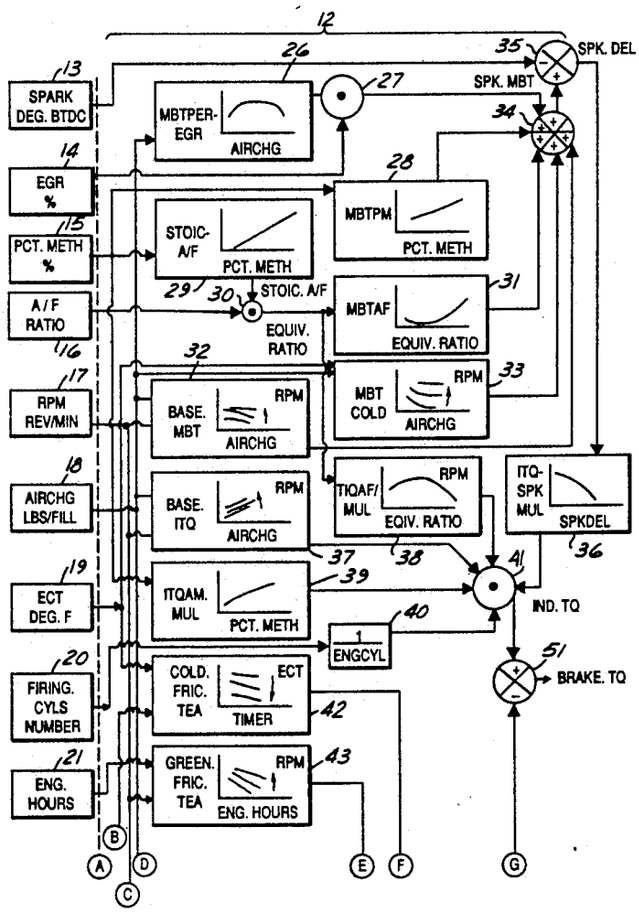
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Primary Examiner—Robert Raevis
Attorney, Agent, or Firm—Peter Abolins; Roger L. May

[57] **ABSTRACT**

A method of inferring and predicting engine torque uses a function of a speed/load table, air/fuel ratio and spark advance. The effects of the magnitudes of engine spark retard, rich or lean air/fuel ratios and exhaust gas recirculation are accounted for using a series of multipliers. Friction torque is accounted for through a speed/air charge table look-up.

7 Claims, 10 Drawing Sheets



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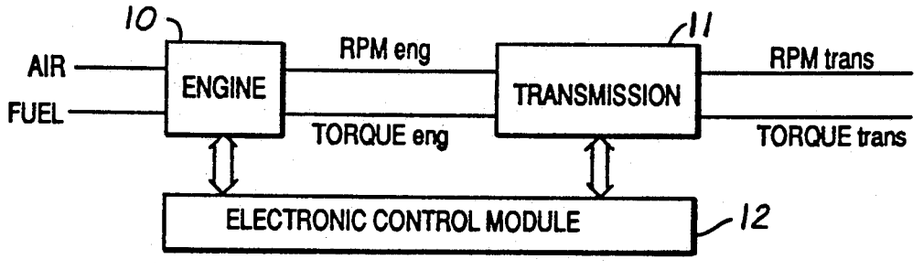
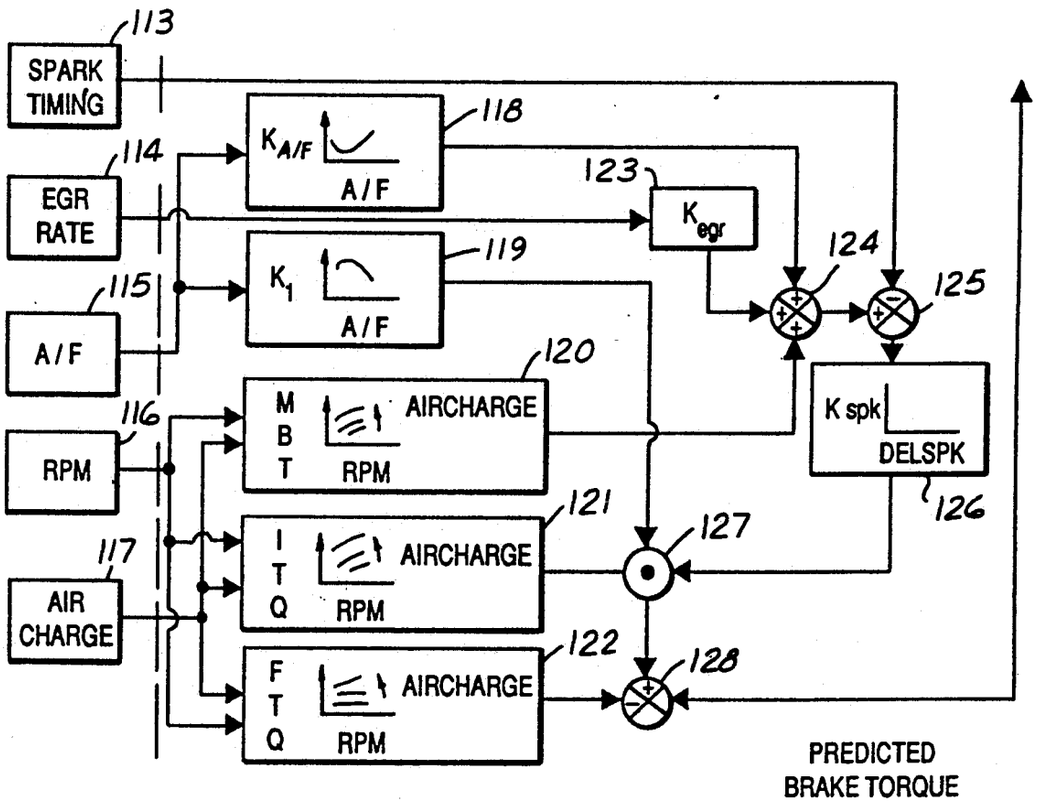


FIG. 1



(PRIOR ART)

FIG. 2

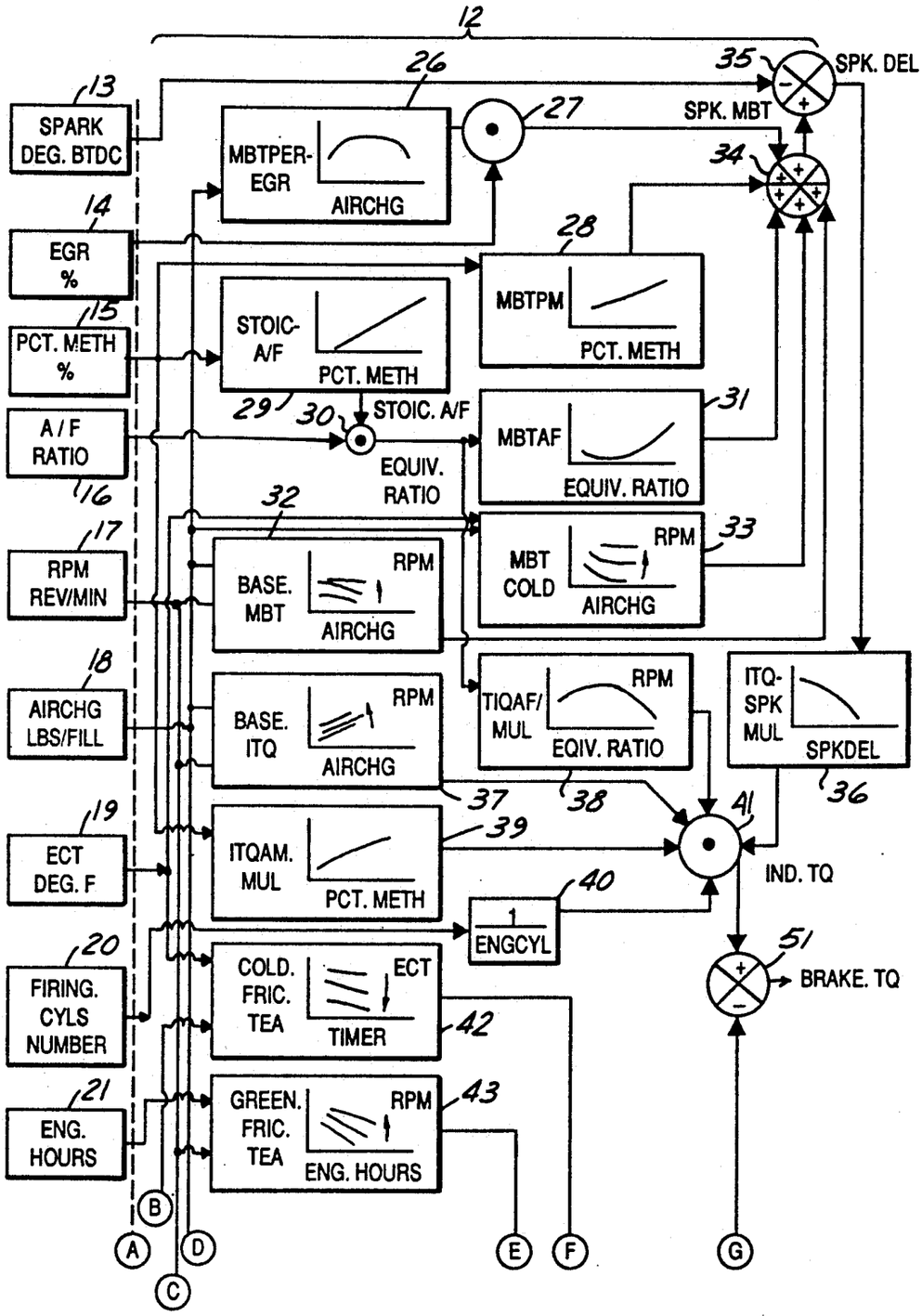

12
13
SPARK DEG. BTDC
14
EGR %
15
PCT. METH %
A/F RATIO
16
17
RPM REV/MIN
18
AIRCHG LBS/FILL
19
ECT DEG. F
20
FIRING. CYLS NUMBER
21
ENG. HOURS
26
MBTPER-EGR
AIRCHG
27
35
SPK. DEL
SPK. MBT
34
28
MBTPM
PCT. METH
STOIC-A/F
PCT. METH
29
30
STOIC. A/F
EQUIV. RATIO
MBTAF
EQUIV. RATIO
31
32
BASE. MBT
RPM
AIRCHG
MBT COLD
RPM
AIRCHG
33
BASE. ITQ
RPM
AIRCHG
37
TIQAF/MUL
RPM
EQIV. RATIO
38
ITQ-SPK MUL
SPKDEL
36
41
IND. TQ
ITQAM. MUL
PCT. METH
39
1/ENGCYL
40
51
BRAKE. TQ
COLD. FRIC. TEA
ECT
TIMER
42
GREEN. FRIC. TEA
RPM
ENG. HOURS
43
A
B
C
D
E
F
G

FIG.3

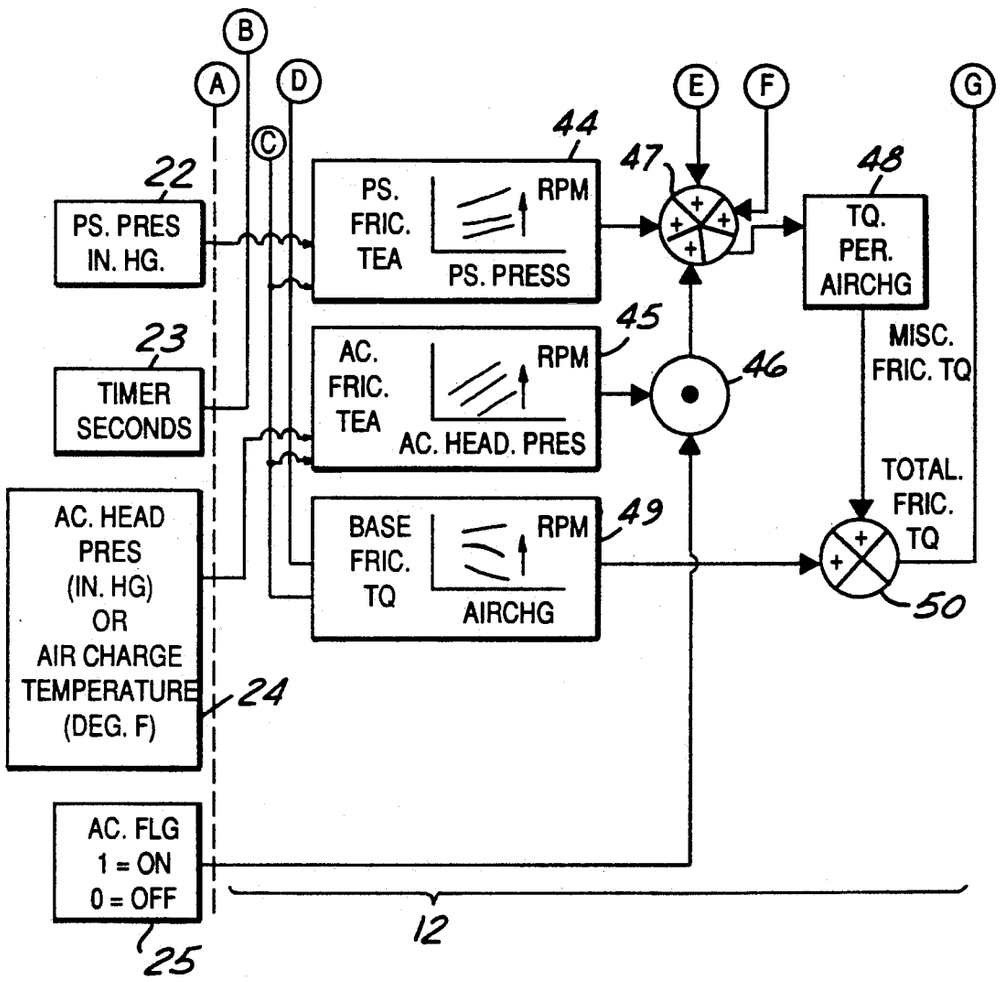

B
A
D
C
E
F
G
44
47
48
22
PS. PRES IN. HG.
PS. FRIC. TEA
RPM
PS. PRESS
TQ. PER. AIRCHG
45
23
TIMER SECONDS
AC. FRIC. TEA
RPM
AC. HEAD. PRES
46
MISC. FRIC. TQ
TOTAL. FRIC. TQ
AC. HEAD PRES (IN. HG) OR AIR CHARGE TEMPERATURE (DEG. F)
BASE FRIC. TQ
RPM
AIRCHG
49
50
24
AC. FLG 1 = ON 0 = OFF
25
12

FIG.3A

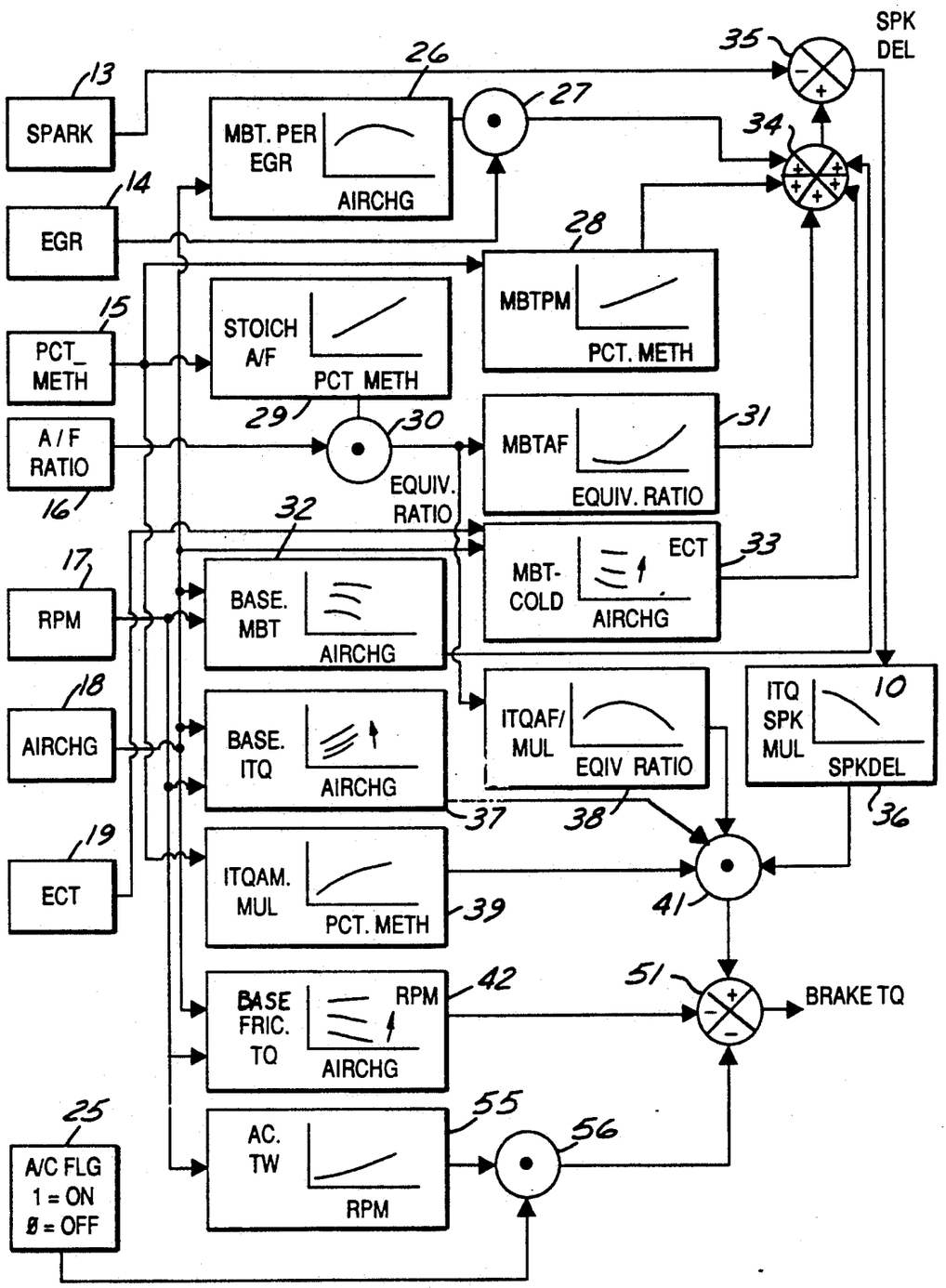

SPARK
13
EGR
14
PCT_ METH
15
A / F RATIO
16
RPM
17
AIRCHG
18
ECT
19
A/C FLG 1 = ON 0 = OFF
25
MBT. PER EGR
AIRCHG
26
27
STOICH A/F
PCT METH
29
30
EQUIV. RATIO
32
BASE. MBT
AIRCHG
BASE. ITQ
AIRCHG
ITQAM. MUL
PCT. METH
39
BASE FRIC. TQ
RPM
AIRCHG
42
AC. TW
RPM
55
56
MBTPM
PCT. METH
28
MBTAF
EQUIV. RATIO
31
MBT- COLD
ECT
AIRCHG
33
ITQAF/ MUL
EQIV RATIO
37
38
ITQ SPK MUL
10
SPKDEL
36
41
35
SPK DEL
34
51
BRAKE TQ

FIG.4

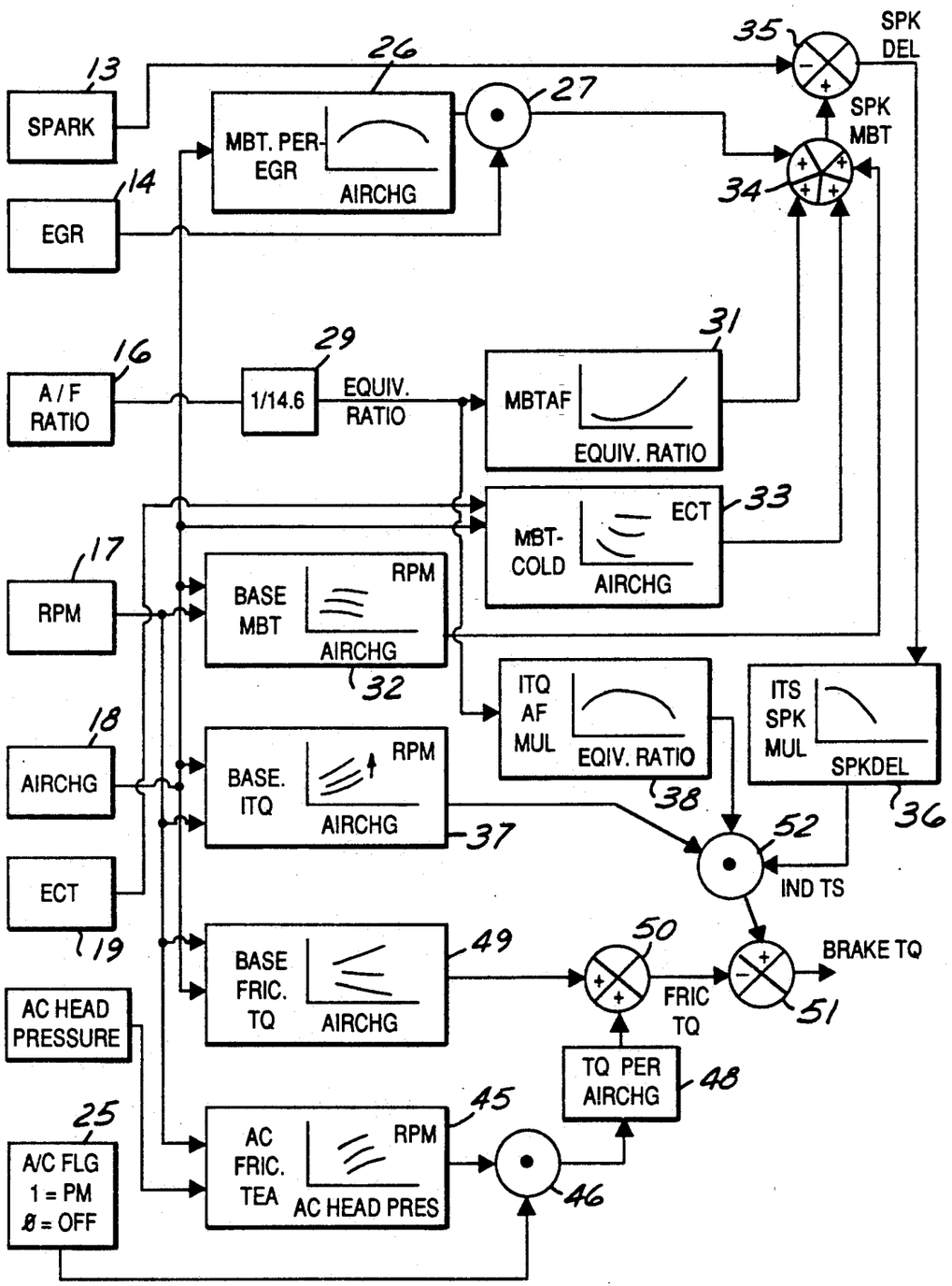

SPARK
13
EGR
14
A / F RATIO
16
RPM
17
AIRCHG
18
ECT
19
AC HEAD PRESSURE
A/C FLG 1 = PM 0 = OFF
25
MBT. PER-EGR
AIRCHG
26
27
1/14.6
29
EQUIV. RATIO
MBTAF
EQUIV. RATIO
31
MBT-COLD
ECT
AIRCHG
33
BASE MBT
RPM
AIRCHG
32
ITQ AF MUL
EQIV. RATIO
38
ITS SPK MUL
SPKDEL
36
BASE. ITQ
RPM
AIRCHG
37
52
IND TS
BASE FRIC. TQ
AIRCHG
49
50
FRIC TQ
BRAKE TQ
51
TQ PER AIRCHG
48
AC FRIC. TEA
RPM
AC HEAD PRES
45
46
35
SPK DEL
SPK MBT
34

FIG.5

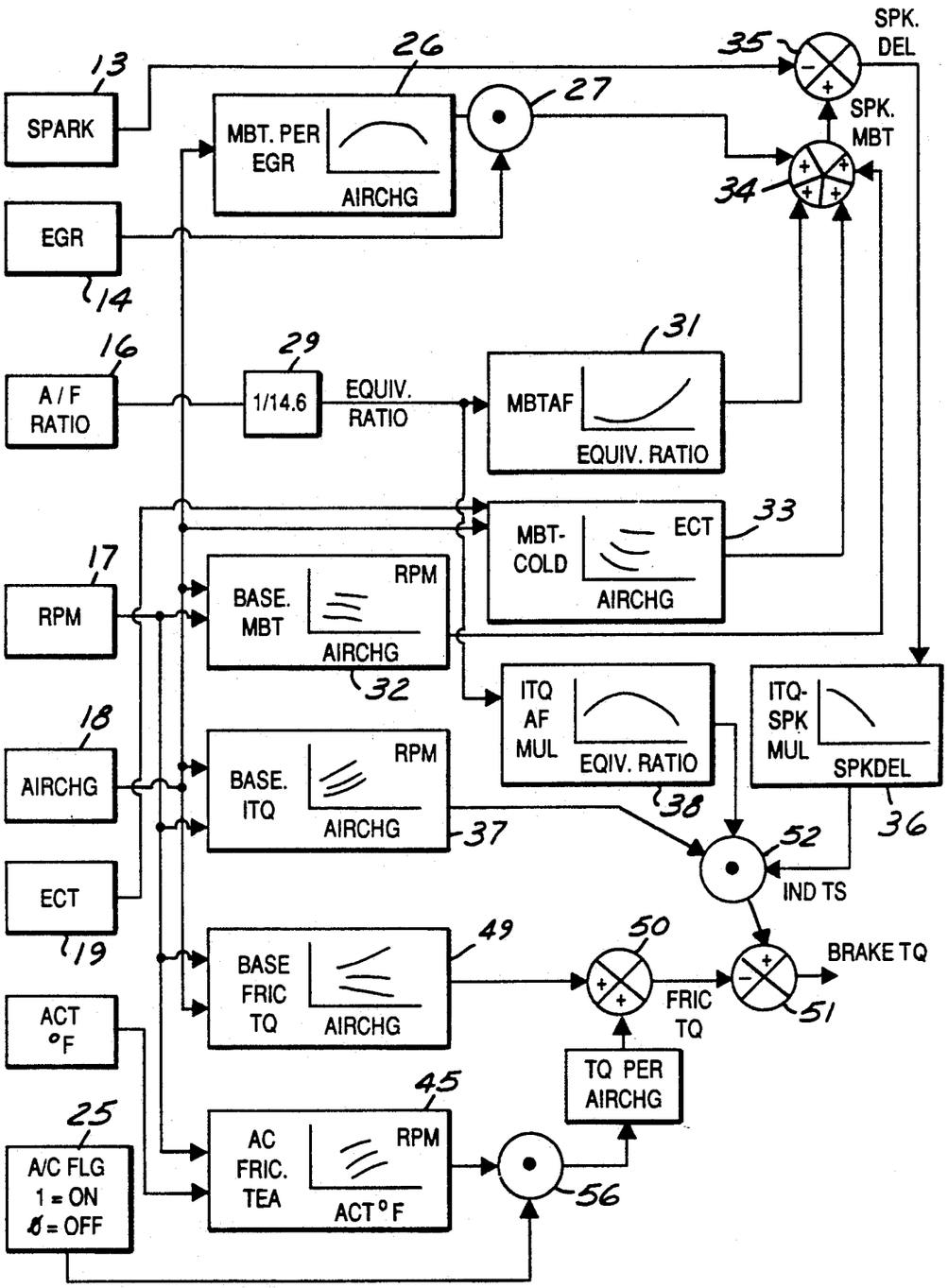

SPARK
13
MBT. PER EGR
AIRCHG
26
27
35
SPK. DEL
SPK. MBT
34
EGR
14
A / F RATIO
16
1/14.6
29
EQUIV. RATIO
MBTAF
EQUIV. RATIO
31
MBT-COLD
ECT
AIRCHG
33
RPM
17
BASE. MBT
RPM
AIRCHG
32
ITQ AF MUL
EQIV. RATIO
38
ITQ-SPK MUL
SPKDEL
36
AIRCHG
18
BASE. ITQ
RPM
AIRCHG
37
52
IND TS
ECT
19
BASE FRIC TQ
AIRCHG
49
50
FRIC TQ
BRAKE TQ
51
ACT °F
TQ PER AIRCHG
25
A/C FLG 1 = ON 0 = OFF
AC FRIC. TEA
RPM
ACT °F
45
56

FIG.6

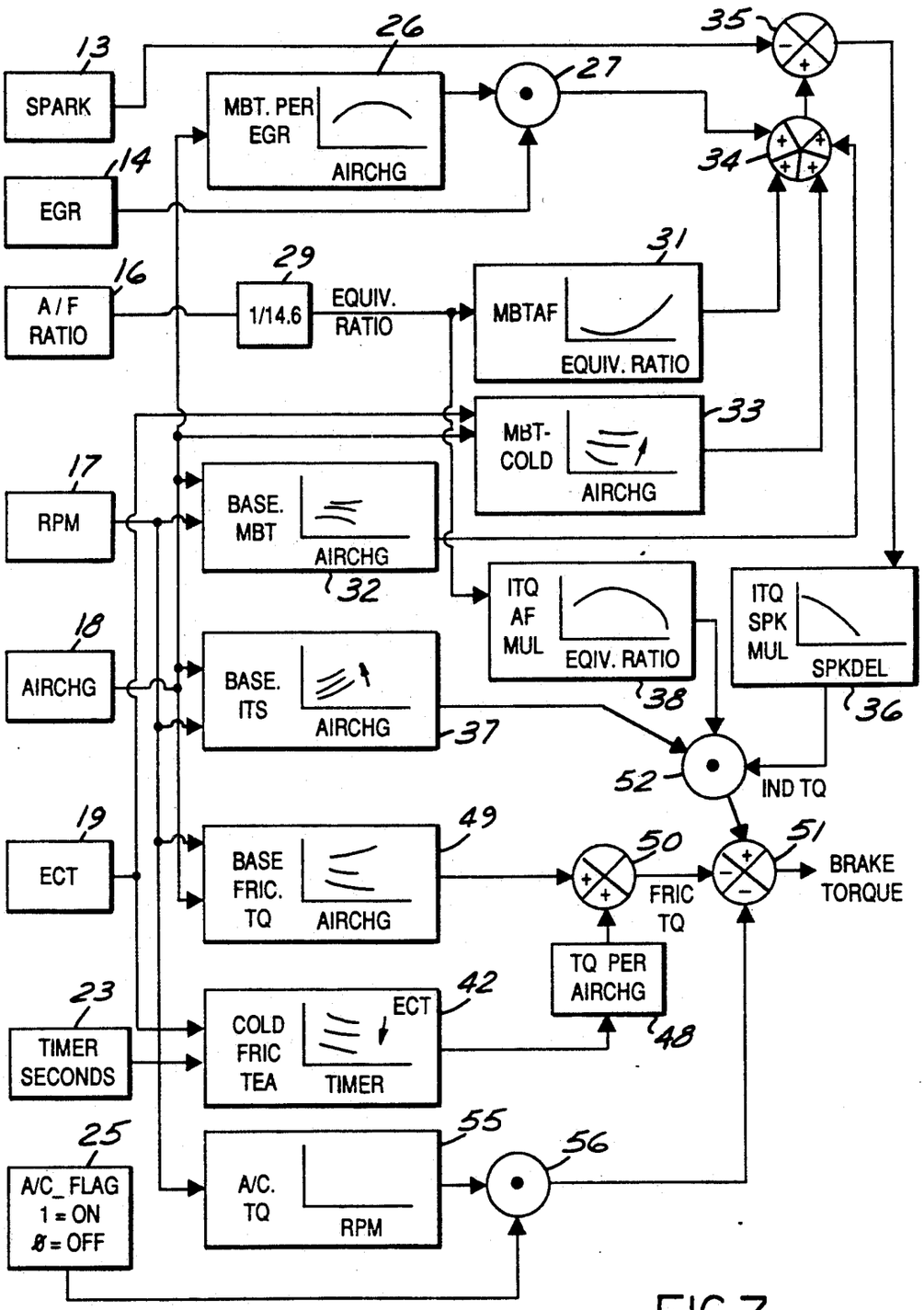

13
SPARK
14
EGR
16
A / F RATIO
17
RPM
18
AIRCHG
19
ECT
23
TIMER SECONDS
25
A/C_FLAG 1 = ON 0 = OFF
26
MBT. PER EGR
AIRCHG
27
29
1/14.6
EQUIV. RATIO
31
MBTAF
EQUIV. RATIO
33
MBT-COLD
AIRCHG
BASE. MBT
AIRCHG
32
ITQ AF MUL
EQIV. RATIO
38
ITQ SPK MUL
SPKDEL
36
35
34
BASE. ITS
AIRCHG
37
52
IND TQ
49
BASE FRIC. TQ
AIRCHG
50
FRIC TQ
51
BRAKE TORQUE
TQ PER AIRCHG
48
42
COLD FRIC TEA
ECT
TIMER
55
A/C. TQ
RPM
56

FIG.7

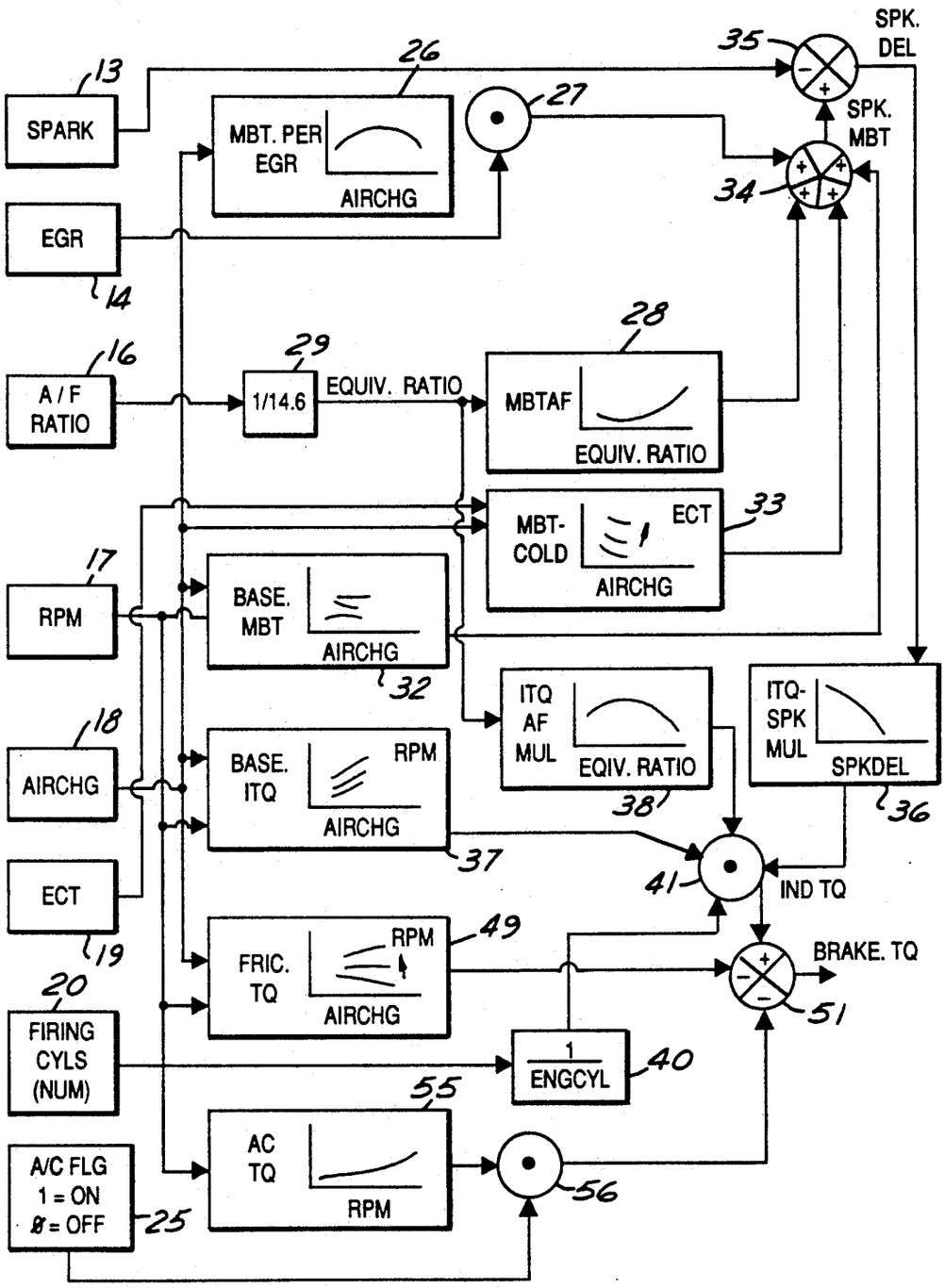


FIG.8

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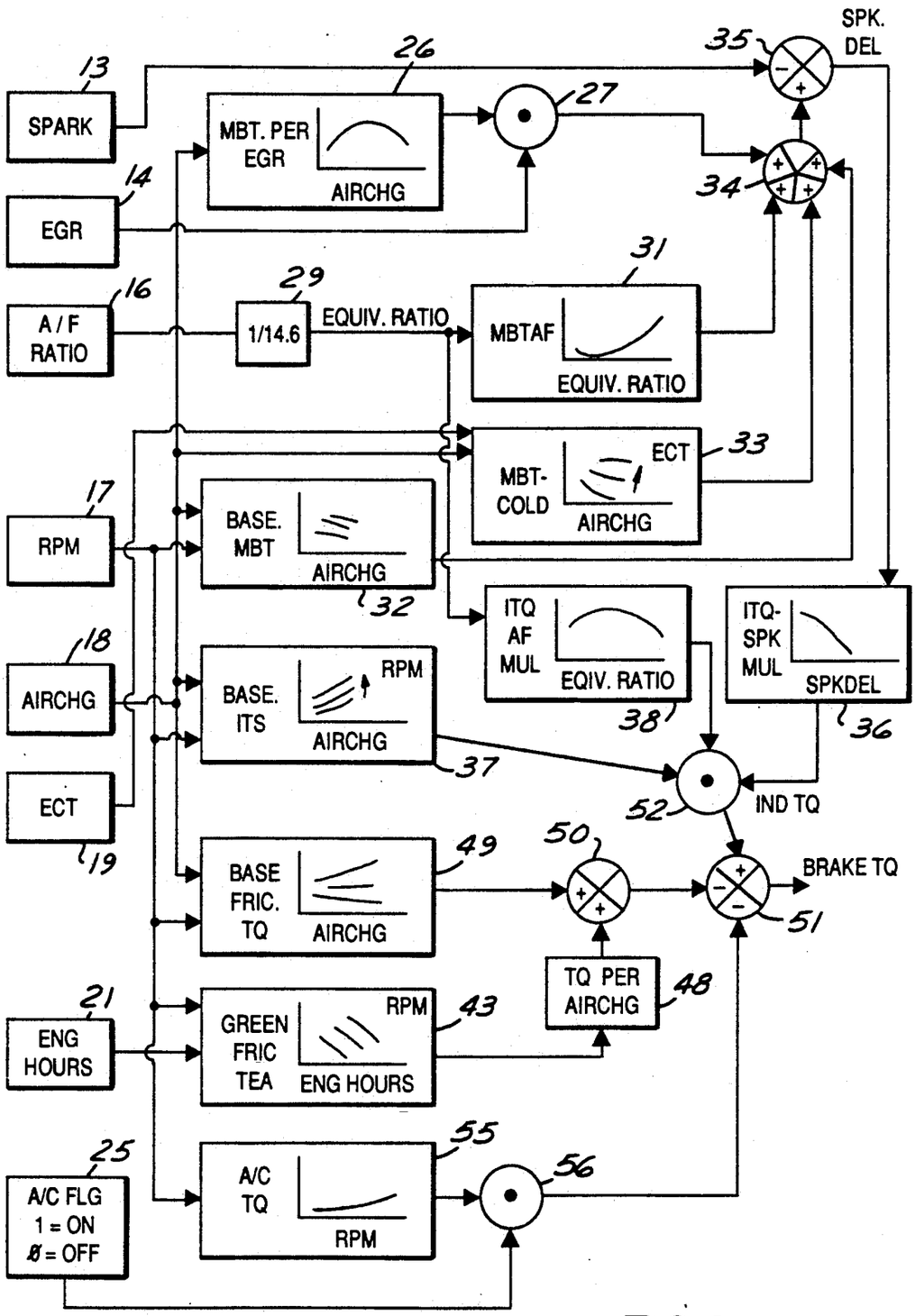

SPK. DEL
35
26
13
SPARK
MBT. PER EGR
AIRCHG
27
14
EGR
34
31
29
16
A / F RATIO
1/14.6
EQUIV. RATIO
MBTAF
EQUIV. RATIO
ECT
33
MBT-COLD
AIRCHG
17
RPM
BASE. MBT
AIRCHG
32
ITQ AF MUL
EQIV. RATIO
38
ITQ-SPK MUL
SPKDEL
36
18
AIRCHG
BASE. ITS
RPM
AIRCHG
37
ECT
19
52
IND TQ
49
50
BRAKE TQ
BASE FRIC. TQ
AIRCHG
51
TQ PER AIRCHG
48
21
ENG HOURS
GREEN FRIC TEA
RPM
ENG HOURS
43
55
25
A/C FLG 1 = ON 0 = OFF
A/C TQ
RPM
56

FIG.9

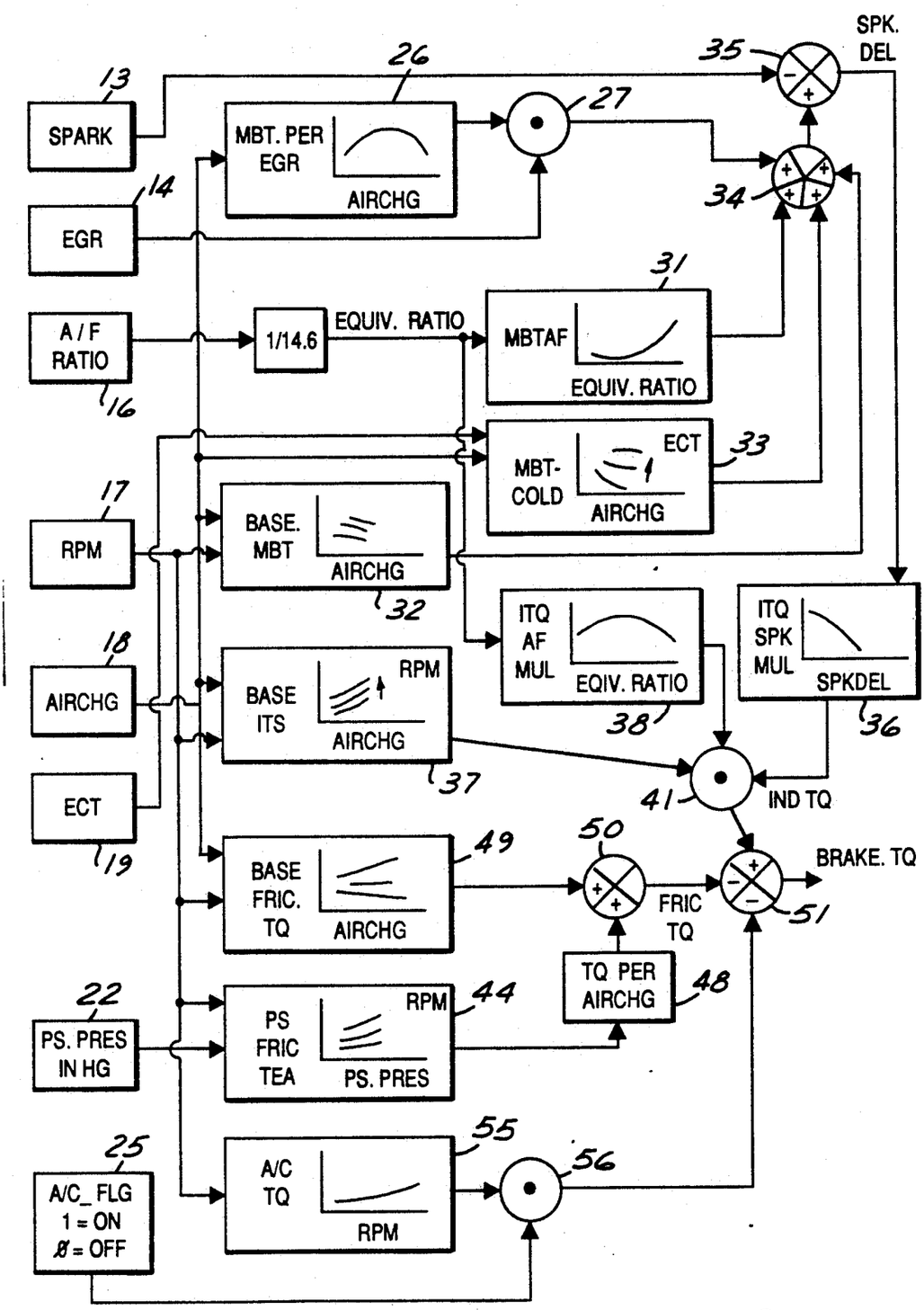

SPARK
13
EGR
14
A/F RATIO
16
RPM
17
AIRCHG
18
ECT
19
PS. PRES IN HG
22
A/C_FLG 1 = ON 0 = OFF
25
MBT. PER EGR
AIRCHG
26
27
1/14.6
EQUIV. RATIO
MBTAF
EQUIV. RATIO
31
MBT-COLD
ECT
AIRCHG
33
BASE. MBT
AIRCHG
32
BASE ITS
RPM
AIRCHG
37
ITQ AF MUL
EQIV. RATIO
38
ITQ SPK MUL
SPKDEL
36
SPK. DEL
35
34
41
IND TQ
BRAKE. TQ
51
BASE FRIC. TQ
AIRCHG
49
50
FRIC TQ
TQ PER AIRCHG
48
PS FRIC TEA
RPM
PS. PRES
44
A/C TQ
RPM
55
56

FIG.10

METHOD AND APPARATUS FOR INFERRING ENGINE TORQUE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to engines and in particular to inferring the torque produced by an engine. One use of such an inferred engine torque is as an input parameter for a control system governing operation of an automatic transmission associated with the engine.

2. Prior Art

Knowledge of engine torque is required as an input for automatic transmission control strategies and transmission failure mode management strategies.

Direct measurement of engine torque is not currently practical so various inferences have been used over the years in both mechanically controlled powertrains and microprocessor controlled powertrains.

Known mechanical transmission control systems predicted torque from throttle angle or engine intake manifold vacuum and an aneriod atmospheric pressure sensor.

These mechanical systems suffered from many sources of error including the influence of exhaust gas recirculation rate on the prediction, changes in accessory torque losses, and changes in friction torque during the warmup period or over the life of the engine.

Known microprocessor based powertrain control systems inferred engine torque from engine speed and engine airflow. For systems equipped with a manifold pressure sensor the airflow was calculated after accounting for the influence of exhaust gas recirculation. Thus this source of error was minimized. A lookup function of air conditioning torque versus engine speed was used to adjust the predicted torque when the air conditioner clutch was enabled by the microprocessor.

These early microprocessor based torque prediction systems were subject to the effect of changes in spark advance, EGR percent, and air/fuel ratio which occur over various barometric pressures, ambient temperatures and time since engine startup.

Referring to FIG. 2, also known in the prior art is an electronic engine control module including a stored table **118** which is a MBT spark adjustment for air/fuel read only memory function and has an input from air/fuel ratio input **115**. A block **119** is an indicated torque adjustment for air/fuel ratio and has an input from air/fuel ratio input **115**. A block **120** has a stored table for an unadjusted MBT spark and has inputs from engine speed rpm input **116** and air charge input **117**. A block **121** is an unadjusted indicated torque round table and has inputs from engine speed rpm input **116** and engine air charge input **117**. A block **122** has a stored table indicating friction torque read only memory table and has inputs from air charge input **117** and engine speed rpm indicator input **116**. A block **123** is a MBT spark adjustment for EGR, read only memory scalar and has an input from engine EGR rate input **114**.

A summer **124** has positive inputs from block **118**, block **123**, and block **120** to provide an adjusted MBT spark which is the sum of the outputs of blocks **118**, **123** and **120**. A summer **125** has a negative input from spark timing input **113** and a positive input from adder **124** to determine the difference between MBT and actual spark advance. The output of summer **125** is applied to a table storing the indicated torque adjustment for spark retard in a block **126**. The output of block **126** is applied

to a multiplier **127** which also has inputs from block **119** and block **121**. Multiplier **127** provides an adjusted indicated torque which is the product of blocks **119**, **121**, and **126**. The output of multiplier **127** is applied to a summer **128**. As an output of block **128**, brake torque is indicated less friction torque. The output of summer **128** is applied to a coupling to transmission **111**.

This level of microprocessor based control system had inaccuracies due to air conditioning head pressure, power steering torque requirements, cold engine friction, green engine friction, intentional or otherwise known cylinder shutdown (via spark or injector turn-off), and the influence of non-gasoline fuels like methanol/gasoline blends in flexible fuel vehicles.

A real time torque calculation is accomplished by determining the distance (i.e., actual spark advance) from MBT spark (SPK_DELTA) by looking up MBT spark (FN1617) and adjusting it for EGR (MBTEGR) and LAMBSE (FN730) then subtracting the actual current spark (SAFTOT). Indicated (COMBUSTION) engine torque is then looked up from a table of RPM and LOAD (FN1615A) and multiplied by a function of SPK_DELTA (FN621) and a function of LAMBSE (FN623).

Thus an improved torque prediction algorithm would be desirable to account for operating variables which influence torque output including engine coolant temperature and air conditioning friction.

SUMMARY OF THE INVENTION

This invention recognizes that a predicted torque calculation can be made more accurate by predicting the air conditioning torque requirement versus head pressure, power steering torque requirements versus power steering pressure switch, cold engine friction versus time since start and engine coolant temperature, green engine friction versus total engine revolutions since new, and the influence of non-gasoline fuels like methanol measured by a percent methanol sensor. The effect of intentional or otherwise known engine cylinder shutdown is also accounted for.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram of a means for inferring engine torque in accordance with an embodiment of this invention;

FIG. 2 is a logic flow diagram of the operation of an electronic engine control module in accordance with the prior art; and

FIGS. 3 and 3A is a logic flow diagram of the operation of an electronic engine control module in accordance with an embodiment of this invention.

FIG. 4 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating percent methanol fuel;

FIG. 5 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating air conditioning head pressure;

FIG. 6 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating air charge temperature;

FIG. 7 is a logical diagram of the operation of the electronic control module in accordance with an em-

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bodiment of this invention including an input indicating engine cooling temperature and a timer input;

FIG. 8 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating firing cylinders;

FIG. 9 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating engine operating hours; and

FIG. 10 is a logical diagram of the operation of the electronic control module in accordance with an embodiment of this invention including an input indicating power steering pressure.

DETAILED DESCRIPTION OF THE INVENTION

Torque calculation in accordance with an embodiment of this invention advantageously uses a speed/load table of indicated engine torques for 100% gasoline, all engine cylinders enabled, a stoichiometric air/fuel ratio, MBT spark, and 0% exhaust gas recirculation rate (EGR). The effects of percentage methanol, number of cylinders firing, spark retard, rich or lean air/fuel ratios, and EGR are accounted for through a series of multipliers. The calculations are based on indicated torque because the effects above act on top of the pistons, independently of various frictional losses which subtract from the indicated torque before it impacts the transmission. This formulation thus allows the effects to be accounted for with relatively simple indicated torque multipliers.

Alternately, the base indicated torque tables could be defined for a fuel other than gasoline, and the percent methanol modified could be for other flexible fuels like propane.

Torque calculation in accordance with an embodiment of this invention advantageously uses a speed-/AIRCHG table of friction torques for a warmed upengine, with friction stabilized (no longer reducing with engine hours), air conditioning clutch disabled, and power steering at straight ahead pressure level. Additional friction due to deviation from the above conditions always add to the friction torque.

The effect of cold engine friction is predicted from a table of engine coolant temperature and the time since the engine was started. Alternately, an oil temperature sensor replaces the engine coolant temperature sensor.

The effect of air conditioning torque requirements are predicted first from a flag indicating that the microprocessor has enabled the air conditioner clutch, and then from a table of torque requirements versus air conditioning head pressure and engine speed. Alternately, if the vehicle is not equipped with a head pressure sensor, inlet air temperature is a suitable predictor for head pressure and the table of torque requirements is a function of engine speed and inlet air temperature.

The effect of power steering torque requirements are predicted from a table of torque requirements versus power steering pressure level and engine speed. In its simplest form the power steering pressure is a two position switch indicating high and low pressure. Alternately, it is a continuous measurement.

The effect of green engine friction is predicted from an engine hour meter if the vehicle is so equipped. Alternately total engine revolutions could be used. The green engine friction torque losses are contained in a lookup table versus engine speed and engine hours.

In summary, the designations for inputs used in the torque calculation are:

RPM—engine speed (revolutions/minute), a sensor input.

AIRCHG—air charge lbs/cylinder-filling) which equals an estimate of air mass flow, (AM lbs/minute) divided by the number of cylinder fillings per minute: AIRCHG=AM/(RPM * ENGCYL/2) AM may be a direct output of an air meter or calculated in speed-density system.

SPK—final spark advance (degree BTDC), calculated and output by the microprocessor.

A/F—air/fuel ratio, a calculation modified by a feedback sensor.

EGR—actual EGR percent (%), a sensor input.

AC_FLG—air conditioning flag (1=A/C clutch engaged, 0=A/C clutch freewheeling), an output of the microprocessor.

ECT—engine coolant temperature (degrees Fahrenheit), a sensor input.

ACT—inlet air temperature (degrees Fahrenheit), a sensor input.

AC_PRES—air conditioning head pressure (inches Mercury), a sensor input.

PS_PRES—power steering pressure (inches Mercury), a sensor input.

TIMER—time since engine was started, a calculation.

PCT_METH—percent methanol in fuel (%), a sensor input.

FIRING_CYLS—number of cylinders firing which can be less than the number available, ENGCYL, for instance during decel fuel shutoff modes, a calculation by the microprocessor.

The designation for the output used in the torque calculation is:

BRAKE_TQ—brake engine torque (Fft-lbs)

The designations for calibration items used in the torque calculation are:

ENGCYL—number of engine cylinder available (=8 for 8 cylinder engine).

BASE_ITQ(RPM,AIRCHG)—a table containing indicated torque at MBT spark, stoichiometric air/fuel ratio 0% EGR, 100% gasoline, all cylinders firing.

ITQSPKMUL(SPKDEL)—indicated torque multiplier versus degrees of spark retard from MBT.

STOIC_A/F(PCT_METH)—the stoichiometric A/F ratio corresponding to the percent methanol.

ITQAFMUL(EQUIV_RATIO)—indicated torque multiplier versus equivalence ratio (air/fuel ratio divided by stoichiometric equivalence ratio for given percent methanol).

ITQPMMUL(PCT_METH)—indicated torque multiplier versus percent methanol.

BASE_MBT(RPM,AIRCHG)—a table of MBT spark values values corresponding to BASE_ITQ.

MBTAF(EQUIV_RATIO)—adder to BASE MBT due to deviation from stoichiometric equivalence ratio.

MBTPEREGR(AIRCHG)—number which when multiplied by percent EGR produces an adder to BASE_MBT.

MBTPM(PCT_METH,AIRCHG)—adder to BASE_MBT which accounts for less than 100% gasoline (percent methanol).

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MBTCOLD(ECT,AIRCHG)—adder which accounts for increase in BASE MBT when engine is cold.

BASE_FRIC_TQ(RPM,AIRCHG)—a table of friction torque values for a warmed-up engine, broken-in (friction stabilized), air conditioning clutch disabled, power steering at a base pressure level (straight ahead).

Note, the following tables have the suffix "TEA". This stands for Torque Equivalent AIRCHG. Multiplying the output of these tables by the TQ_PER AIRCHG constant Yields the desired torque for the balance of the calculations. The data is stored in AIRCHG units for convenience of sharing with other strategy elements needing similar information such as idle stability control.

COLD_FRIC_TEA(ECT,TIMER)—torque equivalent AIRCHG for cold friction versus engine coolant temperature and the time since the engine was started.

AC_FRIC_TEA(RPM,AC_HEAD_PRES-)—torque equivalent AIRCHG for the air conditioner torque requirements versus engine speed and air conditioning head pressure.

GREEN_FRIC_TEA(RPM,ENG_HOURS)—adder which when converted to torque compensates for higher friction in a new ("green") engine.

PS_FRIC_TEA(RPM,PS_PRES)—adder which when converted to torque compensates BASE FRIC_TQ for power steering pump torque requirements.

The torque calculation is performed by the following sequence of operations:

```
AIRCHG = AM/(ENGCYL*N)
STOIC_A/F = (100 − PCT_METH)*14.6 * PCT_METH*7.6
EQUIV_RATIO = A/F / STOIC_A/F
SPK_MBT = BASE_MBT(RPM,AIRCHG) + MBTAF(EQUIV_RATIO) +
          MBTPEREGR(AIRCHG)*EGR +
          MBTPM(PCT_METH,AIRCHG) +
          MBTCOLD(ECT,AIRCHG)
SPKDEL = SPK_MBT − SPK
IND_TQ = BASE_ITQ(RPM,AIRCHG) * ITQSPKMUL(SPKDEL)
          * ITQAFMUL(EQUIV_RATIO) * ITQPMMUL(PCT_METH)
          * FIRING_CYLS/ENGCYL
MISC_FRIC_TEA = COLD_FRIC_TEA(ECT,TIMER)
                + AC_FRIC_TEA(RPM,AC_HEAD_PRES)
                + PS_FRIC_TEA(RPM,PS_PRES)
                + GREEN_FRIC_TEA(RPM,ENG_HOURS)
MISC_FRIC_TQ = MISC_FRIC_TEA * TQ_PER_AIRCHG
TOTAL_FRIC_TQ = BASE_FRIC_TQ + MISC_FRIC_TQ
BRAKE_TQ = IND_TQ − TOTAL_FRIC_TQ
```

All of the above functions can be developed from engine mapping data. Some data is stored as torque equivalent airflows to enable its use for idle stability control strategy.

Referring to FIGS. **1**, **3**, and **3A**, air and fuel are applied to an engine **10** which has a torque and a rpm output applied to a transmission **11**. Both engine **10** and transmission **11** are coupled to an electronic engine control module **12** which includes various algorithms for processing a spark timing input **13**, an exhaust gas recirculation rate input **14**, a percent methanol fuel input **15**, an air/fuel ratio input **16**, an engine rpm input **17**, an engine air charge input **18**, an engine coolant temperature **19**, a firing cylinder indication input **20**, engine operating hours **21**, power steering pressure **22**, a timer input **23**, an input **24** indicating air conditioning head pressure or air change temperature, and a flag input **25** indicating air conditioning on or off.

Referring to FIGS. **1**, **3**, and **3A** electronic engine control module **12** includes a stored table **26** which is a MBT spark adjustment for EGR read only memory function and has an input from AIRCHG input **18**. The output of table **26** is applied to a multiplier **27** which also has inputs from EGR input **14**. A block **28** is a MBT spark adjustment for percent methanol and has an input from PCT_METH input **15**. A block **29** has a stored table for the stoichiometric fuel/air ratio as a function of percent methanol and has an input from PCT_METH input **15**. Multiplier **30** provides an equivalence ratio which is the product of stoichiometric fuel/air ratio from block **29** and the of air/fuel ratio input **16**.

When there is no percent methanol input **15**, e.g. in situations where only gasoline is used and the fuel, the stoichiometric fuel to air ratio of 0.0685 is used as a multiplier in place of block **29**. A block **31** is a MBT spark adjustment for equivalence ratio and has an input from multiplier **30**. A block **32** has a stored table for an unadjusted MBT spark and has inputs from engine speed RPM input **17** and air charge input **18**. A block **33** has a stored table of MBT spark adjustments for cold engine coolant temperature and has inputs from ECT input **19** and AIRCHG input **18**.

A summer **34** has positive inputs from multiplier **27**, block **28**, block **31**, block **32** and block **33** to provide an adjusted MBT spark which is the sum of the output of multiplier **27** and blocks **28**, **31**, **32**, and **33**. A summer **35** has a negative input from spark timing input **13** and a positive input from adder **34** to determine the difference between MBT and actual spark advance. The output of summer **35** is applied to a table storing the indicated torque adjustment for spark retard in a block **36**.

A block **37** is an unadjusted indicated torque round table and has inputs from engine speed RPM input **17** and engine air charge input **18**.

A block **38** is an indicated torque adjustment for equivalence ratio and has an input from multiplier **30**.

A block **39** is an indicated torque adjustment for percent methanol and has an input from PCT_METH input **15**.

A block **40** is an indicated torque adjustment for the percent of engine cylinders firing and has an input from FIRING_CYLS input **20** and read only memory scalar ENGCYL, the number of cylinders available.

Multiplier **41** has positive inputs from block **36**, block **37**, block **38**, block **39**, and block **40** to provide indicated

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torque which is the product of the outputs of block **36**, block **37**, block **38**, block **39**, and block **40**.

A block **42** has cold friction torque equivalent airflow and has inputs from engine coolant temperature input **19** and time since start input **23**. A block **43** has green engine friction torque equivalent airflow and has inputs from engine hours input **21** and engine speed RPM input **17**. A block **44** has power steering pump torque equivalent airflow and has inputs from power steering pressure input **22** and engine speed RPM input **17**. A block **45** has air conditioning compressor torque equivalent airflow when the air conditioner is turned on and has inputs fro air conditioning head pressure input **24** and engine speed RPM input **17**. The output of block **45** is applied to a multiplier **46** which also has inputs from AC FLAG input **25**. The output of multiplier **46** is the air conditioning compressor torque equivalent airflow.

A summer **47** has positive inputs from block **42**, block **43**, block **44**, and multiplier **46** to provide miscellaneous torque equivalent airflow which is the sum of the output of blocks **42**, **43**, **44**, and multiplier **46**.

A block **48** is a friction torque adjustment for torque equivalent airflow, read only memory scalar and has input from summer **47**.

A block **49** is an unadjusted friction torque round table and has inputs from engine speed RPM input **17** and engine air charge input **18**.

A summer **50** has positive inputs from block **48** and block **49** to provide total friction torque which is the sum of the output of blocks **48** and **49**.

A summer **51** has a negative input form summer **50** and a positive input from multiplier **41** to provide brake torque which is the sum of the negative output of sum **50** and positive output of multiplier **41**.

The output of summer **51** is used to schedule transmission line pressures and other powertrain applications.

Subcombinations of the inputs of FIGS. **3** and **3A** are possible to generate a brake torque output. That is, various additional inputs can be added to a base input group combination of spark input **13**, exhaust gas recirculation input **14**, air/fuel ratio input **16**, engine rpm input **17**, air charge input **18**, engine coolant temperature input **19** and air conditioning flag input **25**. To the base input group can be added, separately, the following inputs to create new input combinations to generate brake torque:

1.) percent methanol input **15** (FIG. **4**)
2.) air conditioning head pressure or air charge temperature input **24** (FIG. **5** and **6**)
3.) timer input **23** (FIG. **7**)
4.) firing cylinder number **20** (FIG. **8**)
5.) engine hours input **21** (FIG. **9**)
6.) power steering pressure input **22** (FIG. **10**)

Particularly advantageous combinations of inputs and processing blocks include those of Figures:

A) FIGS. **6**, **7**, and **8**
B) FIGS. **5**, **7**, **8** and **10**
C) FIGS. **5**, **7**, **8**, **9** and **10**
D) FIGS. **4**, **5**, **7**, **8** and **10**
E) FIGS. **4**, **5**, **7**, **8**, **9** and **10**

The processing of the above inputs is as shown in the referred Figures and are deviations from the arrangement illustrated in and discussed in connection with FIGS. **3** and **3A**. That is, tables which would normally receive information from inputs which are not used do not provide a table generated output. As mentioned before, in the absence of a percent methanol input **15**, the output from table **29** is a stoichiometric fuel/air ratio of 0.068.

Various modifications and variations will no doubt occur to those skilled in the art to which this invention pertains. For example, information processing constructions other than that described herein may be used in conjunction with this invention. These and all other such variations are to be considered within the scope of the appended claims.

What is claimed:

1. A method of determining engine torques in an internal combustion engine including the steps of:

providing inputs for carrying signals indicating engine spark timing, exhaust gas circulation percent, percent methanol, air/fuel ratio, engine speed, engine coolant temperature, the number of firing cylinders, number of engine hours of operation the power steering pressure, a timer input, an air conditioning head pressure input, and an air conditioning (A/C) on/off flag;

providing stored tables in a memory indicating relationships between air charge and MBT PER EGR (a first table), stoichiometric air/fuel versus percent methanol (a second table), a MBT percent methanol versus percent methanol (a table three), and MBT air/fuel ratio versus equivalence ratio (a fourth table), a base MBT versus air charge as a function of rpm (a fifth table), MBT cold versus air charge as a function of engine coolant temperature (a sixth table), a base indicted torque versus air charge as a function of rpm (a seventh table), an indicated torque air/fuel multiplier versus equivalence ratio (an eighth table), an indicated torque percent methanol multiplier versus percent methanol (a ninth table), an indicated spark multiplier versus spark delay (a tenth table), a cold friction torque equivalent air charge versus the timer as a function of engine coolant temperature (an eleventh table), a green friction torque equivalence charge versus engine hours as a function of rpm (a twelfth table), power steering friction torque equivalent air charge versus power steering pressure as a function of rpm (a thirteenth table), an air conditioning frictional torque equivalence charge versus air conditioning head pressure as a function of rpm (a fourteenth table), a base friction torque versus air charge as a function of rpm (a fifteenth table);

applying the air charge input to said first table, said fifth table, said sixth table, said seventh table, and said fifteenth table;

applying the output of said first table and the output of the egr input to a first multiplier;

applying the output of the first multiplier to the positive input of a first adder;

applying an output from the first adder to the positive input of a second adder;

and applying the output of the spark input to a negative input of said second adder;

applying said percent methanol input to said second table and said third table and said ninth table;

applying said air/fuel ratio input to a second multiplier which also receives an input from the second table, the output of the second multiplier being applied to said fourth table and said eighth table;

applying said engine speed input to said fifth table, said seventh table, said twelfth table, said thirteenth table, said fourteenth table, and said fifteenth table;

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applying said engine coolant input to said sixth table and said eleventh table;

applying the number of firing cylinders input to an inverter which has an output applied to a multiplier three, which also receives input from table nine, table seven, multiplier two through table eight, said second adder through table ten;

applying inputs to adder one from table five, table six, table four, and table three;

applying said engine hours input to table twelve;

applying said power steering pressure input to table thirteen; applying said timer input to table eleven, applying said air conditioning head pressure to table fourteen, and applying the AC flag to a multiplier four which also receives an input from table fourteen;

applying the output of adder three to a torque per air charge module applying an output from said torque per air charge module to an adder four, applying an input from table fifteen to said adder four;

applying the output of adder four to an adder five as a negative input, and applying a positive input to said adder five from multiplier three; and

providing an output from adder five indicating brake torque.

2. A method of determining engine torque in an internal combustion engine including the steps of:

providing inputs for carrying signals indicating engine spark timing, exhaust gas circulation percent, percent methanol, air/fuel ratio, engine speed, engine coolant temperature, and an air conditioning (A/C) on/off flag;

providing stored tables in a memory indicating relationships between air charge and MBT PER EGR (a first table), stoichiometric air/fuel versus percent methanol (a second table), and MBT percent methanol versus percent methanol (a table three), and MBT spark adder ratio versus equivalence ratio (a fourth table), a base MBT versus air charge as a function of rpm (a fifth table), MBT cold versus air charge as a function of engine coolant temperature (a sixth table), a base indicated torque versus air charge as a function of rpm (a seventh table), an indicated torque air/fuel multiplier versus equivalence ratio (an eighth table), an indicated torque percent methanol multiplier versus percent methanol (a ninth table), an indicated spark multiplier versus spark delay (a tenth table), a base friction torque versus air charge as a function of rpm (a fifteenth table); and an air conditioning torque versus engine speed (a sixteenth table);

applying the air charge input to said first table, said fifth table, said sixth table, said seventh table, and said fifteenth table;

applying the output of said first table and the output of the egr input to a first multiplier;

applying the output of the first multiplier to the positive input of a first adder;

applying an output from the first adder to the positive input of a second adder;

and applying the output of the spark input to a negative input of said second adder;

applying said percent methanol input to said second table and said third table and said ninth table;

applying said air/fuel ratio input to a second multiplier which also receives an input from the second table, the output of the second multiplier being applied to said fourth table and said eighth table;

applying said engine speed input to said fifth table, said seventh table, and said fifteenth table;

applying said engine coolant input to said sixth table;

applying inputs to adder one from table five, table six, table four, and table three;

applying the output of adder two to table ten;

applying to a multiplier three outputs from table nine, table seven, table eight, and table ten;

applying the output of multiplier three as a positive input to an adder five, applying the output of table fifteen to a negative input of adder five and applying the output of multiplier four to a negative input of adder five;

applying the AC flag to a multiplier four which also receives inputs from table sixteen; and

providing an output from adder five indicating brake torque.

3. A method of determining engine torque in an internal combustion engine including the steps of:

providing inputs for carrying signals indicating engine spark timing, exhaust gas circulation percent, air/fuel ratio, engine speed, engine coolant temperature, an air conditioning head pressure input, and an air conditioning (A/C) on/off flag;

providing stored tables in a memory indicating relationships between air charge and MBT PER EGR (a first table), stoichiometric air/fuel versus percent methanol (a second table), and MBT spark adder versus equivalence ratio (a fourth table), a base MBT versus air charge as a function of rpm (a fifth table), MBT cold versus air charge as a function of engine coolant temperature (a sixth table), a base indicated torque versus air charge as a function of rpm (a seventh table), an indicated torque air/fuel multiplier versus equivalence ratio (an eighth table), an indicated spark multiplier versus spark delay (a tenth table), an air conditioning friction torque equivalence charge versus air conditioning head pressure as a function of rpm (a fourteenth table), a base friction torque versus air charge as a function of rpm (a fifteenth table);

applying the air charge input to said first table, said fifth table, said sixth table, said seventh table, and said fifteenth table;

applying the output of said first table and the output of the egr input to a first multiplier;

applying the output of the first multiplier to the positive input of a first adder;

applying an output from the first adder to the positive input of a second adder;

and applying the output of the spark input to a negative input of said second adder;

applying said air/fuel ratio input to a fuel/air table, the output of the fuel/air ratio table being applied to said fourth table and said eighth table;

applying said engine speed input to said fifth table, said seventh table, said fourteenth table, and said fifteenth table;

applying said engine coolant input to said sixth table;

a multiplier three receives inputs from tables seven, eight and ten.

applying inputs to adder one form table five, table six, table four, and multiplier one;

applying said air conditioning head pressure to table fourteen, and applying the AC flag to a multiplier four which also receives inputs from table fourteen;

applying the output of multiplier four to a torque per air charge module applying an output from said

torque per air charge module to an adder four applying an input from table fifteen to said adder four;

applying the output of summer four to an adder five as a negative input, and applying a positive input to said adder five from multiplier three; and

providing an output from adder five indicating brake torque.

4. A method of determining engine torque in an internal combustion engine including the steps of:

providing inputs for carrying signals indicating engine spark timing, exhaust gas circulation percent, air/fuel ratio, engine speed, engine coolant temperature, an air conditioning (A/C) on/off flag, and an air charge temperature input;

providing stored tables in a memory indicating relationships between air charge and MBT PER EGR (a first table), stoichiometric air/fuel versus percent methanol (a second table), and MBT spark adder versus equivalence ratio (a fourth table), a base MBT versus air charge as a function of rpm (a fifth table), MBT cold versus air charge as a function of engine coolant temperature (a sixth table), a base indicated torque versus air charge as a function of rpm (a seventh table), an indicated torque air/fuel multiplier versus equivalence ratio (an eighth table), an indicated spark multiplier versus spark delay (a tenth table), an air conditioning frictional torque equivalence charge versus air charge temperature as a function of rpm (a fourteenth table), a base friction torque versus air charge as a function of rpm (a fifteenth table);

applying the air charge input to said first table, said fifth table, said sixth table, said seventh table, and said fifteenth table;

applying the output of said first table and the output of the egr input to a first multiplier;

applying the output of the first multiplier to the positive input of a first adder;

applying an output from the first adder to the positive input of a second adder;

and applying the output of the spark input to a negative input of said second adder;

applying said air/fuel ratio input to a fuel/air ratio table, the output of the fuel/air ratio table being applied to said fourth table and said eighth table;

applying said engine speed input to said fifth table, said seventh table, said fourteenth table, and said fifteenth table;

applying said engine coolant input to said sixth table;

a multiplier three receives inputs from tables seven, eight and ten;

applying inputs to adder one from table five, table six, table four, and multiplier one;

applying air change temperature to table fourteen and applying the AC flag to a multiplier four which also receives inputs from table fourteen;

applying the output of multiplier four to a torque per air charge module, applying an output from said torque per air charge module to an adder four, applying an input from table fifteen to said adder four;

applying the output of said adder four to an adder five as a negative input, and applying a positive input to said adder five from multiplier three; and

providing an output from adder five indicating brake torque.

5. A method of determining engine torque in an internal combustion engine including the steps of:

providing inputs for carrying signals indicating engine spark timing, exhaust gas circulation percent, air/fuel ratio, engine speed, engine coolant temperature, a timer input, and an air conditioning (A/C) on/off flag;

providing stored tables in a memory indicating relationships between air charge and MBT PER EGR (a first table), stoichiometric air/fuel versus percent methanol (a second table), and MBT spark adder versus equivalence ratio (a fourth table), a base MBT versus air charge as a function of rpm (a fifth table), MBT cold versus air charge as a function of engine coolant temperature (a sixth table), a base indicated torque versus air charge as a function of rpm (a seventh table), an indicated torque air/fuel multiplier versus equivalence ratio (an eight table), an indicated spark multiplier versus spark delay (a tenth table), a cold friction torque equivalent air charge versus the timer as a function of engine coolant temperature (an eleventh table), a base friction torque versus air charge as a function of rpm (a fifteenth table) an air conditioning torque versus rpm (a sixteenth table);

applying the air charge input to said first table, said fifth table, said sixth table, said seventh table, and said fifteenth table;

applying the output of said first table and the output of the egr input to a first multiplier;

applying the output of the first multiplier to the positive input of a first adder;

applying an output from the first adder to the positive input of a second adder;

applying the output of the spark input to a negative input of said second adder;

applying said air/fuel ratio input to a fuel/air ratio table the output of the fuel/air ratio table being applied to said fourth table and said eighth table;

applying said engine speed output to said fifth table, said seventh table, said fifteenth table and said sixteenth table;

applying said engine coolant input to said sixth table and said eleventh table;

applying to a multiplier three inputs from tables seven, eight and said second adder through table ten;

applying inputs to adder one from table five, table six, table four, and multiplier one;

applying said timer input to table eleven, and applying the AC flag to a multiplier four which also receives inputs from table sixteen;

applying the output of table eleven to a torque per air charge module, applying an output from said torque per air charge module to an adder four, applying an input from table fifteen to said adder four;

applying the output of adder four to an adder five as a negative input, and applying a positive input to said adder five from multiplier three; and

providing an output from adder five indicating brake torque.

6. A method of determining engine torque in an internal combustion engine including the steps of:

providing inputs for carrying signals indicating engine spark timing, exhaust gas circulation percent, air/fuel ratio, engine speed, engine coolant temper-

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ature, the number of firing cylinders, and an air conditioning (A/C) on/off flag;

providing stored tables in a memory indicating relationships between air charge and MBT PER EGR (a first table), stoichiometric air/fuel versus percent methanol (a second table), and MBT spark adder versus equivalence ratio (a fourth table), a base MBT versus air charge as a function of rpm (a fifth table), MBT cold versus air charge as a function of engine coolant temperature (a sixth table), a base indicated torque versus air charge as a function of rpm (a seventh table), an indicated torque air/fuel multiplier versus equivalence ratio (an eighth table), an indicated spark multiplier versus spark delay (a tenth table), a base friction torque versus air charge as a function of rpm (a fifteenth table);

applying the air charge input to said first table, said fifth table, said sixth table, said seventh table, and said fifteenth table;

applying the output of said first table and the output of the egr input to a first multiplier;

applying the output of the first multiplier to the positive input of a first adder;

applying an output from the first adder to the positive input of a second adder;

and applying the output of the spark input to a negative input of said second adder;

applying said air/fuel ratio input to a fuel/air table the output of the fuel/air ratio table being applied to said fourth table and said eighth table;

applying said engine speed input to said fifth table, said seventh table, said fifteenth table;

applying said engine coolant input to said sixth table;

applying the number of firing cylinders input to a multiplier indicating the inverse of the number of cylinders which has an output applied to a multiplier three, which also receives inputs from table seven, eight and ten, and said second adder through table ten;

applying inputs to adder one from table five, table six, table four, and multiplier one;

and applying the AC flag to a multiplier four which also receives inputs from table sixteen

applying a positive input to said adder five form multiplier three, a negative input from multiplier four, and a negative input from table fifteen; and

providing an output from adder five indicating brake torque.

7. A method of determining engine torque in an internal combustion engine including the steps of:

providing inputs for carrying signals indicating engine spark timing, exhaust gas circulation percent, air/fuel ratio, engine speed, engine coolant temperature, power steering pressure, and an air conditioning on/off flag;

providing stored tables in a memory indicating relationships between air charge and MBT PER EGR (a first table), stoichiometric air/fuel versus percent methanol (a second table), and MBT air/fuel ratio versus equivalence ratio (a fourth table), a base MBT versus air charge as a function of rpm (a fifth table), MBT cold versus air charge as a function of engine coolant temperature (a sixth table), a base indicated torque versus air charge as a function of rpm (a seventh table), an indicated torque air/fuel multiplier versus equivalence ratio (an eighth table), an indicated spark multiplier versus spark delay (a tenth table), power steering friction torque equivalent air charge versus power steering pressure as a function of rpm (a thirteenth table), a base friction torque versus air charge as a function of rpm (a fifteenth table), and an air conditioning torque versus rpm (a sixteenth table);

applying the air charge input to said first table, said fifth table, said sixth table, said seventh table, and said fifteenth table;

applying the output of said first table and the output of the egr input to a first multiplier;

applying the output of the first multiplier to the positive input of a first adder;

applying an output from the first adder to the positive input of a second adder;

and applying the output of the spark input to a negative input of said second adder;

applying said air/fuel ratio input to a fuel/air ratio table the output of the fuel/air ratio table being applied to said fourth table and said eighth table;

applying said engine speed output to said fifth table, said seventh table, said thirteenth table, said fifteenth table, and said sixteenth table;

applying to multiplier three inputs from table seven and eight and an input from said second adder through table ten;

applying inputs to adder one from table five, table six, table four, and multiplier one;

applying said power steering pressure input to table thirteen, and applying the AC flag to a multiplier four which also receives inputs from table sixteen;

applying the output of table thirteen to a torque per air charge module, applying an output from said torque per air charge module to an adder, applying an input from table fifteen to said adder four;

applying the output of adder four to an adder five as a negative input, and applying a positive input to said adder five from multiplier three; and

providing an output from adder five indicating brake torque.

* * * * *

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US006047681A

United States Patent [19]

Scherer et al.

[11] **Patent Number: 6,047,681**

[45] **Date of Patent: Apr. 11, 2000**

[54] **PROCESS AND APPARATUS FOR ADJUSTING THE TORQUE OF AN INTERAL-COMBUSTION ENGINE**

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[73] Assignee: **DaimlerChrysler AG**, Germany

[21] Appl. No.: **08/901,453**

[22] Filed: **Jul. 28, 1997**

[30] **Foreign Application Priority Data**

Jul. 26, 1996 [DE] Germany 196 30 213

[51] **Int. Cl.**[7] **F02P 5/02**; F02D 43/04

[52] **U.S. Cl.** **123/406.46**; 123/406.5; 123/406.51

[58] **Field of Search** 123/339.11, 329, 123/406.23, 406.46, 406.5, 406.51

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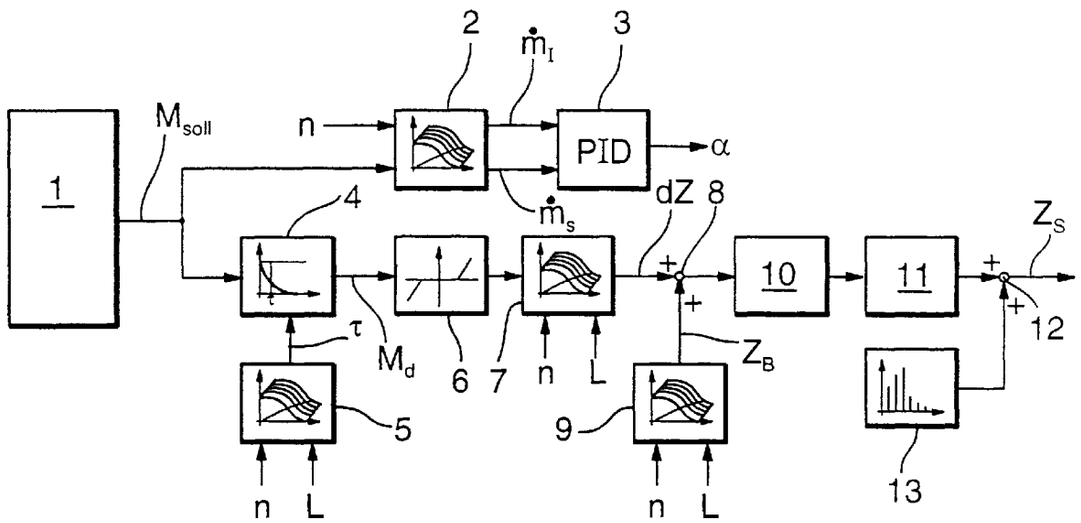
Primary Examiner—Erick R. Solis

Attorney, Agent, or Firm—Evenson, McKeown, Edwards & Lenahan, P.L.L.C.

[57] **ABSTRACT**

The invention provides a process and an apparatus for controlling the engine torque of an internal-combustion engine. A dynamic desired torque component is determined from a demanded desired engine torque, and is used to determine a corresponding displacement of the ignition point or of the injection start, while a remaining quasi-static desired torque component is regulated by a corresponding adjustment of the air flow rate or of the fuel injection duration.

19 Claims, 2 Drawing Sheets



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Fig. 1

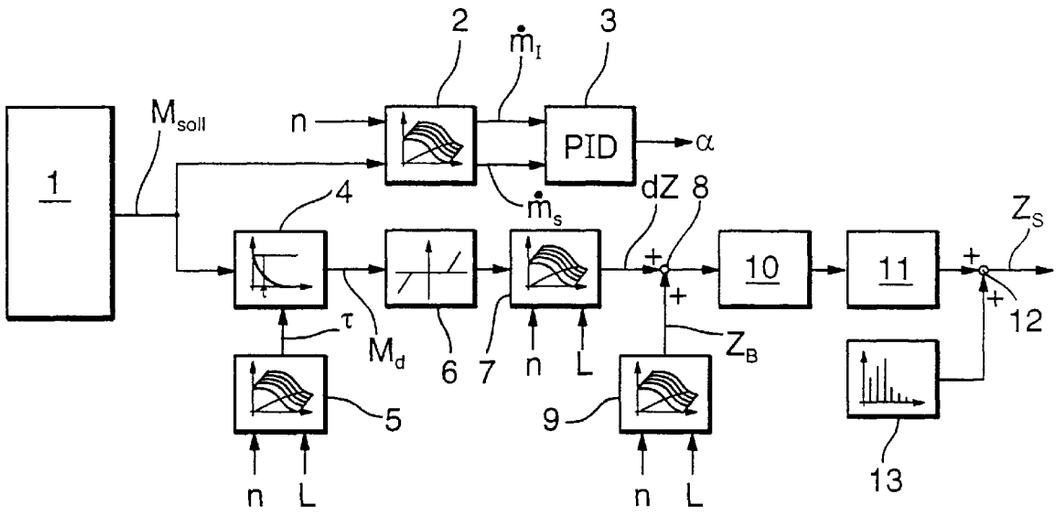

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13
n L
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Fig. 2

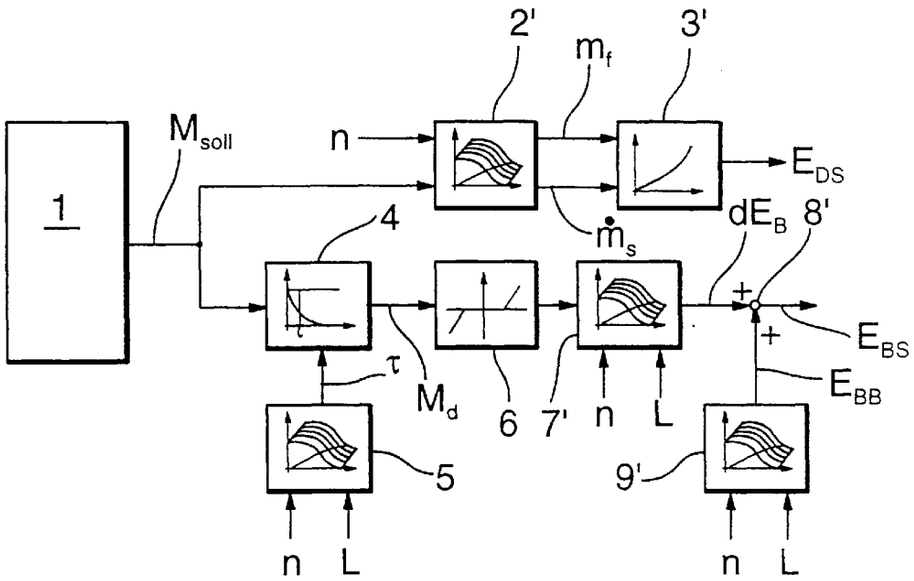

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3'
M_{soll}
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E_{DS}
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E_{BS}
τ
M_d
6 7' n L
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5
9'
n L
n L

Fig. 3

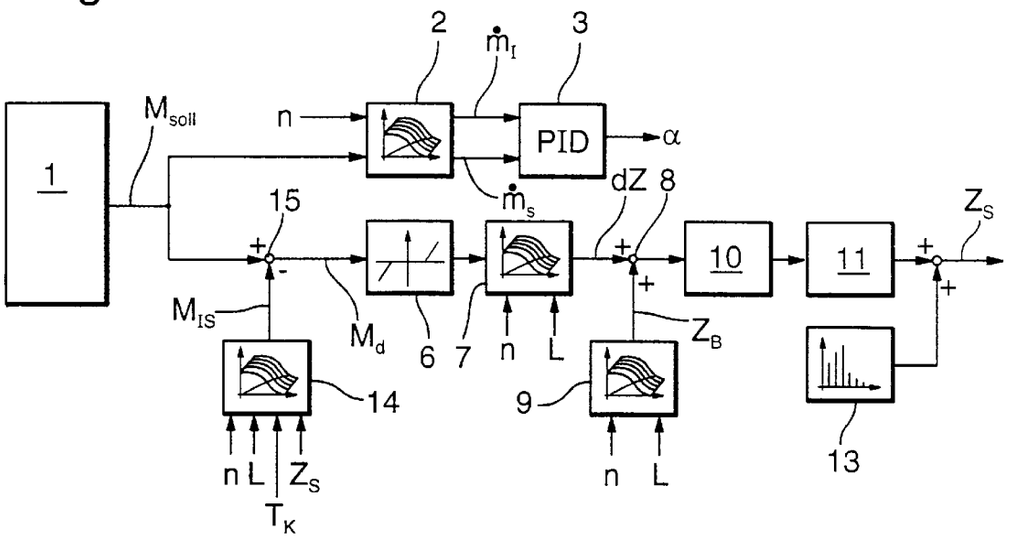
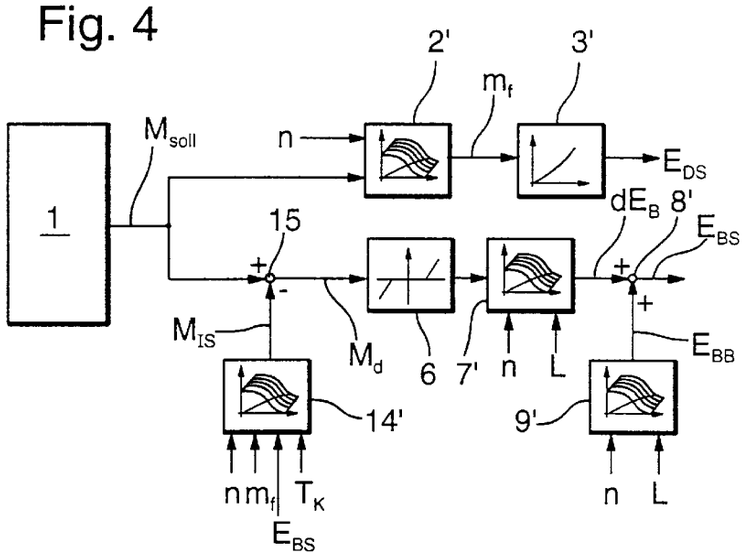


Fig. 4



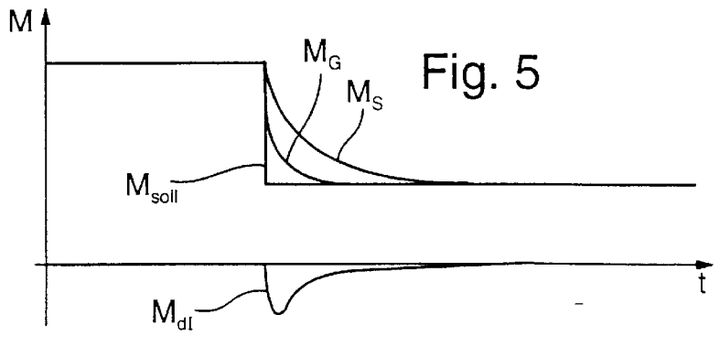


Fig. 5

PROCESS AND APPARATUS FOR ADJUSTING THE TORQUE OF AN INTERAL-COMBUSTION ENGINE

BACKGROUND AND SUMMARY OF THE INVENTION

The invention relates to a process and apparatus for adjusting the torque of an internal-combustion engine by regulating the ignition point and the air flow rate in an Otto engine, or by regulating the start and the duration of fuel injection in a diesel engine.

Modern Otto engines usually have an electronic throttle valve control system for regulating the air flow rate, in which the accelerator pedal is mechanically uncoupled from the throttle valve. To regulate the pertaining transmission line of a vehicle, modern engine—transmission management concepts use a torque interface in which the desired engine torque is normally adjusted either statically by means of a characteristic diagram which links the air flow rate, rotational engine speed and engine torque quantities, or dynamically by means of an air flow rate control. The dynamics of engine torque regulation by controlling only the air flow rate are significantly restricted by the finite speed of the throttle valve control element, and mainly by the filling characteristics of the suction pipe. However, certain engine functions, such as the idling regulating or traction upshift in the case of automatic transmissions, require a highly dynamic engine (that is, rapid) torque response, which cannot be satisfactorily achieved by the quasi-static air flow rate regulation. Conventionally, the required highly dynamic engine torque response is therefore achieved by ignition control, the resulting engine torque intervention not being coordinated with the air flow rate regulating. Such ignition control usually consists of a slight displacement of the ignition point, which is predetermined as a function of the engine operating point. In the case of diesel engines with electronic fuel injection, the demanded engine torque is conventionally adjusted exclusively by a corresponding selection of the injection duration, while the injection start is normally predetermined as a function of the engine operating point.

German Patent Document DE 42 15 107 C1 discloses a process for controlling an internal-combustion engine in which a desired value for the torque transmitted to the road is determined from the angular position of the accelerator pedal. Taking into account the transmitting function of the engine and of the transmission line, the fuel quantity to be injected into the internal-combustion engine is determined from this desired value. Based on the fuel quantity to be injected, a desired value is then determined for the required air flow rate taking into account a desired value for the fuel/air ratio, by inverting a predetermined suction pipe dynamics function. The air flow rate is then regulated by the corresponding adjustment of a throttle valve control element. The fuel quantity actually injected is then determined by means of the measured actual air flow rate.

German Published Patent Document DE 44 40 640 A1 discloses a process for transient control of an internal-combustion engine, which takes into account the accumulating effect of the suction pipe. For this purpose, a control unit uses an air flow rate density function (filed in a memory) to generate a value for the air flow rate at the cylinder input as a function of the suction pipe air density and the rotational engine speed. From this value a pertaining engine load value is then determined.

A fuel control unit for an internal-combustion engine disclosed in German Patent Document DE 41 12 908 A1 achieves a fast fuel control response during an engine acceleration without a reduction of the engine output torque, by following up the first injection calculated on the basis of the intake air temperature and of the internal cylinder pressure, with a second injection quantity which is calculated on the basis of the engine acceleration condition.

A device for controlling and/or regulating the fuel metering and/or the ignition angle of an internal-combustion engine disclosed in German Patent Document DE 39 42 966 A1 is designed so that, in the steady-state operation, the measuring value of a periodically fluctuating quantity (for example, the suction pipe pressure) which is crank-angle-synchronously measured once per ignition, is used always at the same crankshaft position for controlling or regulating the fuel metering or the ignition angle. In dynamic operation, on the other hand, every measuring value is used for controlling or regulating the fuel metering or the ignition angle. As a result, the transition from steady-state to dynamic engine operation can be recognized very rapidly, and can be taken into account in adjusting the fuel metering or the ignition angle.

German Patent Document DE 43 15 885 C1 discloses a process for adjusting the desired output torque of an internal-combustion engine, in which a desired engine load value is determined from the desired output torque, as a function of the rotational engine speed and the throttle valve opening angle. The measured actual value is regulated to the desired value by adjusting of the throttle valve control element. Conversion between regulation of the load and regulation of the air flow rate takes place by means of a load filter, which compensates the deviations of the measured air flow rate occurring in dynamic operating conditions from the air flow rate actually flowing into the combustion space. The transition between the two types of regulation can take place in a continuous or switched manner, preferably by using a one-sided hysteresis during the change-over from engine load regulation to air flow rate regulation.

One object of the present invention is to provide a process and apparatus of the initially mentioned type which adjusts the engine torque to a desired value with the least possible expenditures in both steady-state and transient engine operation with a comparatively short reaction time.

Another object of the invention is to ensure an engine operation with optimal fuel consumption and the exhaust gas emissions.

These and other objects and advantages are achieved by the torque adjustment process and apparatus according to the invention, in which the demanded desired engine torque is split into a dynamic component and a remaining quasi-static component. The dynamic component is used to determine corresponding adjustment of the ignition point in the case of an Otto engine or of the injection start in the case of a diesel engine. That is, the dynamic component is used as a command variable for a desired-engine-torque-dependent displacement of the ignition point or of the injection start, while the quasi-static desired torque component is regulated by means of a corresponding adjustment of the air flow rate (for an Otto engine) or of the injection duration (a diesel engine). In order to achieve minimal exhaust emission and fuel consumption, variation of the ignition point or of the injection start is expediently kept as small as possible. This means that the dynamic desired torque component represents exactly that part of the demanded desired engine torque which cannot be adjusted by the quasi-statically (that is, more sluggishly) reacting air flow rate or injection duration adjustment alone. Therefore, the present invention permits

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optimal coordination of quasi-static engine torque adjustment (by way of air flow rate and injection duration regulation) on the one hand, and highly dynamic engine torque adjustment (by regulating the ignition point or the injection start), on the other hand.

In a preferred embodiment of the invention, the dynamic desired torque component is determined by high-pass filtering of the demanded desired engine torque with a decay time constant which is selected as a function of the engine operating point.

In another preferred embodiment, a model-based estimation is made of the quasi-static desired torque component achieved by air flow rate or injection duration regulation. To obtain the dynamic desired torque component, the estimated value is subtracted from the demanded desired engine torque. In the simplest case, the model can be formed by a characteristic diagram of the quasi-static actual torque component as a function of rotational engine speed, engine cooling water temperature and, in the case of an Otto engine, the engine load and ignition point or, in the case of a diesel engine, the fuel quantity (and thus of the injection duration) and the injection start.

Other objects, advantages and novel features of the present invention will become apparent from the following detailed description of the invention when considered in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a block diagram of a device according to the invention for engine torque adjustment in an Otto engine which determines a dynamic desired torque component by high-pass filtering;

FIG. **2** is a block diagram of a device according to the invention for engine torque adjustment in a diesel engine which determines a dynamic desired torque component by high-pass filtering;

FIG. **3** is a block diagram of a device for engine torque adjustment in an Otto engine which determines a dynamic desired torque component using a model-based estimate of a quasi-static actual torque component;

FIG. **4** is a block diagram of a device according to the invention for engine torque adjustment in a diesel engine which determines a dynamic desired torque component using a model-based estimate of a quasi-static actual torque component; and

FIG. **5** is a diagram which illustrates the operation of the devices of FIGS. **1** to **4** in the case of a sudden change of the desired engine torque.

DETAILED DESCRIPTION OF THE DRAWINGS

FIGS. **1** to **4** are block diagrams which show different devices for adjusting the engine torque in the case of Otto or diesel engines. For a better understanding, the mutually functionally corresponding components and the same physical quantities have the same reference symbols in the various figures.

FIG. **1** illustrates a device for adjusting engine torque which is suitable for an Otto engine. On the input side, an engine torque coordination unit **1** provides a signal indicative, for example, of the desired engine torque (M_{des}) requested by the driver via the accelerator pedal. This desired engine torque signal (M_{des}) is, on the one hand, supplied to a device for regulating the air flow rate and to a high pass filter which is connected in front of a device for adjusting the ignition point. The device for regulating the air flow rate includes an input-side air flow rate calculating unit **2** and an adjoining PID air flow rate regulator **3**. The air flow rate calculating unit **2** receives information concerning the momentary rotational engine speed (n) as well as the demanded desired engine torque (M_{des}), and uses this information to calculate a desired air flow rate value ($\dot{m}_s$), based on a stored characteristic diagram.

In addition, the air flow rate calculating unit **2** also detects the actual air flow rate value ($\dot{m}_I$) by way of a corresponding sensor system, and transmits both the actual value (m_I) and the associated desired value ($\dot{m}_s$) to the PID air flow rate regulator **3** which determines therefrom a suitable control signal (α) for an air-flow-rate-regulating throttle valve. As is well known, because of the finite throttle valve adjusting speed and mainly because of the suction pipe filling characteristics, engine torque cannot be adjusted in this manner to follow a highly dynamic desired engine torque change without a noticeable sluggishness. That is, it can adjust only a quasi-static desired engine torque part.

In order to adjust the dynamic desired torque component which exceeds this quasi-static part, an ignition point adjusting branch, with the input-side high-pass filter, is provided in parallel to the air-flow-rate-regulating branch. The ignition point adjusting branch is able to react very rapidly to sudden changes of the engine torque; however, in order to minimize exhaust emissions and fuel consumption, the ignition point displacement implemented by this branch must be kept as low as possible. This means that the ignition point adjusting branch is used only to adjust specifically that dynamic desired engine torque component which cannot be regulated by the air-flow-rate-regulating branch. The high pass filter stage, which precisely determines this dynamic desired torque component (M_d), consists of a high pass filter **4** with an adjustable decay time constant (τ), and a characteristic time constant diagram unit **5** which indicates the decay time constant (2) for the high pass filter **4** by means of a stored characteristic diagram, as a function of the rotational engine speed (n) and of the engine load (L). For example, in the case of a higher rotational engine speed (n), a larger decay time constant (τ) is provided. As a result, the high pass filter **4** filters the dynamic desired engine torque part (M_d), as a function of the engine operating point, from the desired engine torque (M_{des}) supplied to it, and in turn provides the dynamic desired engine torque (M_d) to the device for the ignition point adjustment which follows. Due to the high pass characteristic of the high pass filter stage, after the decay of the transients during a change of the engine torque desire, and at a constant engine load, the dynamic desired torque component (M_d) will completely disappear. This ensures a return of the engine operating condition to the optimal range, for both consumption and emission.

The device for the ignition point adjustment receives the dynamic desired torque component (M_d) from the high pass filter **4**, by way of an input-side dead zone unit **6** which suppresses very small ignition point changes. Thereafter, unit **7** determines an ignition point displacement (dZ) which corresponds to the supplied dynamic desired torque component (M_d) as a function of the rotational engine speed (n) and of the engine load (L), by means of a stored characteristic diagram. An adder **8** adds this ignition point displacement (dZ) to an ignition point base value (Z_B) determined by an ignition point calculating unit **9** by means of a stored characteristic diagram as a function of the rotational engine speed (n) and of the engine load (L). A unit **10** limits the rate of change of the ignition point value supplied by the Adder **8** to a predeterminable extent, and a unit **11** limits its

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absolute value; that is, the unit **11** limits the ignition point value to a predeterminable maximum. The resulting ignition point adjusting signal is supplied to an adder **12** which adds it to the output signal of a conventional knock regulating stage **13**. The output signal of the adder **12** is then used as an adjusting signal (Z_S) for the ignition point adjustment. It is understood that the ignition point can be expressed as an ignition angle relative to a reference angle, for example, the top of dead center of piston of a reciprocating piston engine.

The embodiment of FIG. **1** therefore permits a comparatively rapid engine torque adjustment which can follow very fast desired engine torque changes, and after the conclusion of a transient phase changes back comparatively rapidly to an operation which is optimal with respect to exhaust emissions and fuel consumption.

FIG. **2** shows a device which is functionally analogous to that of FIG. **1** and which is suitable for a diesel fuel engine with an electronic diesel injection. To the extent that the same components and physical quantities are shown here as in FIG. **1**, which is recognizable by the use of the same reference symbols, reference can be made concerning their description to statements concerning FIG. **1**. As a modification, instead of an air flow rate regulating device, a device for adjusting the fuel injection duration is provided, which comprises a unit **2'** for calculating the fuel flow rate and a unit **3'** for calculating the injection duration. The fuel flow rate calculating unit **2'** determines the fuel flow rate ($\dot{m}_f$) by means of a stored characteristic diagram, as a function of the supplied rotational engine speed (n) and the supplied desired engine torque (M_{des}). From the fuel flow rate value (m_f) supplied to it, the injection duration calculating unit **3'** determines a corresponding injection duration by means of a stored characteristic curve, and emits this information as an injection duration adjusting signal (E_{DS}).

Instead of the ignition point adjusting branch of the device of FIG. **1**, the device of FIG. **2** contains an injection start adjusting branch. The high pass filter stage **4**, **5** which is connected at the head of this branch has a decay time constant (2) that can be adjusted as a function of the engine operating point. The dead zone unit **6** (analogous to FIG. **1**) is followed by a unit **7'** which determines an injection start displacement (dE_B) corresponding to the dynamic desired engine torque component (M_d), by means of a stored characteristic diagram, as a function of the rotational engine speed (n) and of the engine load (L). The determined injection start displacement (dE_B) is added in an adder **8'**, to an injection start base value (E_{BB}) which is calculated by an injection start determination unit **9'** by means of a stored characteristic diagram as a function of the rotational engine speed (n) and the engine load (L). The output signal of the adder **8'** is used as the injection start adjusting signal (E_{BS}). It is understood that the injection start can be represented as a injection start angle relative to a reference angle, for example, the top of dead center of a particular piston of a reciprocating piston engine.

The method of operation of the device of FIG. **2** and the resulting advantageous effects correspond to those of the device of FIG. **1**, to which reference is made here. The comparatively rapidly reacting injection start adjusting branch regulates precisely that dynamic desired engine torque part (M_d) which cannot be regulated by the more sluggish, that is, quasi-statically reacting, device for adjusting the injection duration in the case of sudden changes of the desired engine torque. After the termination of a transient phase, the system changes comparatively rapidly back to the method of operation in which the engine torque is adjusted only by way of a corresponding adjustment of the injection duration, and which is optimal with respect to the exhaust gas emissions and the fuel consumption.

FIG. **3** again shows a device which is suitable for torque adjustment of an Otto engine. This embodiment corresponds to that of FIG. **1** except that, instead of the high pass filter stage, a model-based estimated value stage is provided to determine the dynamic desired engine torque component (M_d) that cannot be regulated by the air flow rate regulation, by estimating the quasi-static engine torque part (M_{IS}) which can be adjusted by the air flow rate regulation. With respect to the remaining components, reference can be made to the description of FIG. **1**.

The estimated value stage contains an estimated value determination unit **14** and a subtractor **15**. The estimated value determination unit **14** estimates the quasi-static engine torque part (M_{IS}) which can be controlled by the air flow rate regulating branch, by means of a stored model for the air flow rate regulation as a function of the supplied actual values of the rotational engine speed (n), the engine load (L), the engine cooling water temperature (T_K) and the ignition point adjusting signal (Z_S). In the simplest case, this model comprises a characteristic diagram which determines the quasi-static engine torque part (M_{IS}) of the air flow rate regulation as a function of the four mentioned input quantities. The estimated value (M_{IS}) for the quasi-static engine torque part is subtracted by means of the subtracting device **15** from the demanded desired engine torque (M_{des}), and the resulting difference is transmitted to the dead zone unit **6** as the dynamic desired engine torque part (M_d) to be regulated by the ignition point adjusting branch.

The method of operation of the embodiment of FIG. **3**, and the advantageous effects achievable thereby, correspond to those of the embodiment of FIG. **1**, to which reference can be made here. In particular, by means of this device, the dynamic desired torque component which was not adjusted by the air flow rate regulation can be considerably reduced directly by a suitable change of the ignition point. The characteristic diagram stored in the unit **7** for calculating the ignition point displacement can easily be applied because the ignition point displacement required for an engine torque change at a particular operating point can be determined in a steady-state manner on an engine test bench.

The embodiment of FIG. **4**, which is adapted for a diesel engine, is identical with that of FIG. **2** except that, instead of the high pass filter stage, (analogously to the modification of FIG. **3** in comparison to that of FIG. **1**), an estimated value stage is provided. This estimated value stage corresponds essentially to that of FIG. **3**. It contains a modified estimated value determination unit **14'** which estimates the quasi-static engine torque (M_{IS}) which can still be mastered by the injection duration adjusting branch, by means of a stored model as a function of the supplied rotational engine speed (n), the fuel flow rate ($\dot{m}_f$), the injection start adjusting signal (E_{BS}) and the engine cooling water temperature (T_K) quantities. The estimated value (M_{IS}) is then subtracted in the subtractor device **15** from the demanded desired engine torque (M_{des}), and the resulting difference signal is treated as the dynamic desired engine torque part (M_d) which is to be regulated by the injection start adjusting branch and is supplied to the dead zone unit **6**. The method of operation of the device of FIG. **4**, and the advantages achieved by means of it, otherwise correspond to those of the device according to FIG. **2**, to which reference can be made here.

FIG. **5** which illustrates the operation of the embodiments of FIGS. **1** to **4**, shows an example of the engine torque (M) as a function of time (t). At a defined point in time, an abrupt

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reduction occurs of the demanded desired engine torque (M_{des}). The quasi-static engine torque part (M_S), which can be controlled by the quasi-statically reacting air flow rate regulating branch or injection duration adjusting branch, follows the abrupt desired torque change only comparatively slowly. In contrast, the ignition point adjusting branch (or the injection start adjusting branch) reacts very rapidly and supplies a dynamic engine torque part (M_{dI}) which follows the abrupt desired engine torque change very rapidly.

The engine torque (M_G), which is adjusted as a whole by the respective device, is additively composed of the dynamic (M_{dI}) and the quasi-static engine torque component (M_S) and in this manner follows the abrupt desired engine torque change much better than the quasi-static engine torque component by itself (M_S). As soon as the adjusted overall engine torque (M_G) has approximately reached the now reduced desired engine torque value (M_{des}), the dynamic engine torque part (M_{dI}) caused by the ignition point adjusting branch (or the injection start adjusting branch) returns relatively rapidly to zero. Thereafter the engine torque adjustment to the subsequent quasi-static desired engine torque value (M_{des}) is again taken over solely by the air flow rate regulating branch (or by the injection duration adjusting branch) in a manner which is optimal with respect to the exhaust gas emissions and the fuel consumption. An analogous method operation is naturally obtained for highly dynamic increases of the desired engine torque.

Although the invention has been described and illustrated in detail, it is to be clearly understood that the same is by way of illustration and example, and is not to be taken by way of limitation. The spirit and scope of the present invention are to be limited only by the terms of the appended claims.

We claim:

1. Process for controlling engine torque of an internal-combustion engine in response to a demanded desired engine torque signal, comprising:

determining a dynamic desired torque component (M_d), from said demanded desired engine torque (M_{des});

determining a corresponding ignition point displacement (dZ) based on the dynamic desire torque component (M_d);

adjusting an ignition point of said engine in response to said ignition point displacement; and

adjusting a remaining quasi-static desired torque component by a corresponding adjustment of the air flow rate of said engine;

wherein said determining of a dynamic desired torque component (M_d) comprises high pass filtering of the demanded desired engine torque (M_{des}) by means filter having a decay time constant (2) predetermined as a function of an engine operating point of said engine.

2. Process for controlling engine torque of an internal-combustion engine in response to a demanded desired engine torque signal, comprising:

determining a dynamic desired torque component (M_d), from said demanded desired engine torque (M_{des});

determining a corresponding ignition point displacement (dZ) based on the dynamic desire torque component (M_d);

adjusting an ignition point of said engine in response to said ignition point displacement; and

adjusting a remaining quasi-static desired torque component by a corresponding adjustment of the air flow rate of said engine;

wherein the quasi-static desired torque component which can be adjusted by adjustment of the air flow rate is estimated by means of an air flow rate model, and the dynamic desired torque component (M_d) is determined by subtraction of an estimated value from the demanded desired engine torque (M_{des}).

3. Process for controlling engine torque of an internal-combustion engine in response to a demanded desired engine torque signal, comprising:

determining a dynamic desired torque component (M_d) from said demanded desired engine torque (M_{des});

determining a corresponding injection start displacement (dE_B) based on the dynamic desired torque component (M_d);

adjusting an injection start of said engine in response to said injection start displacement; and

adjusting a remaining quasi-static desired torque component by a corresponding adjustment of the injection duration of said engine.

4. Device for controlling engine torque of an internal-combustion engine in response to a demanded desired engine torque signal, comprising:

a device for demanding a desired engine torque (M_{des});

a device for adjusting an air flow rate of said engine;

a device for adjusting an ignition point of said engine; and

a device for determining a dynamic desired torque component (M_d) of the demanded desired engine torque (M_{des}) which cannot be regulated by the device for adjusting the air flow rate, the determined dynamic desired torque component being supplied to the device for adjusting the ignition point as an indication of a corresponding displacement of the ignition point.

5. Device for controlling the engine torque in the case of an internal-combustion engine in response to a demanded desired engine torque signal, comprising:

a device for demanding a desired engine torque (M_{des})

a device for adjusting a fuel injection duration of said engine;

a device for adjusting a fuel injection start of said engine; and

a device for determining a dynamic desired torque component (M_d) of the demanded desired engine torque (M_{des}) which cannot be regulated by the device for adjusting the fuel injection duration, the determined dynamic desired torque component being supplied to the device for adjusting the injection start as an indication for a corresponding displacement of the injection start of said engine.

6. Process for controlling engine torque of an internal combustion engine in response to a demanded desired engine torque signal by adjusting a first engine operating parameter to which said engine torque has a relatively rapid response, and a second engine operating parameter to which said engine torque has a relatively slower response, said processing comprising:

determining a first dynamic component of said demanded desired engine torque;

determining a second, remaining quasi-static component of said demanded desired engine torque;

adjusting said first engine operating parameter based on said first component of said demanded desired engine torque, independently of said second component; and

adjusting said second engine operating parameter based on said second component of said demanded desired engine torque, independently of said first component.

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7. Apparatus for controlling engine torque of an internal combustion engine in response to a demanded desired engine torque signal by adjusting a first engine operating parameter to which said engine torque has a relatively rapid response, and a second engine operating parameter to which said engine torque has a relatively slower response, said apparatus comprising:

means for determining a first dynamic component of said demanded desired engine torque

means for determining a second, remaining quasi-static component of said demanded desired engine torque;

means for adjusting said first engine operating parameter based on said first component of said demanded desired engine torque, independently of said second component; and

means for adjusting said second engine operating parameter based on said second component of said demanded desired engine torque, independently of said first component.

8. A method of controlling engine torque of an internal combustion engine in response to a demanded desired engine torque signal corresponding a desired engine torque, comprising:

adjusting a quasi-static desired torque component by a corresponding adjustment of an intake air flow rate of said engine in response to said desired engine torque signal;

determining a portion of said desired engine torque which cannot be regulated by adjustment of the intake air flow rate;

determining a dynamic desired torque component corresponding to said determined portion of said desired engine torque;

adjusting an ignition point of said engine in response to said dynamic desired torque component, independently of quasi-static component.

9. Process according to claim 3, when said step of determining a dynamic desired torque component (M_d) comprises high pass filtering of the demanded desired engine torque (M_{des}) by means filter having a decay time constant (2) predetermined as a function of an engine operating point of said engine.

10. Process according to claim 3 wherein the quasi-static desired torque component which can be adjusted by adjustment of the fuel injection duration is estimated by means of a fuel injection duration model, and the dynamic desired torque component (M_d) is determined by subtraction of an estimated value from the demanded desired engine torque (M_{des}).

11. Device according to claim 4, where the device for determining the dynamic desired torque component (M_d) comprises a high pass filter stage which has a decay time constant (τ) that can be changed as a function of an operating point of said engine.

12. Device according to claim 4, wherein the device for determining the dynamic desired torque component (M_d) comprises an estimation unit which uses a stored model to estimate a quasi-static engine torque component which can be regulated by the device for adjusting the air flow rate, and determines the dynamic desired torque component (M_d) by subtraction of estimated values from the demanded desired engine torque (M_{des}).

13. Device according to claim 5, wherein the device for determining the dynamic desired torque component (M_d) contains a high pass filter stage which has a decay time constant (2) that can be changed as a function of an operating point of said engine.

14. Device according to claim 5, where the device for determining the dynamic desired torque component (M_d) comprises an estimation unit which uses a stored model to estimate a quasi-static engine torque component which can be regulated by the device for adjusting the injection duration, and determines the dynamic desired torque component (M_d) by subtraction of estimated values from the demanded desired engine torque (M_{des}).

15. Process according to claim 6 where said internal combustion engine is an Otto engine, said first engine operating parameter is air flow rate to said engine, and said second engine operating parameter is an engine ignition point.

16. Process according to claim 6 where said internal combustion engine is a Diesel engine, said first engine operating parameter is fuel injection duration, and said second engine operating parameter is a fuel injection starting point.

17. Process according to claim 6 where said step of determining said second component of said desired engine torque comprises subtracting said first component from said desired engine torque.

18. Apparatus according to claim 7 where said internal combustion engine is an Otto engine, said first engine operating parameter is air flow rate to said engine, and said second engine operating parameter is an engine ignition point.

19. Process according to claim 7 where said step of determining said second component of said desired engine torque comprises means for subtracting said first component from said desired engine torque.

* * * * *

US005282449A

United States Patent [19]

Takahashi et al.

[11] **Patent Number: 5,282,449**

[45] **Date of Patent: Feb. 1, 1994**

[54] **METHOD AND SYSTEM FOR ENGINE CONTROL**

[75] Inventors: **Shinsuke Takahashi**, Yokohama; **Teruji Sekozawa**, Kawasaki; **Makoto Shioya**, Suginami, all of Japan

[73] Assignee: **Hitachi, Ltd.**, Tokyo, Japan

[21] Appl. No.: **846,960**

[22] Filed: **Mar. 6, 1992**

[30] **Foreign Application Priority Data**

Mar. 6, 1991 [JP] Japan 3-039838

[51] **Int. Cl.**[5] **F02D 41/14**

[52] **U.S. Cl.** **123/350**; 123/480

[58] **Field of Search** 123/350, 399, 480, 478

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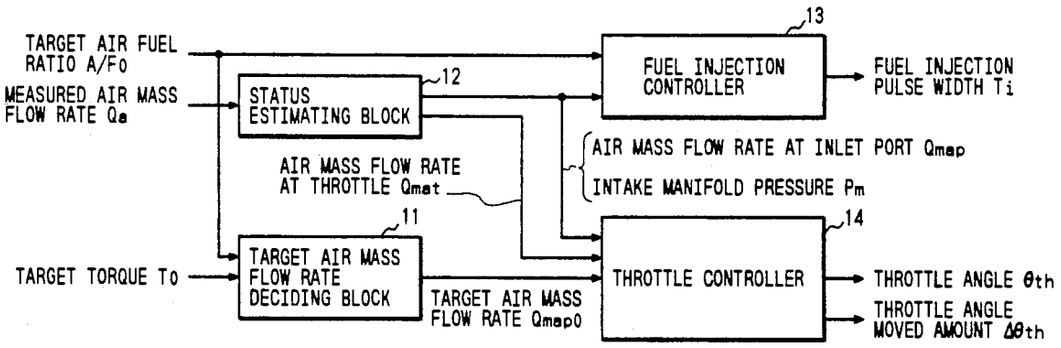
60-175742 9/1985 Japan .

Primary Examiner—Andrew M. Dolinar
Attorney, Agent, or Firm—Antonelli, Terry, Stout & Kraus

[57] **ABSTRACT**

To ensure a high-precision simultaneous control of the enginegenerated torque, air fuel ratio of the automobile engine and related factor, the present invention calculates the target air mass flow rate as the air mass flow rate at the inlet port which achieves the target torque, estimates the air flow condition inside the intake manifold, supplies the result to the fuel injection control system and the throttle control system, and determines the fuel injection pulse width which achieves the target air fuel ratio according to the estimated air mass flow rate at the inlet port for the fuel injection control system, while determining the throttle angle which achieves the target torque according to the estimated condition and the target air mass flow rate for the throttle control system.

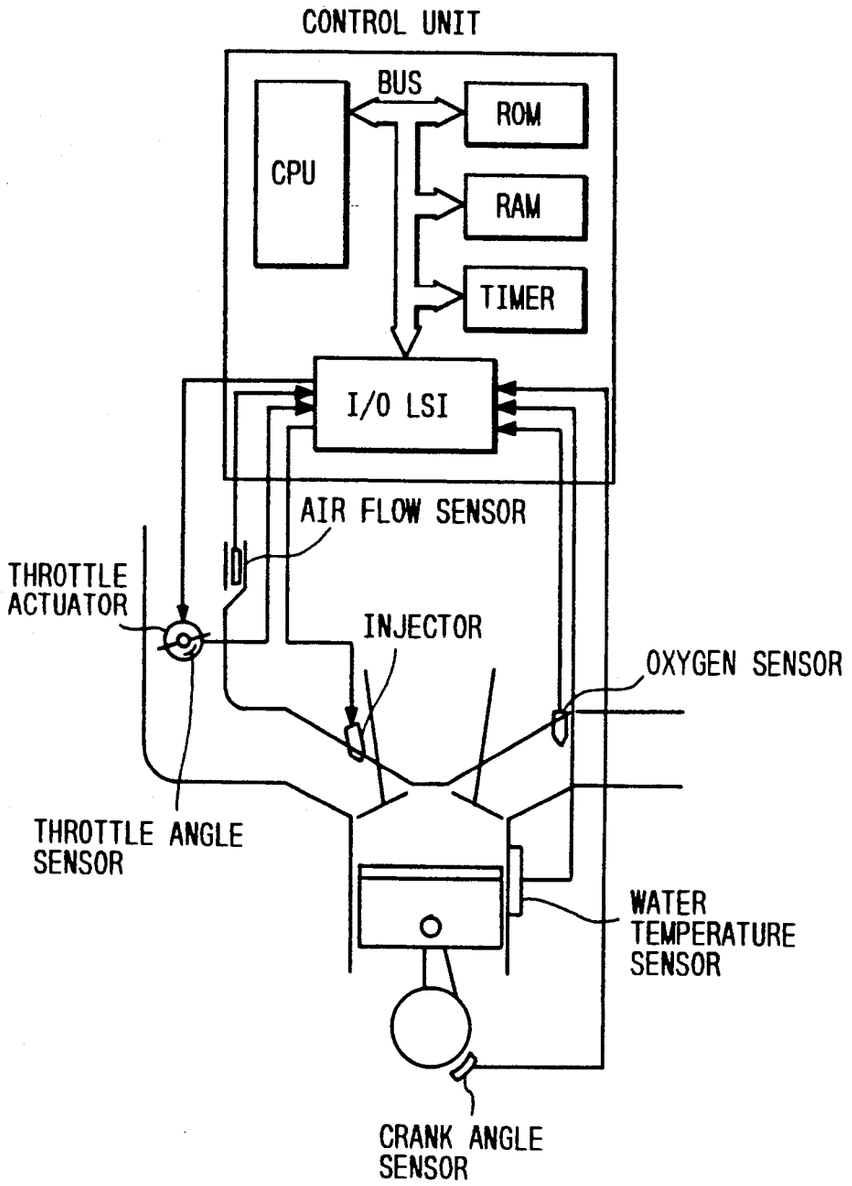
28 Claims, 12 Drawing Sheets



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FIG. 1



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FIG. 2

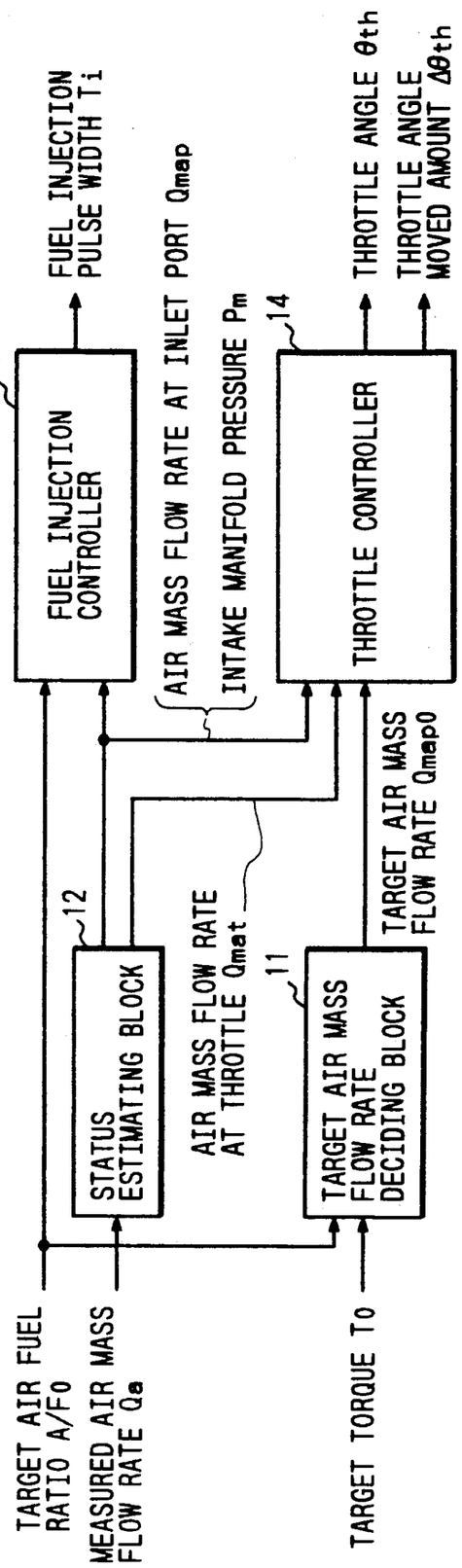

FUEL INJECTION PULSE WIDTH Ti
THROTTLE ANGLE θth
THROTTLE ANGLE MOVED AMOUNT Δθth
13
FUEL INJECTION CONTROLLER
AIR MASS FLOW RATE AT INLET PORT Qmap
INTAKE MANIFOLD PRESSURE Pm
14
THROTTLE CONTROLLER
12
STATUS ESTIMATING BLOCK
AIR MASS FLOW RATE AT THROTTLE Qmat
11
TARGET AIR MASS FLOW RATE DECIDING BLOCK
TARGET AIR MASS FLOW RATE Qmap0
TARGET AIR FUEL RATIO A/F0
MEASURED AIR MASS FLOW RATE Qa
TARGET TORQUE T0

FIG. 3

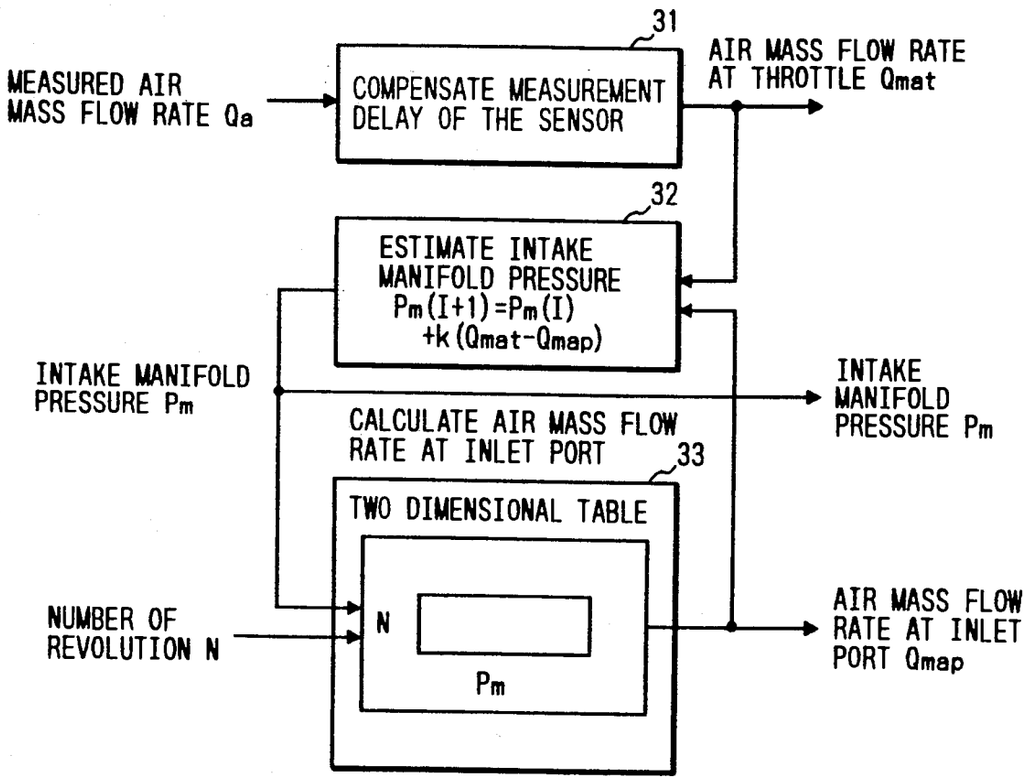

31
MEASURED AIR MASS FLOW RATE Qa
COMPENSATE MEASUREMENT DELAY OF THE SENSOR
AIR MASS FLOW RATE AT THROTTLE Qmat
32
ESTIMATE INTAKE MANIFOLD PRESSURE
Pm(I+1)=Pm(I)
+k(Qmat-Qmap)
INTAKE MANIFOLD PRESSURE Pm
INTAKE MANIFOLD PRESSURE Pm
CALCULATE AIR MASS FLOW RATE AT INLET PORT
33
TWO DIMENSIONAL TABLE
N
Pm
NUMBER OF REVOLUTION N
AIR MASS FLOW RATE AT INLET PORT Qmap

FIG. 4

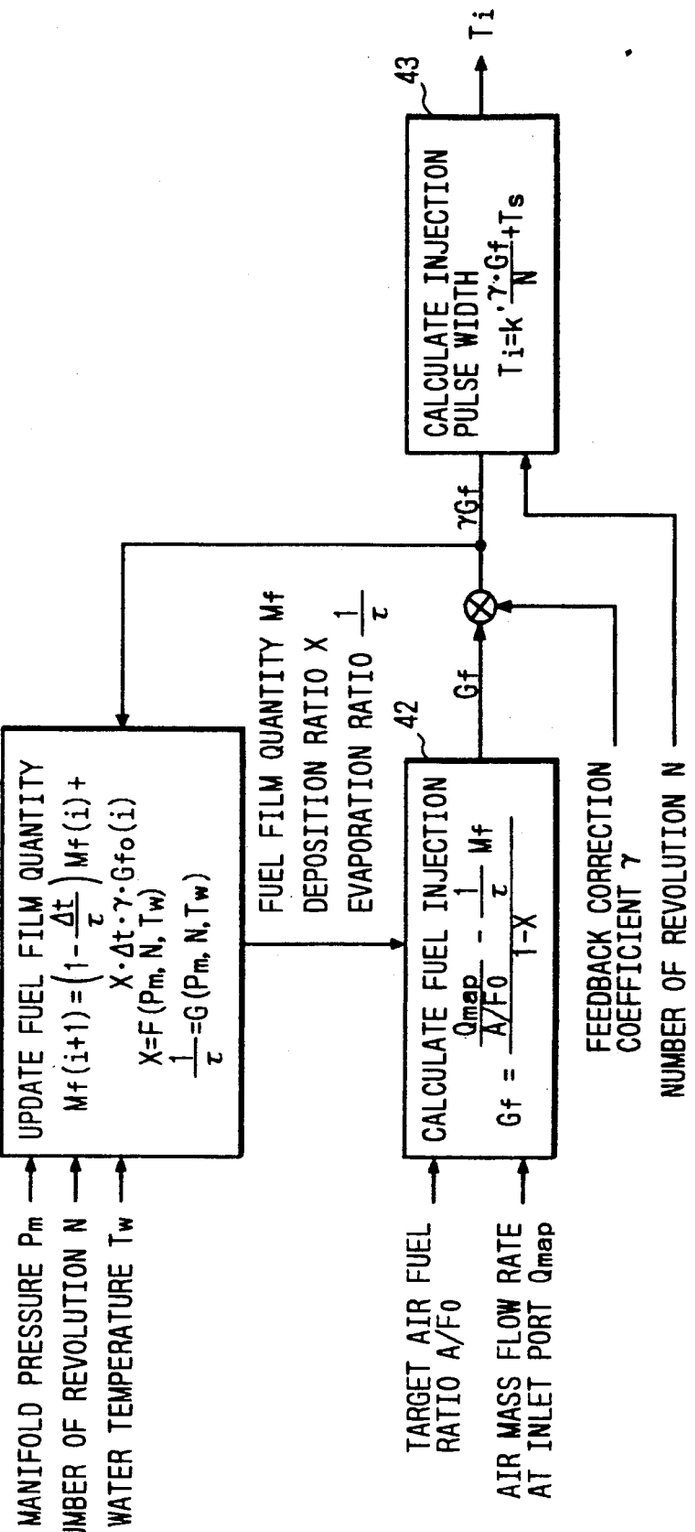

41
UPDATE FUEL FILM QUANTITY
$Mf(i+1)=\left(1-\frac{\Delta t}{\tau}\right)Mf(i)+X\cdot\Delta t\cdot\gamma\cdot Gfo(i)$
$X=F(Pm, N, Tw)$
$\frac{1}{\tau}=G(Pm, N, Tw)$
INTAKE MANIFOLD PRESSURE Pm
NUMBER OF REVOLUTION N
WATER TEMPERATURE Tw
FUEL FILM QUANTITY Mf
DEPOSITION RATIO X
EVAPORATION RATIO $\frac{1}{\tau}$
42
CALCULATE FUEL INJECTION
$Gf=\frac{\frac{Qmap}{A/Fo}-\frac{1}{\tau}Mf}{1-X}$
TARGET AIR FUEL RATIO A/Fo
AIR MASS FLOW RATE AT INLET PORT Qmap
Gf
γGf
FEEDBACK CORRECTION COEFFICIENT γ
NUMBER OF REVOLUTION N
43
CALCULATE INJECTION PULSE WIDTH
$Ti=k'\frac{\gamma\cdot Gf}{N}+Ts$
Ti

FIG. 5

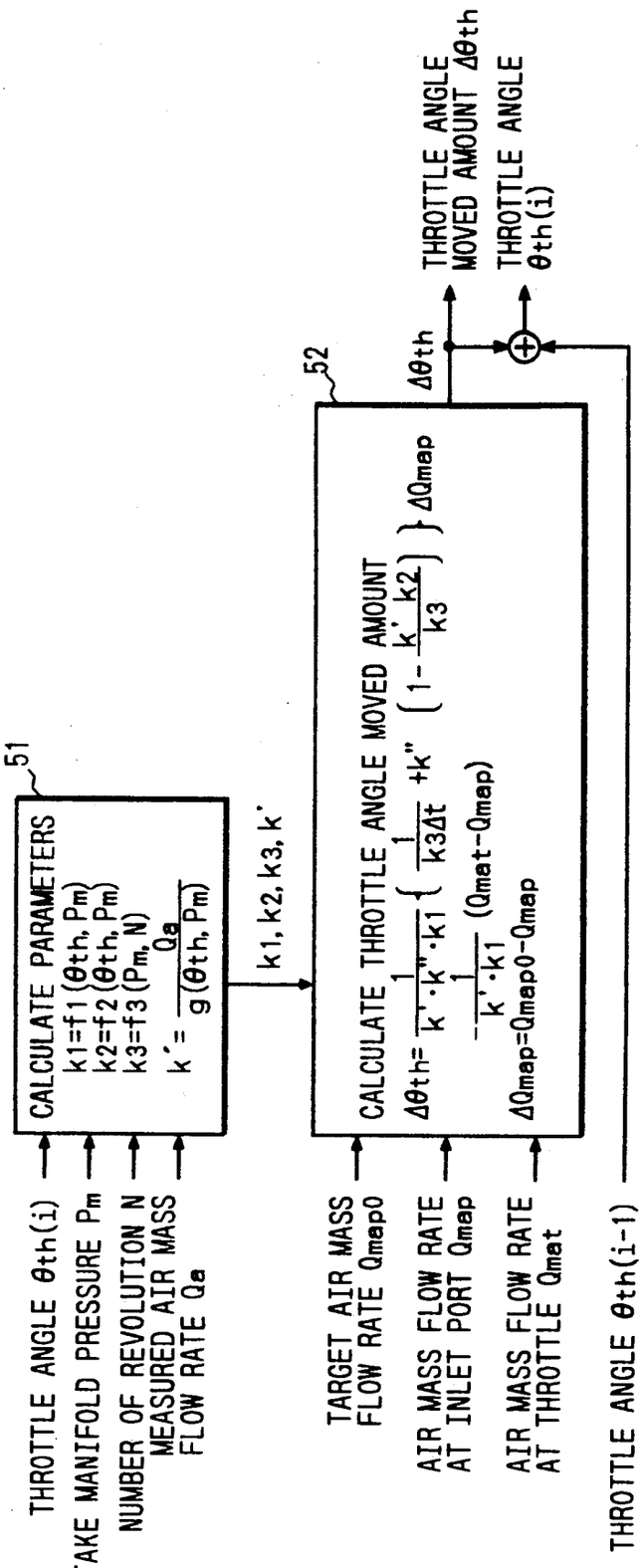

51
CALCULATE PARAMETERS
k1=f1(θth, Pm)
k2=f2(θth, Pm)
k3=f3(Pm, N)
k'=Qa / g(θth, Pm)
THROTTLE ANGLE θth(i)
INTAKE MANIFOLD PRESSURE Pm
NUMBER OF REVOLUTION N
MEASURED AIR MASS FLOW RATE Qa
k1, k2, k3, k'
52
CALCULATE THROTTLE ANGLE MOVED AMOUNT
Δθth= 1/(k'·k''·k1) { 1/(k3Δt) +k'' (1- k'·k2/k3) } ΔQmap
-1/(k'·k1) (Qmat-Qmap)
ΔQmap=Qmap0-Qmap
TARGET AIR MASS FLOW RATE Qmap0
AIR MASS FLOW RATE AT INLET PORT Qmap
AIR MASS FLOW RATE AT THROTTLE Qmat
THROTTLE ANGLE θth(i-1)
Δθth
THROTTLE ANGLE MOVED AMOUNT Δθth
THROTTLE ANGLE θth(i)

FIG. 6

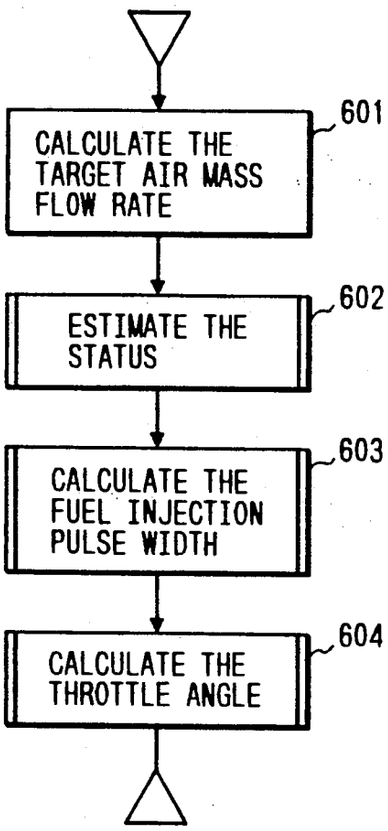
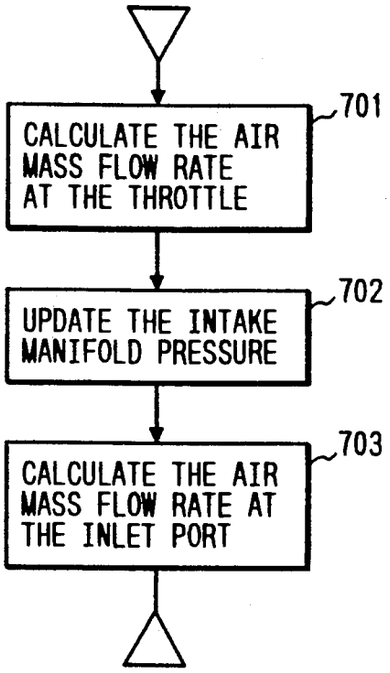


FIG. 7



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FIG. 8

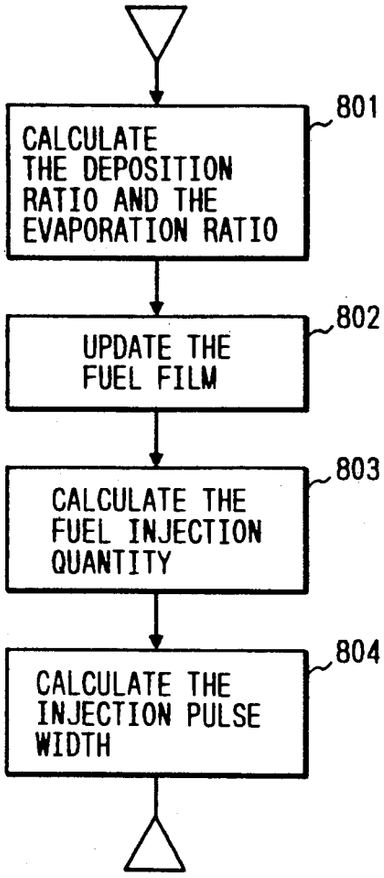


FIG. 9

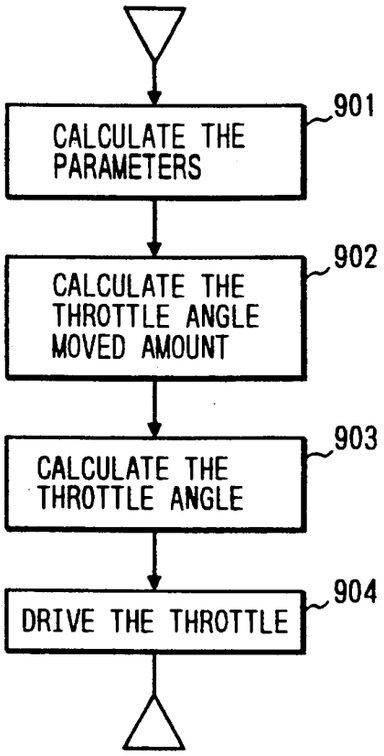


FIG. 10

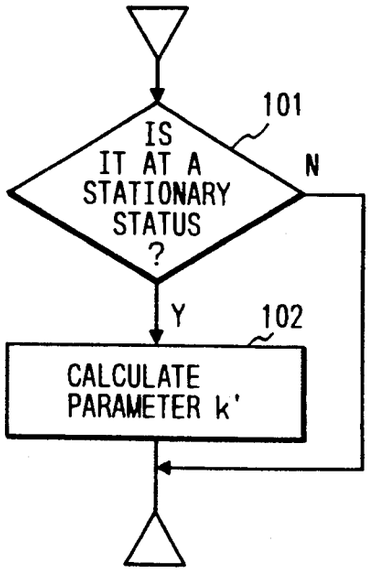


FIG. 11

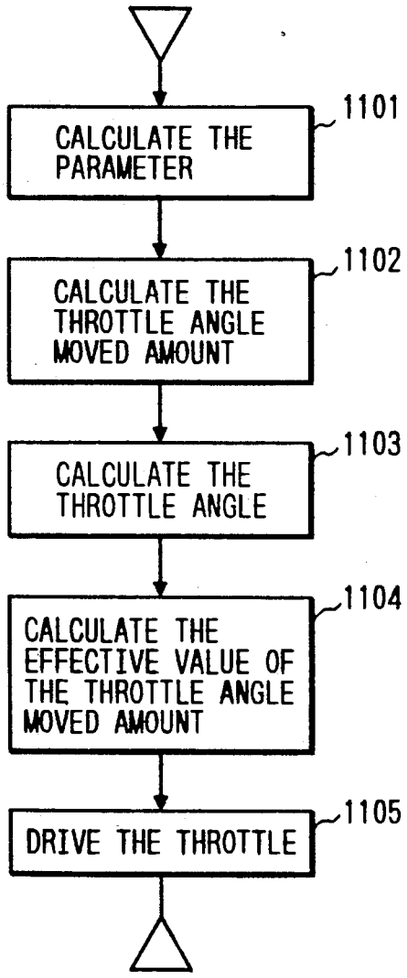
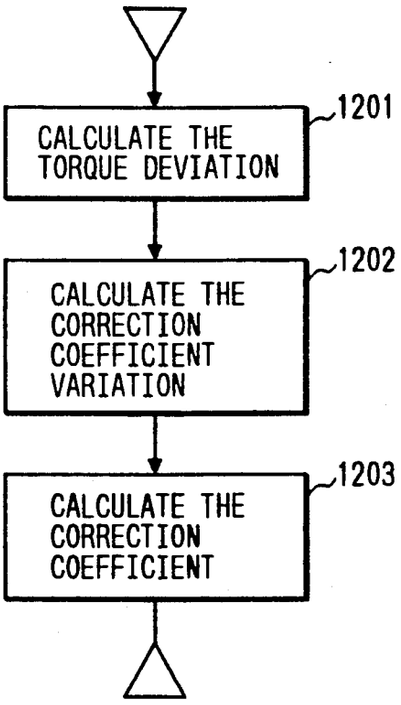
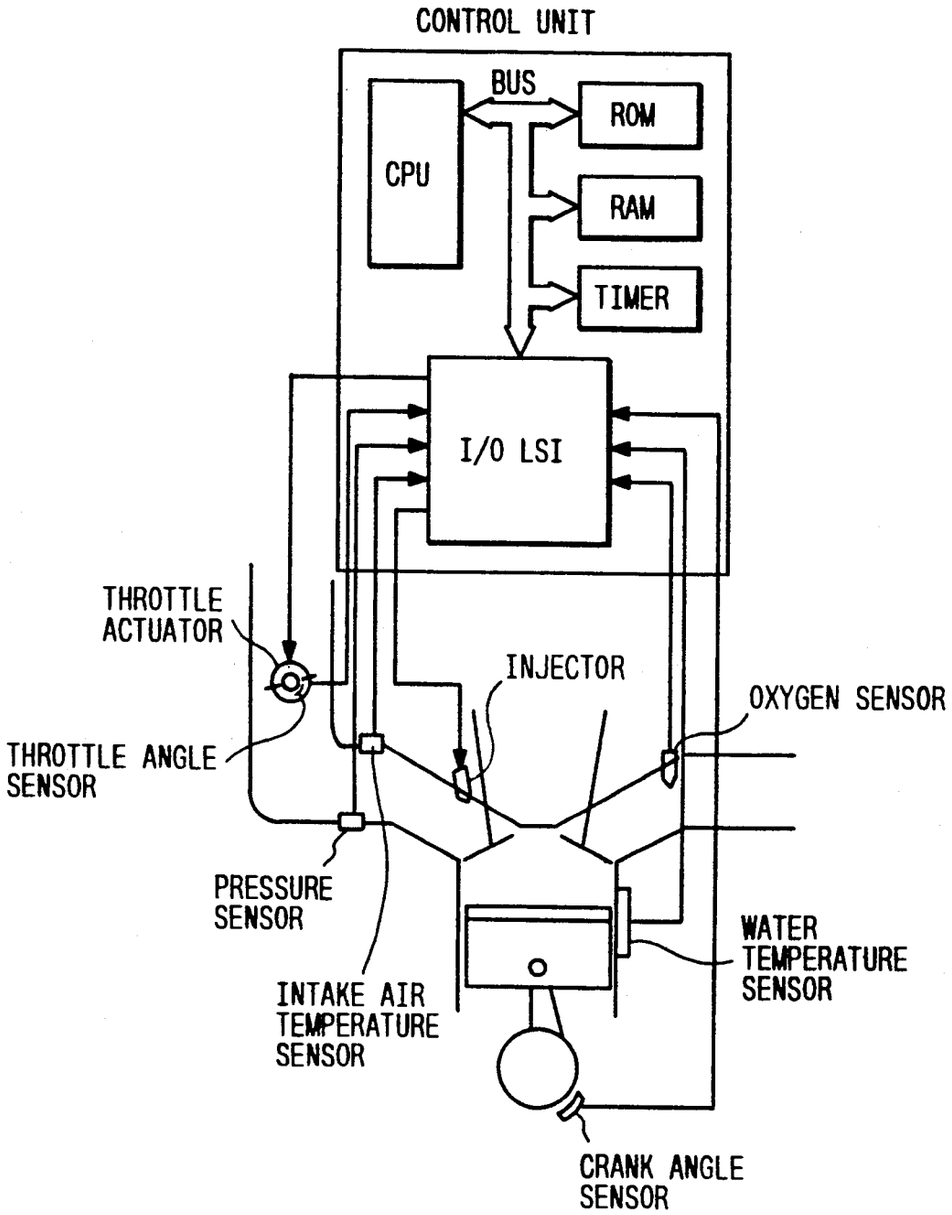


FIG. 12



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FIG. 13



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FIG. 14

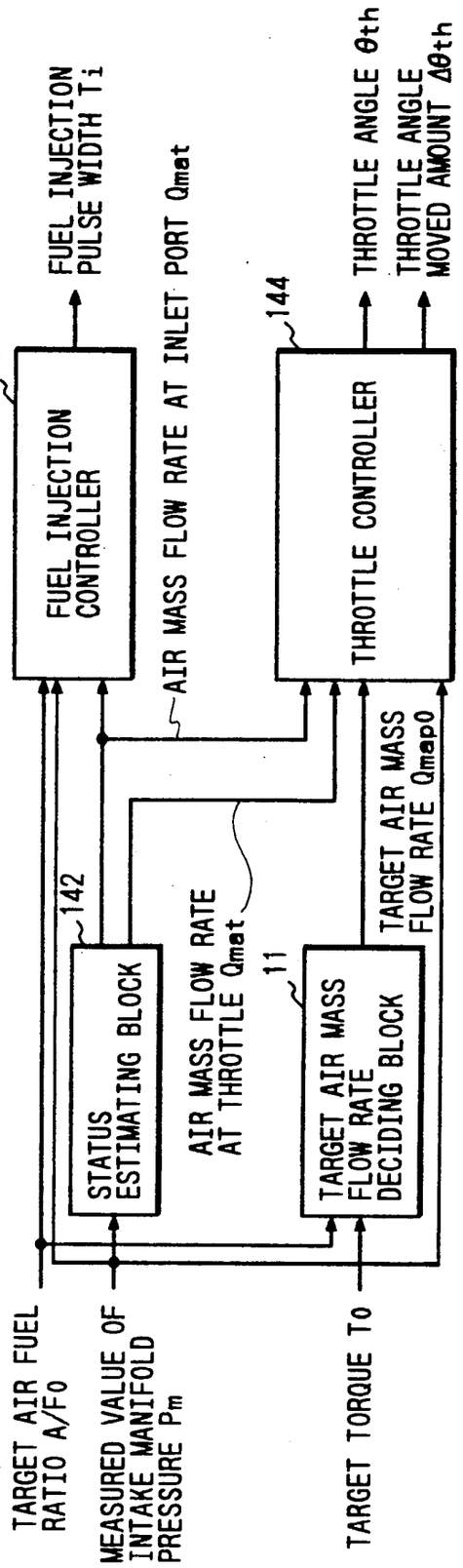

FUEL INJECTION PULSE WIDTH Ti
THROTTLE ANGLE θth
THROTTLE ANGLE MOVED AMOUNT Δθth
13
FUEL INJECTION CONTROLLER
144
THROTTLE CONTROLLER
AIR MASS FLOW RATE AT INLET PORT Qmat
142
STATUS ESTIMATING BLOCK
AIR MASS FLOW RATE AT THROTTLE Qmat
11
TARGET AIR MASS FLOW RATE DECIDING BLOCK
TARGET AIR MASS FLOW RATE Qmap0
TARGET AIR FUEL RATIO A/F0
MEASURED VALUE OF INTAKE MANIFOLD PRESSURE Pm
TARGET TORQUE To

FIG. 15

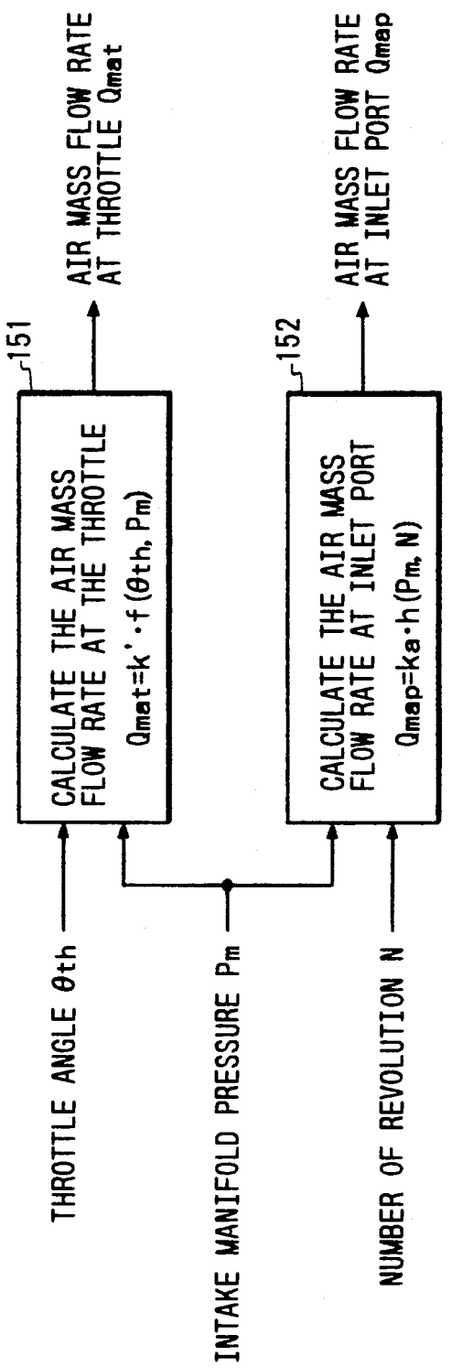
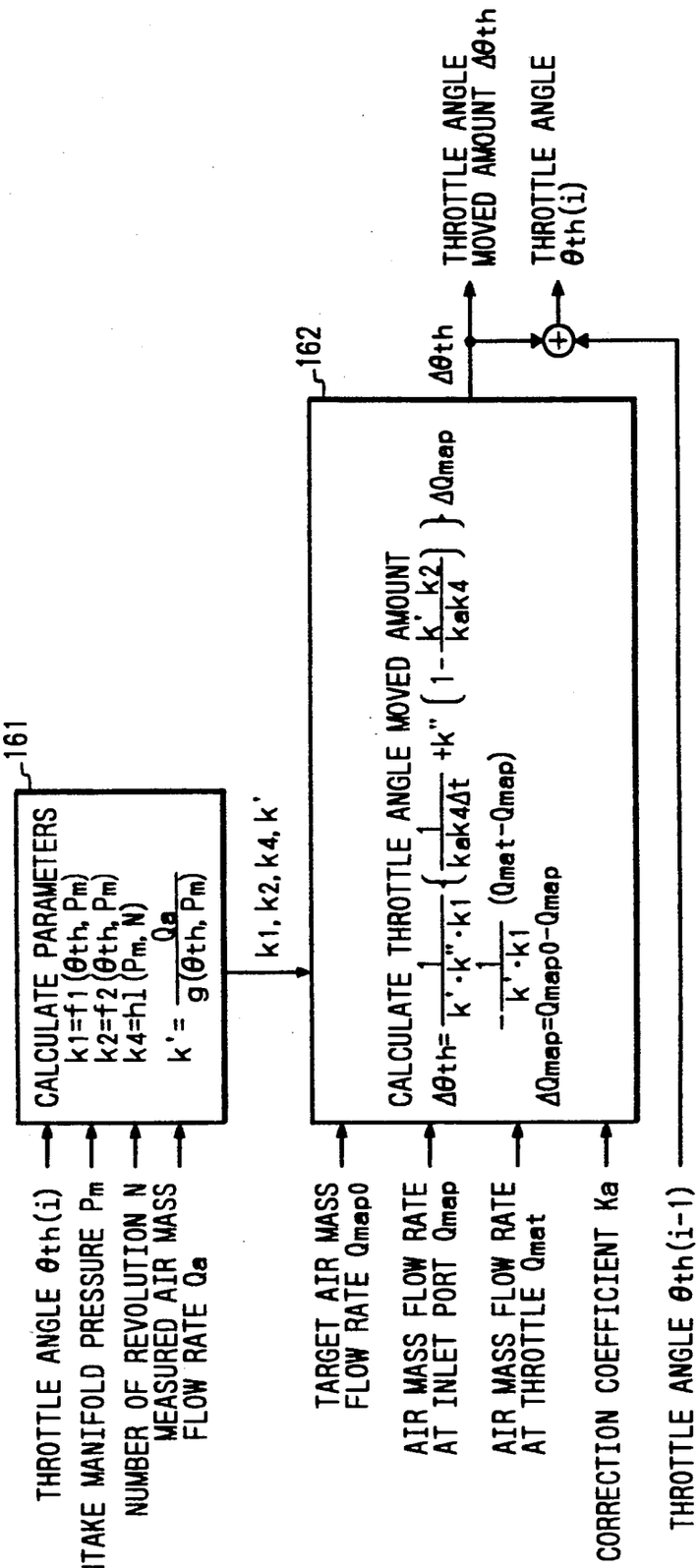

151
AIR MASS FLOW RATE AT THROTTLE Qmat
CALCULATE THE AIR MASS FLOW RATE AT THE THROTTLE
Qmat=k'·f(θth, Pm)
152
AIR MASS FLOW RATE AT INLET PORT Qmap
CALCULATE THE AIR MASS FLOW RATE AT INLET PORT
Qmap=ka·h(Pm, N)
THROTTLE ANGLE θth
INTAKE MANIFOLD PRESSURE Pm
NUMBER OF REVOLUTION N

FIG. 16


161
CALCULATE PARAMETERS
k1=f1(θth, Pm)
k2=f2(θth, Pm)
k4=h1(Pm, N)
k'= Qa / g(θth, Pm)
k1, k2, k4, k'
162
CALCULATE THROTTLE ANGLE MOVED AMOUNT
Δθth= 1/(k'·k"·k1) {1/(kak4Δt) +k" (1- k'·k2/kak4)} ΔQmap
-1/(k'·k1) (Qmat-Qmap)
ΔQmap=Qmap0-Qmap
Δθth
THROTTLE ANGLE MOVED AMOUNT Δθth
THROTTLE ANGLE θth(i)
THROTTLE ANGLE θth(i) —
INTAKE MANIFOLD PRESSURE Pm —
NUMBER OF REVOLUTION N —
MEASURED AIR MASS FLOW RATE Qa —
TARGET AIR MASS FLOW RATE Qmap0 —
AIR MASS FLOW RATE AT INLET PORT Qmap —
AIR MASS FLOW RATE AT THROTTLE Qmat —
CORRECTION COEFFICIENT Ka —
THROTTLE ANGLE θth(i-1) —

METHOD AND SYSTEM FOR ENGINE CONTROL

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention is related to the method and system for simultaneous control of the throttle valve and fuel injection to ensure that the torque and air fuel ratio of the automobile engine will reach target values.

2. DESCRIPTION OF THE PRIOR ART

A method to control the throttle valve and fuel injection to ensure that both torque and air fuel ratio of the automobile engine will reach target values is described in the Japanese Patent Application Laid-open NO.60-175742. According to this method, the angle through which the throttle is moved $\Delta\theta$ is calculated by searching a prearranged table on the basis of the difference (Z-T) between the target torque Z calculated using the proper torque function and actual torque T. Or angle through which the throttle is moved amount $\Delta\theta$ is calculated by PID control according to the said difference. Furthermore, the throttle valve actuator is supplied with a drive signal which changes the throttle angle by a calculated throttle angle angle $\Delta\theta$.

All prior methods utilize feedback control to allow the target value to reach the actual value. When feedback control is used, overshooting tends to occur in the controlled variable when an attempt is made to improve the control response, whereas the tracking performance of the controlled variable to the target value deteriorates when an attempt is made to stabilize the system to eliminate the possibility of overshooting. In either case, the torque which is a controlled variable cannot be controlled to the target value with a high precision. Namely, such prior methods are accompanied by the problem that the engine generated torque cannot be maintained at a proper value within a variety of operating ranges. Another problem is that, since said methods also use a torque sensor, the cost is increased by the price of the sensor.

SUMMARY OF THE INVENTION

An object of the present invention is to provide a method and system for engine control which is capable of solving all said problems; and, it is a further object to provide a method and system for engine control which ensure a high precision control of the torque to reach a target value, without using a torque sensor.

The present invention provided to achieve said object is characterized by the use of a high-precision status estimating model which permits high-precision estimation of the air flow status inside the intake manifold; it is also characterized by the use of the throttle valve, which is feedforward-controlled in such a manner that the air mass flow rate at the inlet port as a major factor for torque generation will reach a torque required to achieve the, target value.

To be more specific, in accordance with the present invention, the operating conditions of the engine dependent on the air mass flow rate are detected, and the air flow status inside the intake manifold dependent on the intake manifold pressure is estimated, thereby permitting calculation of the throttle angle which achieves the target torque based on the said detected value and said estimated value.

The present invention is also characterized by the ability to detect the operating conditions of the engine dependent on the intake manifold pressure, and to estimate the air flow status inside the intake manifold pressure dependent on the air mass flow rate at the throttle and the air mass flow rate at the inlet port, thereby ensuring calculation of the throttle angle which achieves the target torque based on the said detected value and said estimated value.

The present invention is further characterized by the ability to detect the operating conditions of the engine dependent on either the air mass flow rate or intake manifold pressure and to calculate the target air mass flow rate at the inlet port from at least one of the target torques and the said detected value, thereby permitting calculation of the throttle angle, which achieves the above-calculated target air mass flow rate at the inlet port according to the said detected value and said estimated value.

Since it uses a status estimating model which ensures a high precision estimation of the air flow status inside the intake manifold, the present invention further provides a high-precision control of the air mass flow rate at the inlet port and ensures a high-precision maintenance of the engine-generated torque at the target value.

The foregoing and other objects, advantages, manner of operation and novel features of the present invention will be understood from the following detailed description when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

In the accompanying drawings:

FIG. **1** is an overall block diagram representing the engine control system;

FIG. **2** is a block diagram representing simultaneous air fuel ratio and torque control;

FIG. **3** is a block diagram representing the status estimating block;

FIG. **4** is a block diagram representing the fuel injection control system;

FIG. **5** is a block diagram representing the throttle control system;

FIG. **6** is a flow chart representing the simultaneous air fuel ratio and torque control program;

FIG. **7** is a flow chart representing the status estimating subroutine;

FIG. **8** is a flow chart representing the subroutine to calculate the fuel injection pulse width;

FIG. **9** is a flow chart representing the subroutine to calculate the throttle angle;

FIG. **10** is a flow chart representing the subroutine to calculate the parameter;

FIG. **11** is a flow chart representing the subroutine to calculate the throttle angle when using the torque sensor; and FIG. **12** is a flow chart representing the subroutine to calculate the throttle angle correction coefficient.

FIG. **13** is an overall block diagram of an engine control system according to the present invention, having a pressure sensor.

FIG. **14** is a block diagram of simultaneously controlling air-fuel ratio and torque, in said engine control system having a pressure sensor.

FIG. **15** is a block diagram of the status estimating block in FIG. **14**.

FIG. **16** is a block diagram of the throttle controller in FIG. **14**.

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DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Embodiments of the present invention will be described with reference to the drawings. FIG. **1** is an overall block diagram representing the control system when the present invention is embodied by the use of a digital control unit. The control unit is provided with a CPU, ROM, RAM, timer, I/OLSI and buses to provide electrical connection of these units. Detection information issued from the throttle angle sensor, air flow sensor, water temperature sensor, crank angle sensor and oxygen sensor is sent to the RAM via the I/OLSI. The I/OLSI issues the fuel injection valve drive signal to the fuel injector and the drive signal to the throttle valve actuator.

With reference to FIGS. **2** to **4**, description will be made firstly of the configuration and operation of the simultaneous torque and air fuel ratio control system, for which the program is stored in the ROM. As illustrated in FIG. **2**, the control system comprises the status estimating block **12**, target air mass flow rate deciding block **15**, fuel injection control block **13** and throttle control block **14**. The target air-fuel ratio, target torque and measured air mass flow rate are entered as major inputs, while the fuel injection pulse width, throttle angle and throttle angle movement amount are output.

Block **11** calculates the target air mass flow rate at inlet port Q_{mapO} according to the following expression:

$$Q_{map0} = \frac{N \cdot T_0}{K \cdot F_1(A/F_0) \cdot F_2(N) \cdot F_3(\theta_{adv})} \quad \text{(Expression 1)}$$

where,

T_0: Target torque

N: Engine speed (number of revolutions)

A/F_0: Target air fuel ratio

θ_{adv}: Spark advance

K: Constant

F_1, F_2, F_3, : Specified function

Expression **1** has been derived as follows:

The engine-generated torque T depends on the air mass $K \cdot Q_{map}/N$ taken into cylinder at inlet port, air fuel ratio A/F, engine speed (number of revolutions) N and spark advance θ_{adv}. Thus, the following expression is assumed to calculate the torque from these variables:

$$T = K\frac{Q_{map}}{N} \cdot F_1(A/F) \cdot F_2(N) \cdot F_3(\theta_{adv}) \quad \text{(Expression 2)}$$

Of the said four expressions dependent on the engine-generated torque, the variables other than the argument for function F_i (i=1, 2, 3) are fixed, and the variables of the arguments are changed. By measuring the engine-generated torque in this case, function F_i can be determined from the measured value S_i (x) according to the following expression:

$$F_i(x) = k_i \cdot S_i(x) \quad \text{(Expression 3)}$$

where,

X: Air fuel ratio or number of revolutions or spark advance

k_i: Constant

Here constant k_i is determined so that the torques obtained from Expressions 2 and 3 agree with the measured torque at a certain engine operating condition.

Expression 1 is derived by solving the expression 2 which has determined the function, with respect to the air mass flow rate at the inlet port.

Next, the configuration and operation of the status estimating block **12** of FIG. **2** will be described with reference to FIG. **3**. In block **31**, measured air mass flow rate Q_a is subjected to the response delay compensation for the air mass flow sensor. Namely, the air mass flow rate at throttle Q_{mat} is calculated and updated from measured air mass flow rate Q_a according to the following expression:

$$Q_{mat}(i) = \frac{\frac{2T_1 \cdot T_2}{\Delta t^2} - 1}{\frac{T_1 \cdot T_2}{\Delta t^2} + \frac{T_1 + T_2}{2\Delta t}} \cdot Q_{mat}(i-1) - \frac{\frac{T_1 \cdot T_2}{\Delta t^2} - \frac{T_1 + T_2}{2\Delta t}}{\frac{T_1 \cdot T_2}{\Delta t^2} + \frac{T_1 + T_2}{2\Delta t}} \cdot Q_{mat}(i-2) + \frac{\frac{T_3}{2\Delta t}}{\frac{T_1 \cdot T_2}{\Delta t^2} + \frac{T_1 + T_2}{2\Delta t}} \cdot Q_a(i) - \frac{\frac{T_3}{2\Delta t}}{\frac{T_1 \cdot T_2}{\Delta t^2} + \frac{T_1 + T_2}{2\Delta t}} \cdot Q_a(i-2) + \frac{1}{\frac{T_1 \cdot T_2}{\Delta t^2} + \frac{T_1 + T_2}{2\Delta t}} \quad \text{(Expression 4)}$$

where,

Q_a: Measured air mass flow rate

Q_{mat}: Air mass flow rate at throttle

T_1,T_2,T_3: Positive constant

Expression 4 is to be solved on the assumption that the air mass flow rate at the throttle has a relationship of the secondary delay as shown in Expression 5, with respect to the measured air mass flow rate:

$$\frac{Q_a(S)}{Q_{mat}(S)} = \frac{1 + ST_3}{(1 + ST_1)(1 + ST_2)} \quad \text{(Expression 5)}$$

In block **32**, intake manifold pressure P_m calculated from the air mass flow rate at throttle Q_{mat} which is calculated in block **31**, and air mass flow rate at inlet port Q_{map} which is calculated by searching the table **33** according to the following expression:

$$P_m(i+1) = P_m(i) + \frac{R \cdot T_m}{V_m} \cdot \Delta t \cdot (Q_{mat} - Q_{map}) \quad \text{(Expression 6)}$$

where

Q_{mat}: Air mass flow rate at throttle

Q_{map}: Air mass flow rate at inlet port

P_m: Intake manifold pressure

T_m: Intake manifold air temperature (set to approx. 330K)

V_m: Intake manifold volume

R: Gas constant

Δt: Updated cycle for intake manifold pressure

i: Time (one time unit corresponding to Δt)

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Block **33** calculates the air mass flow rate at inlet port Q_{map} by searching the two dimensional table for the intake manifold pressure and engine speed, where the data on air mass flow rate taken in during engine operation in the stationary status are stored. Momentary responses for the air mass flow rate at the throttle, intake manifold pressure and air mass flow rate at the inlet port are obtained by repeating the processing of blocks in the sequence of **31**, **32** and **33**.

The following describes the configuration and operation of the fuel injection control system, with reference to FIG. **4**. Block **41** calculates the deposition ratio X of the injected fuel onto the intake manifold and evaporation ratio ($1/\tau$) of deposited fuel according to Expressions 7 and 8.

$$X=F(P_m, N, T_w) \quad \textit{(Expression 7)}$$

where,
P_m: Intake manifold pressure
N: Engine speed
T_w: Water temperature
F: Function

$$1/\tau = G(P_m, N, Tw) \quad \textit{(Expression 8)}$$

where
P_m: Intake manifold pressure
N: Engine speed
T_w: Water temperature
G: Function

Functions F and G are determined through the specified experiments. These functions can be determined, for example, using the method described in the printouts No. 842049 delivered before the conference at the Society of Automobile Technology. Furthermore, the estimated fuel film quantity Mf is updated, using the said calculated parameters according to the following expression:

$$M_f(i+1) = \left(1 - \frac{\Delta t}{\tau}\right) \cdot M_f(i) + X \cdot \Delta t \cdot G_{fo} \quad \text{(Expression 9)}$$

where,
M_f: Fuel film quantity
G_{f0}: Effective value of fuel injection
X: Deposition ratio
$1/\tau$: Evaporation ratio
Δt: Updated cycle for fuel film quantity
i: Time (one time unit corresponding to Δt)

Furthermore, block **42** calculates the fuel injection quantity using the value calculated in block **41** according to the following expression:

$$G_f = \frac{\frac{Q_{map}}{A/F} - \frac{1}{\tau} \cdot M_f}{1 - X} \quad \text{(Expression 10)}$$

Q_{map}: Air mass flow rate at inlet port
A/F_0: Target air fuel ratio
M_f: Fuel film quantity
X: Deposition ratio
$1/\tau$: Evaporation ratio

Block **42** calculates the fuel injection pulse width Ti according to the following expression:

$$T_i = k \cdot \frac{\gamma \cdot G_f}{N} \cdot T_s \quad \text{(Expression 11)}$$

where
G_f: Fuel injection quantity
N: Engine speed
γ: Feedback correction coefficient
T_s: Invalid injection time

With reference to FIG. **5**, the following describes the configuration and operation of the throttle control system which is characteristic of the present invention:

The said control system determines the throttle angle and the throttle angle moved amount, which achieve the target air mass flow rate, for which four expressions are used as basic expressions as shown below.

$$Q_{mat}=k' \cdot f(\theta_{th}, P_m) \quad \textit{(Expression 12)}$$

where,
Q_{mat}: Air mass flow rate at throttle
θ_{th}: throttle angle
P_m: Intake manifold pressure
k': Variable to be corrected by a specified calculation
f: Specified function

$$\frac{dP_m}{dt} = k'' \cdot f(Q_{mat} - Q_{map}) \quad \text{(Expression 13)}$$

where,
Q_{mat}: Air mass flow rate at throttle
Q_{map}: Air mass flow rate at inlet port
P_m: Intake manifold pressure
t: Time
k'': Constant

$$k'' = \frac{R \cdot T_m}{V_m} \quad \text{(Expression 14)}$$

where,
T_m: Intake manifold air temperature (set to approx. 330K)
V_m: Intake manifold volume
R: Gas constant

$$Q_{map}=g(P_m, N) \quad \textit{(Expression 15)}$$

where
Q_{map}: Air mass flow rate at inlet port
P_m: Intake manifold pressure
N: Engine speed
g: Specified function

In Expression 12, function f is equivalent to the table where the air mass flow rate taken in during engine operation in the stationary status is stored to correspond to the throttle angle and intake manifold pressure. The value of function f can be obtained by searching the table. Expression 13 is derived from the fact that the pressure change per unit time is proportionate to the air mass accumulated in the intake manifold per unit time. In Expression 15, function g is equivalent to the table where the air mass flow rate taken in during engine operation in the stationary status is stored to correspond to the engine speed and intake manifold pressure. The value of function g can be obtained by searching the table.

Expression 12 is totally differentiated in the neighborhood of the throttle angle θ_{th} and intake manifold pres-

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sure P_m, and the following three expressions are obtained:

$$\Delta Q_{mat} = k' \cdot (k_{\Delta\theta th} + k_2 \Delta P_m) \quad \text{(Expression 16)}$$

$$k_1 = f_1(\theta_{th}, P_m) = \frac{\partial f(\Delta_{th}, P_m)}{\partial \theta_{th}} \quad \text{(Expression 17)}$$

$$k_2 = f_2(\theta_{th}, P_m) = \frac{\partial f(\theta_{th}, P_m)}{\partial P_m} \quad \text{(Expression 18)}$$

where, f1 and f2 are equivalent to the two dimensional table for the throttle angle and intake manifold pressure.

The following Expression is obtained by making Expression 13 discrete:

$$\frac{\Delta P_m}{\Delta t} = k'' \cdot \{Q_{mat} + \Delta Q_{mat} - (Q_{map} + \Delta Q_{map})\} \quad \text{(Expression 19)}$$

where ΔQ_{mat}, ΔQ_{map} and ΔP_m are minute variations of the variables.

Then Expression 15 is totally differentiated in the neighborhood of the engine speed and intake manifold pressure P_m and the following two expressions are obtained:

$$Q_{map} = k_3 \cdot P_m \quad \text{(Expression 20)}$$

$$k_3 = g_1(P_m, N) = \frac{\partial g(P_m, N)}{\partial P_m} \quad \text{(Expression 21)}$$

where g1 is equivalent to the two dimensional table for the intake manifold pressure and engine speed.

The ΔQ_{mat} and ΔP_m are eliminated in Expressions 16, 19 and 20 to obtain the relation of $\Delta\theta_{th}$ and ΔQ_{map} as follows:

$$\Delta\theta_{th} = \quad \text{(Expression 22)}$$

$$\frac{1}{k' \cdot k'' \cdot k_1} \cdot \left\{ \frac{1}{k_3 \cdot \Delta t} + k'' \cdot \left(1 - \frac{k' \cdot k_2}{k_3}\right) \right\} \cdot \Delta Q_{map} - \frac{1}{k' \cdot k_1} \cdot (Q_{mat} - Q_{map})$$

Using Expression 22, it is possible to obtain the throttle angle moved amount $\Delta\theta_{th}$ which changes the air mass flow rate at throttle inlet port Q_{map} by Q_{map}. When the target air mass flow rate at inlet port Q_{map} to achieve the target torque is Q_{map0}, the throttle angle moved amount $\Delta\theta_{th}$ to achieve the said target air mass flow rate can be obtained by calculating the ΔQ_{map} from the following Expression and substituting the result into Expression 22.

$$Q_{map} = Q_{map0} - Q_{map} \quad \text{(Expression 23)}$$

FIG. 5 illustrates the configuration of the said throttle control system. Block **51** calculates the said various parameters. In block **52**, throttle angle moved amount $\Delta\theta_{th}$ is calculated from the calculated parameters. Further, throttle angle moved amount $\Delta\theta_{th}$ is added to the throttle angle θ_{th} (i−1) one time unit before, thereby calculating the current throttle angle θ(i). The above is the description of the configuration and operation of the throttle control system.

The following describes the operation of a program when the simultaneous torque and air fuel ratio control system is converted into the program in the ROM. FIGS. **6** to **10** show the program flow chart. FIG. **6** illustrates the main program, while FIGS. **7** to **9** illustrate the subroutine called in the main program. FIG. **10** shows a subprogram which calculates a certain variable in the main program. The programs shown in FIGS. **6** sand **10** are run at the specified cycle. First, the operation of the main program will be described with reference to FIGS. **6** to **9**.

Step **601** in FIG. **6** calculates target air mass flow rate Q_{map0} from the target torque T_0 according to Expression 1. Then step **602** calls the subroutine in FIG. **7** to estimate the air flow condition in the intake manifold. Step **701** in FIG. **7** calculates the air mass flow rate at throttle Q_{mat} according to Expression **4**. The step **702** updates the intake manifold pressure P_m according to Expression 6. Step **703** then searches the table storing the data on the stationary air mass flow rate from the updated intake manifold pressure P_m and engine speed N, and calculated the air mass flow rate at the inlet port. Processing of said subroutine has terminated to return the processing to the main program.

Step **603** in FIG. **6** calls the subroutine in FIG. **8** to calculate the fuel injection pulse width. Step **801** in FIG. **8** calculates deposition ratio X and evaporation ratio $1/\tau$ according to Expressions 7 and 8. At step **802**, the fuel film quantity Mf is updated according to Expression 9. Then step **803** calculates fuel injection G_f according to Expression 10. Finally, step **804** calculates fuel injection pulse width T_i according to Expression 11. The processing of said subroutine is terminated to return processing to the main program.

Step **604** in FIG. **6** calls the subroutine in FIG. **9** to calculate the throttle angle moved amount and throttle angle. Step **901** in FIG. **9** calculates parameters other than k' in block **51** in FIG. **5**. Then step **902** calculates the throttle angle moved amount $\Delta\theta_{th}$ according to Expressions **22** and **23**. Step **903** then calculates current throttle angle θ_{th} (i) according to Expression 24.

$$\theta_{th}(i) = \theta_{th}(i-1) + \Delta\theta_{th} \quad \text{(Expression 24)}$$

where,

i: Time (one time unit corresponding to the execution cycle of the said program)

Finally, step **904** sends to the throttle actuator the throttle angle actuating signal which moves the throttle angle by $\Delta\theta_{th}$. All processing of the main program has now terminated.

With reference to FIG. **10**, the following describes the operation of the program which calculates parameter k' of block **51**: First, step **101** checks if the following Expression has been satisfied or not, thereby checking if the engine is in the stationary operating status or not.

$$|\theta_{th}(i) - \theta_{th}(i-2)| < m_1 \quad \text{(Expression 25)}$$

$$|\theta_{th}(i-2) - \theta_{th}(i-4)| < m_1 \quad \text{(Expression 26)}$$

$$|M_f(i) - M_f(i-2)| < n_1 \quad \text{(Expression 27)}$$

$$|M_f(i-2) - M_f(i-4)| < n_1 \quad \text{(Expression 28)}$$

where m_1 and n_1 are positive constants,

θ_{th}: throttle angle

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M_f: Fuel film quantity

i: Time (one time unit corresponding to 10 msec.)

If the system has determined that the engine is in the stationary operating status, it proceeds to the next processing. If not, the system terminates the processing. Step **102** calculates parameter k' according to the following Expression:

The processing has now terminated.

$$k' = \frac{Q_a}{f(\bar{\theta}_{th}, \bar{P}_m)} \quad \text{(Expression 29)}$$

where,

$\bar{\theta}_{th}$: Current detected throttle angle

$\bar{P}_m$: Current estimated intake manifold pressure

Q_a: Current measured air mass flow rate

The above is the description of the configuration and control program when implementing the air fuel torque control system by means of the digital control unit shown in FIG. **2**.

Using the said embodiment, the above has described the method of providing high-precision control of the engine-generated torque without using the torque sensor. Use of the torque sensor further increases the control precision. In this case, a different program must be used for the subroutine to calculate the throttle angle in the control program. FIG. **11** illustrates the said program. Processing in steps **1101** and **1102** is the same as that in steps **901** and **902**. Step **1103** calculates the throttle angle θ_{th} (i) according to the following Expression:

$$\theta_{th}(i) = m(i) \cdot \{\theta_{th}(i-1) + \Delta\theta_{th}\} \quad \text{(Expression 30)}$$

where,

m(i): correction coefficient calculated according to the torque sensor output

i: time

Correction coefficient m(i) is used to correct the throttle angle so that the torque will reach the target, when the actual torque is deviated from the target value; thereby ensuring highprecision control. Said correction coefficient is calculated by another program to be explained later.

Step **1104** calculates the effective value $\Delta\theta_{th}'$ of the throttle angle moved amount according to the following Expression:

$$\Delta\theta_{th}' = \theta_{th}(i) - \Delta\theta_{th}(i-1) \quad \text{(Expression 31)}$$

Finally, step **1105** sends to the throttle actuator the signal which actuates the throttle by the said calculated value $\Delta\theta_{th}'$. Processing of the said subroutine has now terminated.

With reference to FIG. **12**, the following describes the operation of the program to calculate the correction coefficient m(i):

First, step **1201** calculates the torque deviation e(i) according to the following Expression:

$$e(i) = T(i) - T_0(i) \quad \text{(Expression 32)}$$

where

T: Detected torque

T_0: Target torque

i: Time (one time unit corresponding to the execution cycle of the said program)

Step **1202** calculates the correction coefficient variation Δm (i) according to the following Expression. This means that the correction coefficient is calculated by PID control.

$$\Delta m(i) = K_p\{e(i) - e(i-1)\} + K_1 \cdot \frac{e(i-1) + e(i)}{2} + K_D \cdot \{e(i) - 2e(i-1) + e(i-2)\} \quad \text{(Expression 33)}$$

where,

K_p: Proportional gain

K_i: Integral gain

K_d: Differential gain

Step **1203** calculates the correction coefficient m (i) according to the following Expression. Processing has now terminated.

$$m(i) = m(i-1) + \Delta m(i) \quad \text{(Expression 34)}$$

The above is the description of the modified portion of the control program when the torque sensor is used.

As described above, the present invention provides a means for high-precision determination of the throttle angle such that the air mass flow rate at the inlet port will reach the target, according to the model representing the air mass flow in the intake manifold. This allows the engine-generated torque to be maintained at the target with high precision.

The above description is concerned with the simultaneous torque/air fuel ratio control method in the L Jetronic System which directly detects the air mass flow rate.

The following describes the simultaneous torque/air fuel ratio control method in the D Jetronic System which detects the air mass flow rate indirectly from the measured intake manifold pressure. FIG. **13** is a block diagram representing the control system of said method. A pressure sensor and intake air temperature sensor are provided in place of the air flow sensor, and their signals are sent to the RAM via the I/OLSI. Other configuration is the same as that of the L Jetronic System.

The following describes the configuration of the simultaneous torque/air fuel ratio control system with reference to FIG. **14**. The target air fuel ratio, target torque and intake manifold pressure are input as major input signals, thereby calculating the fuel injection pulse, throttle angle and throttle angle moved amount. The difference with the L Jetronic System is found in processing of the status estimating block and throttle control system. FIG. **15** is a concrete block diagram representing the status estimating block. Block **151** calculates the air mass flow rate at the throttle from the throttle angle and detected intake manifold pressure according to the Expression **12**. Block **152** calculates the air mass flow rate at the inlet port from the intake manifold pressure and the detected engine speed according to the following Expression:

$$\Delta Q_{map} = k_a \cdot h(P_m, N) \quad \text{(Expression 35)}$$

where,

h: two dimensional table

k_a: correction coefficient calculated according to the output of the intake air temperature sensor, etc.

The above is the description of processing of the status estimating block.

The following describes processing of the throttle control system with reference to FIG. **16**. The calcula-

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tion formula of the throttle angle moved amount is derived as shown below:

The following Expression is obtained by total differentiation of the Expression 35 in the neighborhood of the engine speed and intake manifold pressure.

$$\Delta Q_{map} = k_a k_4 \cdot \Delta P_m \quad \text{(Expression 36)}$$

$$K_4 = h_1(P_m, N) = \frac{\partial h(P_m, N)}{\partial P_m} \quad \text{(Expression 37)}$$

Eliminating the ΔQ_{mat} and ΔP_m from Expressions 16, 19 and 36, the relation between the $\Delta\theta_{th}$ and ΔQ_{map} is derived as follows:

$$\Delta\theta_{th} = \frac{1}{k' \cdot k'' \cdot k_1}\left\{\frac{1}{k_a k_4 \tau} + k''\left(1 - \frac{k' k_2}{k_a k_4}\right)\right\}\Delta Q_{map} - \frac{1}{k' \cdot k_1}(Q_{mat} - Q_{map}) \quad \text{(Expression 38)}$$

Block **161** in FIG. **16** calculates various coefficients, thereby providing calculation of the throttle angle moved amount from Expression 38 according to said calculation result in Block **162**.

The above is the description of the overall block diagram of the control system in FIG. **14**. The flow chart of the program to implement the processing of the configuration in FIG. **14** is almost equivalent to that of the L Jetronic system (from FIG. **6** to FIG. **12**). The difference is that FIG. **7** has no processing for estimation of the intake manifold pressure. The concrete processing is the same as that for the L Jetronic system.

What is claimed is:

1. An engine control method, comprising the steps of:
- detecting operating conditions of the engine, including air mass flow rate;
- calculating a value of target torque based upon the detected operating conditions of the engine;
- estimating a value of actual air flow status inside the intake manifold using an air flow model based upon at least one of said detected operating conditions of the engine related to air flow;
- calculating a throttle angle which achieves the calculated value of target torque, based on the calculated value of target torque and said estimated value of actual air flow status; and
- controlling the engine throttle based upon the calculated throttle angle.

2. An engine control method according to claim **1**, wherein said actual air flow status comprises at least one of air mass flow rate at the throttle, air mass flow rate at the inlet port and intake manifold pressure.

3. An engine control method according to claim **2**, further comprising the steps of:
- calculating a target air mass flow rate at the inlet port by use of the calculated target torque, on the basis of a formula defined in advance for the target torque and the air mass flow rate at the inlet port; and
- calculating a throttle angle which achieves the target torque from the said calculated target air mass flow rate at the inlet port and said estimated air flow status.

4. An engine control method according to claim **3**, further comprising the steps of:
- linearizing around the current operating conditions of the engine an air flow model representing an air flow in the intake manifold; and
- calculating the throttle angle which achieves the target torque by use of the linearized model, the estimated value of actual air flow status, and the target air mass flow rate in the inlet port.

5. An engine control method according to claim **2**, further comprising the steps of:
- detecting the engine torque; and
- calculating an effective throttle angle by correcting the calculated throttle angle by a correction coefficient which is obtained from a deviation between the detected torque and said target torque.

6. An engine control method according to claim **1**, further comprising:
- a step of determining a fuel injection which achieves a target air fuel ratio according to a dynamic model representing a fuel transmission characteristics inside said intake manifold.

7. An engine control method according to claim **2**, further comprising:
- a step of calculating said throttle angle, using a dynamic model which represents an air transmission characteristic inside the intake manifold, linearized in the neighborhood of the current engine operating conditions.

8. An engine control method according to claim **1**, further comprising:
- a step of determining a fuel injection which achieves a target air fuel ratio according to a dynamic model representing a fuel transmission characteristics inside said intake manifold.

9. An engine control method according to claim **1**, further comprising:
- a step of calculating said throttle angle, using a dynamic model which represents an air transmission characteristic inside and intake manifold, linearized in the neighborhood of the current engine operating conditions.

10. An engine control method, comprising the steps of:
- detecting operating conditions of the engine including intake manifold pressure;
- calculating a value of target torque based upon the detected operating conditions of the engine;
- estimating a value of actual air flow status inside the intake manifold using an air flow model based at least upon one of said detected operating conditions of the engine related to air flow;
- calculating a throttle angle which achieves the target torque, based on detected operating conditions and said estimated value of actual air flow status; and
- controlling the engine throttle based upon the calculated throttle angle.

11. An engine control method according to claim **10**, wherein said actual air flow status comprises at least air mass flow rate at the throttle and air mass flow rate at the inlet port.

12. An engine control method according to claim **11**, further comprising:
- a step of calculating a target air mass flow rate at the inlet port by use of the calculated target torque, on the basis of a formula defined in advance for the target torque and the air mass flow rate at the inlet port; and
- a step of calculating the throttle angle which achieves the target torque from said calculated target air

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mass flow rate at the inlet port and said estimated actual air flow status.

13. An engine control method according to claim 11, further comprising:

a step of linearizing around the current operating conditions of the engine, an air flow model representing an air flow in the intake manifold; and

a step of calculating the throttle angle which achieves the target torque by use of a linearized model, the estimated actual air flow status, and the target air mass flow rate at the inlet port.

14. An engine control method according to claim 11, further comprising:

a step of detecting the engine torque; and

a step of calculating the effective throttle angle by correcting the calculated throttle angle by a correction coefficient which is obtained from the deviation between said detected torque and the target torque.

15. An engine control method according to claim 10, further comprising:

a step of determining a fuel injection which achieves a target air fuel ratio according to a dynamic model representing a fuel transmission characteristics inside said intake manifold.

16. An engine control method according to claim 10, further comprising:

a step calculating said throttle angle, using a dynamic model which represents an air transmission characteristic inside the intake manifold, linearized in the neighborhood of the current engine operating conditions.

17. An engine control method according to claim 10, further comprising:

a step of detecting the engine torque; and

a step of calculating an effective throttle angle by multiplying the calculated throttle angle by a correction coefficient which is obtained from deviation between the detected torque and the target torque.

18. An engine control method, comprising the steps of:

detecting operating conditions of the engine including intake manifold pressure;

calculating a value of target torque based upon detected operating conditions of the engine;

calculating a target air mass flow rate at the inlet port from the target torque;

calculating a throttle angle which achieves the target torque, based on the intake manifold pressure detected in the detecting step and said target air mass flow rate at the inlet port; and

controlling the engine throttle based upon the calculated throttle angle.

19. An engine control method according to claim 18, further comprising the steps of:

estimating a value of actual air flow status inside the intake manifold using an air flow model based at least on a detected operating condition of the engine related to air flow; and

calculating a throttle angle which achieves the target torque from detected operating conditions and the estimated value of actual air flow status and said calculated target air mass flow rate at the inlet port.

20. An engine control method according to claim 18, further comprising the steps of:

linearizing around the current operating conditions of the engine an air flow model representing an air flow in the intake manifold; and

calculating a throttle angle which achieves the target torque by use of the linearized model, the estimated value of actual air flow status and the target air mass flow rate in the inlet port.

21. An engine control method according to claim 18, further comprising:

a step of determining a fuel injection which achieves a target air fuel ratio according to a dynamic model representing a fuel transmission characteristics inside the intake manifold.

22. An engine control method according to claim 18, further comprising:

a step of obtaining by experiment a relation of correspondence between the engine conditions including the target air mass flow rate at the inlet port and the engine-generated torque; and

a step of calculating the target air mass flow rate at the inlet port from the target torque using the relation.

23. An engine control method according to claim 18, further comprising:

a step of calculating the said throttle angle, using the dynamic model which represents the fuel transmission characteristics inside the said intake manifold, linearized in the neighborhood of the current engine operating conditions.

24. An engine control system comprising:

means for detecting operating conditions of the engine, including a condition related to air flow;

means for calculating a value of target torque based upon detected operating conditions of the engine;

means for estimating a value of actual air flow status inside the intake manifold using an air flow model based at least on one of the detected operating conditions of the engine related to air flow;

means for calculating a throttle angle which achieves the calculated value of target torque, based at least on said estimated value of actual air flow status; and

means for controlling the engine throttle based upon the calculated throttle angle.

25. An engine control system comprising:

means for detecting operating conditions of the engine, including air mass flow rate;

means for calculating a value of target torque based upon detected operating conditions of the engine;

means for estimating a value of actual air flow status inside the intake manifold using an air flow model based at least upon one of said detected operating conditions of the engine related to air flow, said actual air flow status being different from said detected air mass flow rate;

means for calculating a throttle angle which achieves the calculated value of target torque, based at least on said estimated value of actual air flow status; and

means for controlling the engine throttle based upon the calculated throttle angle.

26. An engine control system comprising:

means for detecting operating conditions of the engine, including intake manifold pressure;

means for calculating a value of target torque based upon detected operating conditions of the engine;

means for estimating an actual air flow status inside the intake manifold using an air flow model based

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