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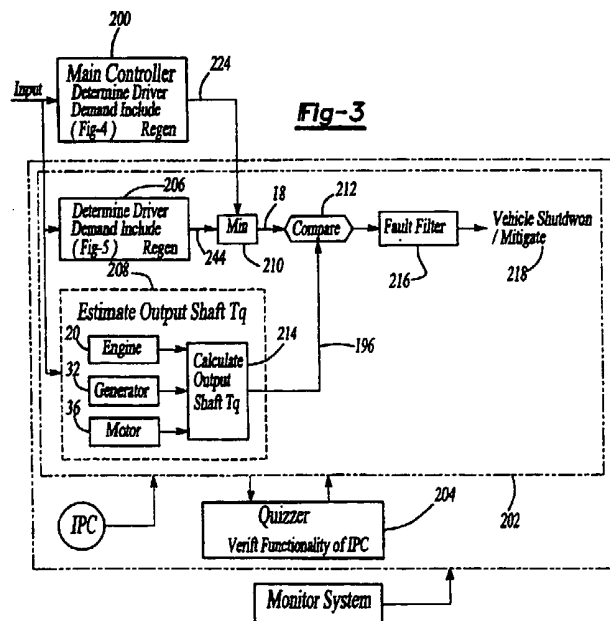43-45 High Road, BUSHEY HEATH, Herts, WD23 1EE,
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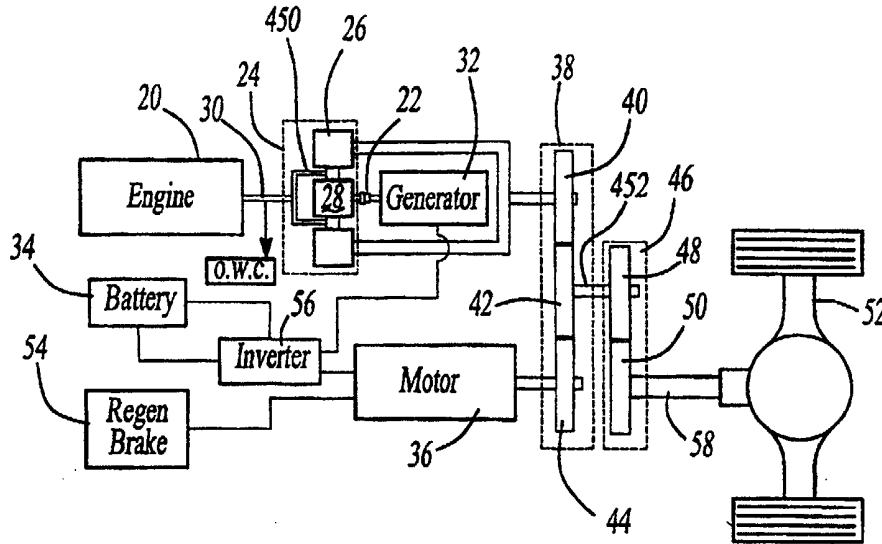B60K 6/02

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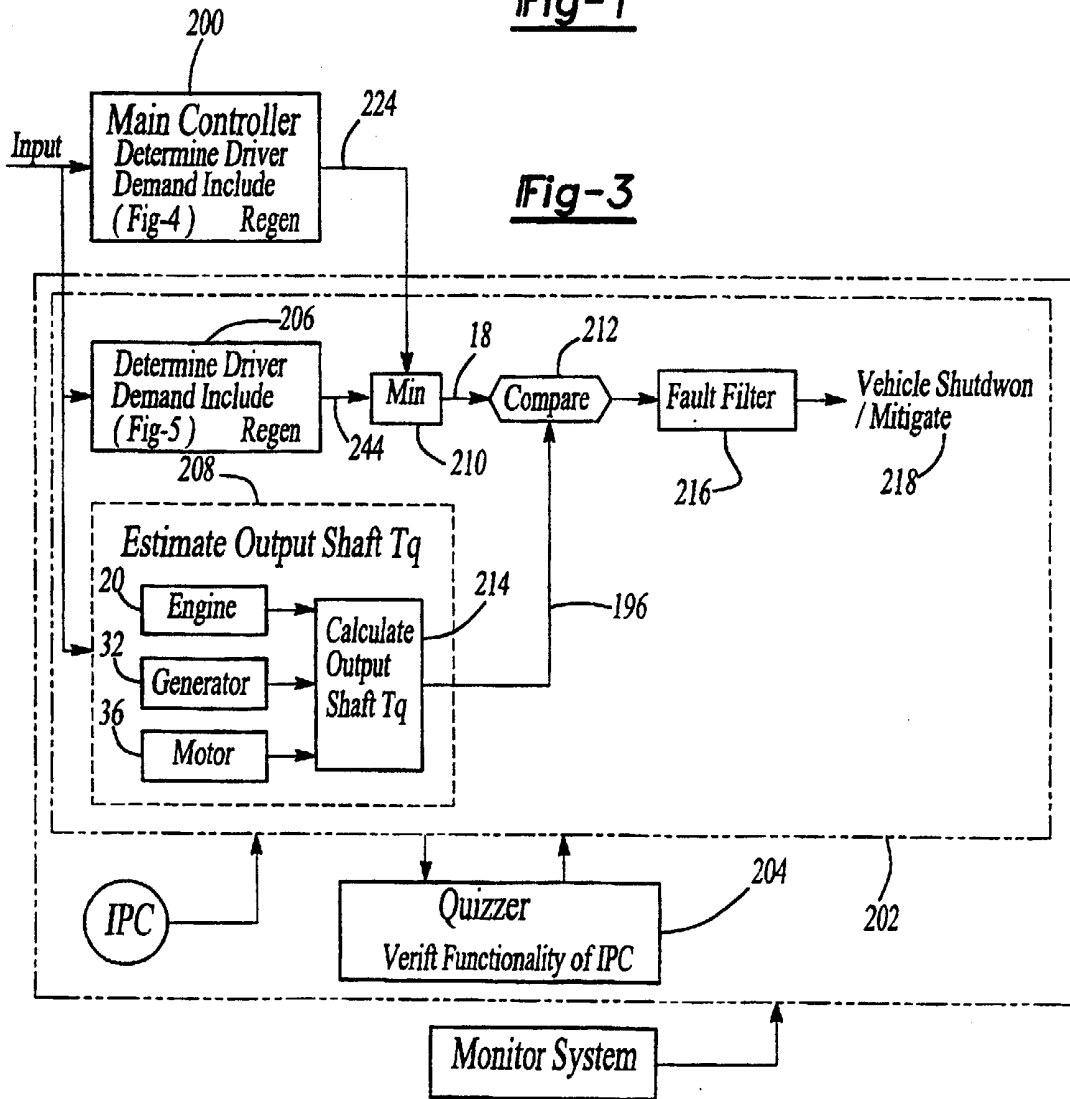Online: EPODOC, JAPIO, WPI

(54) Abstract Title
A torque based monitor in a hybrid electric vehicle

(57) A torque based monitor method, apparatus, and system, for a torque splitting hybrid electric vehicle (HEV) powertrain and regenerative brake system is disclosed. The preferred powertrain configuration includes an internal combustion engine 20, a generator 32, and electric traction motor 36 combined to produce the vehicle's output shaft torque. The invention has a set of vehicle state sensors and communication interfaces connected independently to a main controller 200 and an independent plausibility check (IPC) 202. The IPC monitors and mitigates the powertrain output shaft torque (OST) by reducing powertrain torque when the detected OST is greater than the desired OST. The IPC 202 has a second mode of operation to shut down the powertrain OST of the HEV powertrain when a fault or failure is detected. Additional safety features include a quizzer function 204 to continuously verify the functionality of the IPC 202.
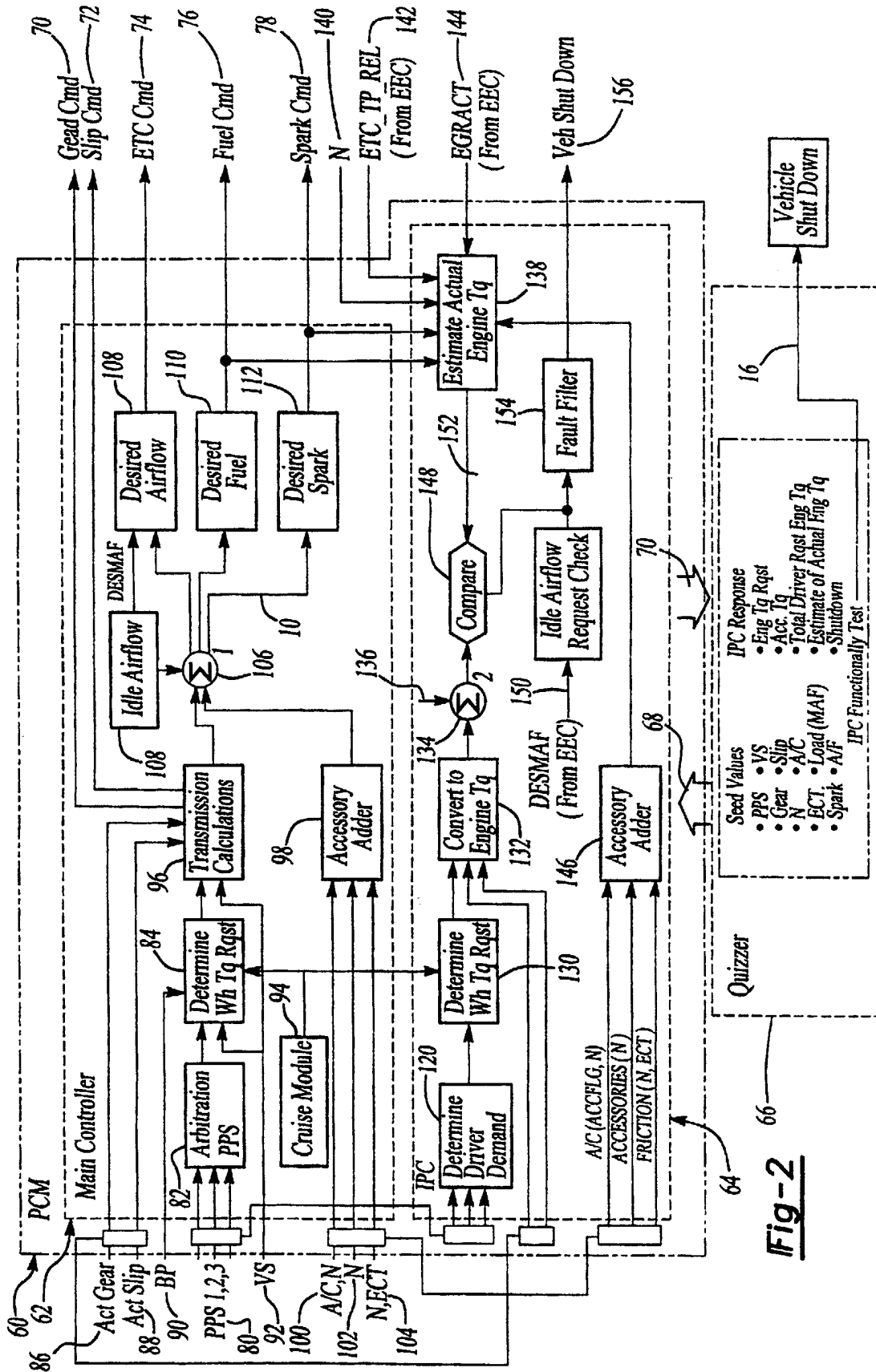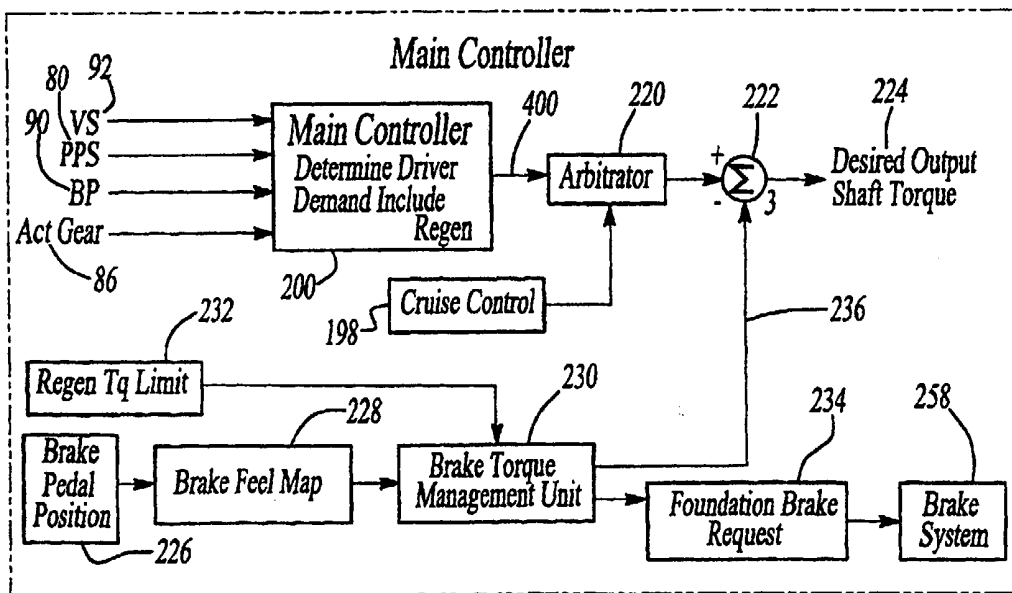
Fig-3

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Fig-1

Fig-3

Gead Cmd 70
Slip Cmd 72
ETC Cmd 74
Fuel Cmd 76
Spark Cmd 78
N 140
ETC_TP_REL (From EEC) 142
EGRACT (From EEC) 144
Veh Shut Down 156

PCM 60
Act Gear 62
Act Slip 86
BP 88
PPS 1,2,3 90
VS 80
A/C,N 92
N 100
N,ECT 102
104

Main Controller

Idle Airflow 108
DESMAF
Desired Airflow 108
Desired Fuel 110
Desired Spark 112
10
106 Σ 1

Transmission Calculations 96
Accessory Adder 98
Arbitration PPS 84
Cruise Module 94
Determine Wh Tq Rqst 82

Estimate Actual Engine Tq 138

136
134 Σ 2
Compare 148
152
Convert to Engine Tq 132
DESMAF (From EEC)
Idle Airflow Request Check 150
Fault Filter 154

IPC
Determine Driver Demand 120
Determine Wh Tq Rqst 130
Accessory Adder 146

A/C (ACCFLG, N) 68
ACCESSORIES (N)
FRICTION (N, ECT)

64

Quizzer 66

Seed Values
• PPS   • VS
• Gear   • Slip
• N   • A/C
• ECT,   • Load (MAF)
• Spark   • A/F

IPC Functionally Test

IPC Repnose
• Eng Tq Rqst
• Acc. Tq
• Total Driver Rqst Eng Tq
• Estimate of Actual Eng Tq
• Shutdown

70

Vehicle Shut Down 16

Fig-2

Fig-4

Fig-5

$$Fig\text{-}6$$
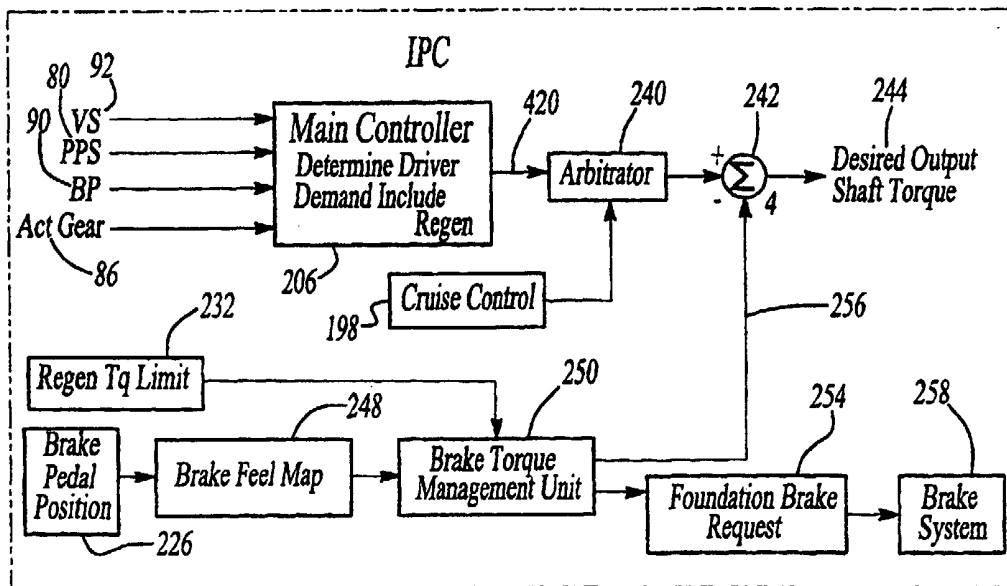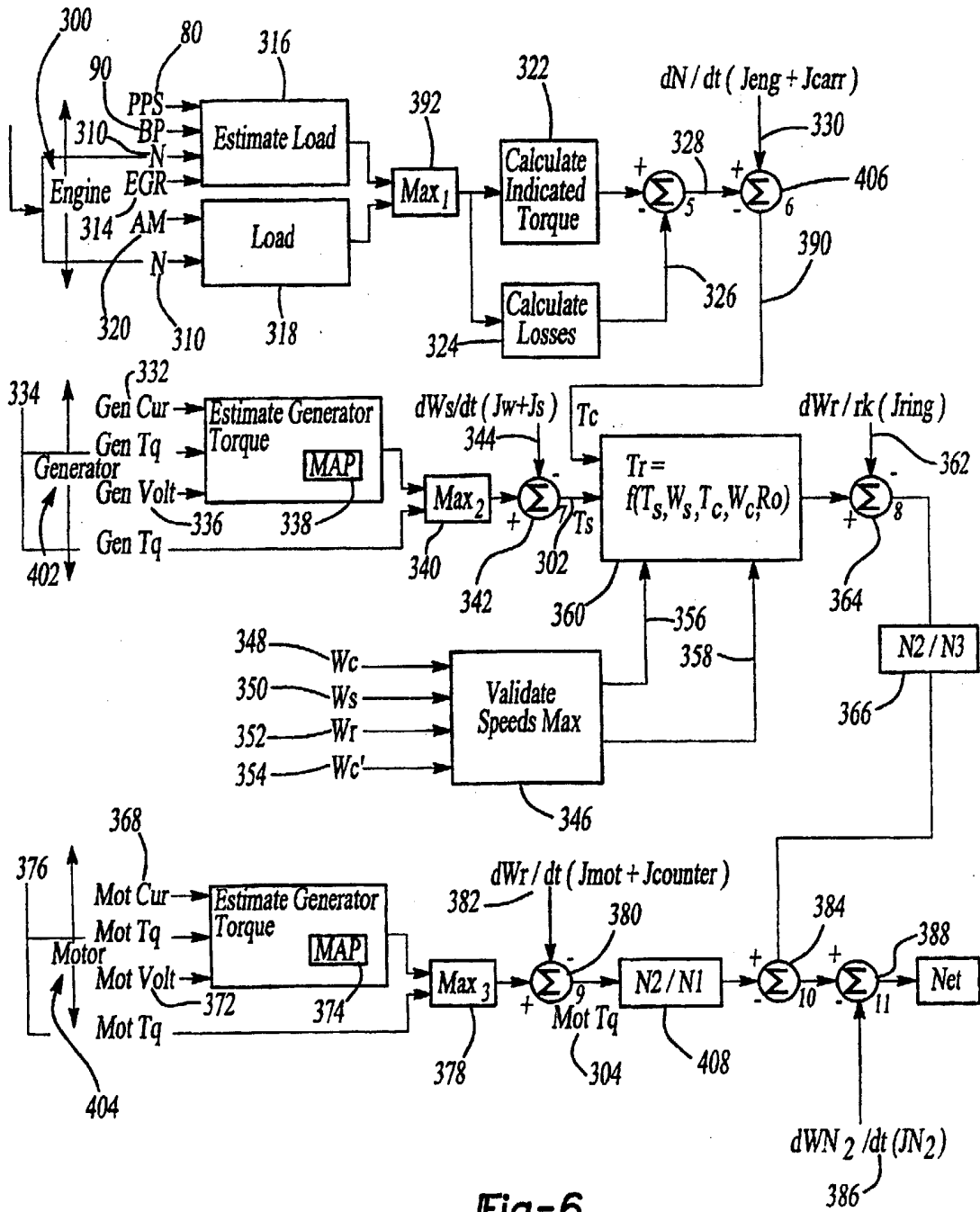
A TORQUE-BASED MONITOR IN A HYBRID ELECTRIC VEHICLE

The present invention relates to a toque based monitor
of detected output torque of the powertrain of a Hybrid

5   Electric Vehicle ("HEV") and compares it to a desired output
torque of the operator.

The need to reduce fossil fuel consumption and
pollutants from automobiles and other vehicles powered by an

10   internal combustion engines (ICE's) is well known. Vehicles
powered by electric motors have attempted to address these
needs. However, electric vehicles have limited range and
limited power coupled with the substantial time needed to
recharge their batteries. An alternative solution is to

15   combine both an ICE and electric traction motor into one
vehicle. Such   vehicles are typically called hybrid
electric vehicles (HEV's). See generally, U.S. Pat. No.
5,343,970 (Severinsky).

20   The HEV has been described in a variety of
configurations. Many HEV patents disclose systems where an
operator is required to select between electric and internal
combustion operation. In other configurations the electric
motor drives one set of wheels and the ICE drives a

25   different set.

Other, more useful, configurations have developed. A
series hybrid electric vehicle (SHEV) is a vehicle with an
engine (most typically an ICE) which powers a generator. The

30   generator, in turn, provides electricity for a battery and
motor coupled to the drive wheels of the vehicle. There is
no mechanical connection between the engine and the drive
wheels.

35   A parallel hybrid electrical vehicle (PHEV) is a
vehicle with an engine (most typically an ICE), battery, and

electric motor combined to provide torque to power the wheels of the vehicle.

A parallel/series hybrid electric vehicle (PSHEV) has characteristics of both the PHEV and the SHEV. The PSHEV is also known as a torque (or power) splitting powertrain configuration. Here, the torque output of the engine is given in part to the drive wheels and in part to an electrical generator. The generator powers a battery and motor that also provide torque output. In this configuration, torque output can come from either source or both simultaneously. The vehicle braking system can even deliver torque to drive the generator to produce charge to the battery.

The desirability of combining the ICE with an electric motor is clear. The ICE's fuel consumption and pollutants are reduced with no appreciable loss of performance or range of the vehicle. Nevertheless, there remains substantial room for development of ways to optimize these HEV's operational parameters.

One such area of HEV development is throttle control mechanisms. In prior art throttle controls, a direct physical link (an accelerator cable) between an accelerator pedal (pedal) and a throttle body controls a throttle plate of the 5 ICE. The throttle plate is pulled open by the accelerator cable as the driver depresses the pedal. This increases engine speed and torque. Although simple and dependable, this throttle control method is unable to adapt fuel consumption efficiency to changing traveling conditions.

An electronic throttle control (ETC) is a recent development for improving throttle control and efficient introduction of fuel air mixtures into an engine's cylinders. With the ETC system, the accelerator pedal is no

longer mechanically connected to the throttle body. Instead,
an actuator positions the throttle plate by a system,
process, or apparatus called a powertrain control module
(PCM). The PCM determines the desired throttle position
5   based on the accelerator pedal's position sensor. This
simple ETC system essentially mimics the conventional
mechanical throttle and is often called the "pedal follower"
ETC system. To protect vehicle occupants, ETC systems soon
added a second independent processor to detect ETC system
10 failures. This processor determines if the system is in a
safe mode of operation. If it is not in safe mode, vehicle
operation is restricted and throttle plate control is
prohibited. Ford's second generation ETC (2GETC) systems
have added greater vehicle control. These systems no longer
15 control in the "pedal follower" mode, but in a "torque
control" mode. Accelerator position, vehicle speed, and
barometric pressure 5 in torque control mode are mapped into
a desired/demanded driver torque request/wheel torque
request. In torque control mode, the PCM can independently
20 control vehicle subsystems such as throttle plate position,
transmission gear, transmission slip, ignition timing, and
fuel delivery to provide the desired wheel torque. To
improve vehicle efficiency, torque control monitor systems
add a monitoring scheme to ensure powertrain torque output
25 is not greater than the demanded torque output. See
generally, U.S. Pat. No. 5,673,668 to Pallett, et. al.

Unfortunately, the 2GETC engine torque output
comparison is no longer sufficient for HEV. The HEV also has
30 an electric traction drive motor and generator adding torque
to the vehicle's powertrain. The ETC for the HEV must
establish control of the HEV's entire powertrain. HEV
patents that reference ETC's are described in U.S. Pat. No.
5,656,921 to Farrall and Pat. No. 5,806,617 to Yamaguchi.

35

It is an object of this invention to provide an apparatus an method for use in improving the performance of a hybrid electric vehicle.

5   According to a first aspect of the invention there is provided an apparatus for a torque based monitor of a torque splitting hybrid electric vehicle powertrain and regenerative brake system in a powertrain control module comprising a main controller, a set of vehicle state
10   sensors, the main controller and the vehicle state sensors being connected through communication interfaces, an independent plausibility check device connected to the vehicle state sensors and the communication interfaces but being independent of the main controller, the check device
15   including a first operating mode comprising a comparison device to determine whether detected output shaft torque is greater than desired output shaft torque and a second operating mode limiting function of a torque output of the hybrid electric vehicle powertrain when a detected output
20   shaft torque is greater than a desired output shaft torque wherein the independent plausibility check device is operable in a second mode of operation comprising a shut down determination of the torque output of the hybrid electric vehicle powertrain when a fault is detected in the
25   powertrain control module.

The apparatus may further comprise a quizzing device connected to the independent plausibility check to verify functionality of the independent plausibility check, wherein
30   the quizzing device seeds the independent plausibility check with vehicle state values, receives an independent plausibility check response, performs a functionality test and shuts down the torque output of the hybrid electric vehicle powertrain if a fault is detected.
35

The main controller may determine a main controller desired output shaft torque from the vehicle state sensors

and the independent plausibility check independently determines an independent plausibility check desired output shaft torque from the vehicle state sensors.

The independent plausibility check may include a minimiser or comparator which determines a vehicle desired output shaft torque as smaller of the main controller desired output shaft torque and the independent plausibility check desired output shaft torque.

The independent plausibility check may comprise a device to determine vehicle detected output shaft torque by combining output shaft torques of an internal combustion engine, a generator, and an electric traction motor, all connected to the independent plausibility check through the vehicle state sensors and the communication interfaces.

A compare device may compare the vehicle desired output shaft torque to the detected output shaft torque and processed through a fault filter, the fault filter determining mitigation or hybrid electric vehicle shutdown when detected output shaft torque is greater than desired output shaft torque or a powertrain control module fault is detected.

According to a second aspect of the invention there is provided a method for monitoring torque of a torque splitting hybrid electric vehicle powertrain and regenerative braking system with a powertrain control module having a main controller comprising the steps of monitoring a set of vehicle state sensors and communication interfaces through the main controller and determining when main controller detected output shaft torque is greater than main controller desired output shaft torque, monitoring the set of vehicle state sensors and communication interfaces shared with the main controller through an independent plausibility check and determining when independent plausibility check

detected output shaft torque is greater than independent plausibility check desired output shaft torque, limiting torque output of the hybrid electric vehicle powertrain when the detected output shaft torque is greater than desired output shaft torque and shutting down torque output of the hybrid electric vehicle powertrain when a fault is detected in the powertrain control module.

The method may further comprise the step of quizzing the independent plausibility check to verify functionality of the independent plausibility check processor, including seeding the independent plausibility check processor with vehicle state values, receiving an independent plausibility check processor response, performing a functionality test and shutting down torque output of the hybrid electric vehicle powertrain if a fault is detected.

Determining the desired output shaft torque may comprise the main controller processor determining a main controller desired output shaft torque from the vehicle state sensors and the independent plausibility check processor independently determining an independent plausibility check desired output shaft torque from the shared vehicle state sensors.

A vehicle desired output shaft torque may be determined by comparing the main controller desired output shaft torque with the independent plausibility check desired output shaft torque and choosing the smaller of the two.

An independent plausibility check detected output shaft torque may be determined and comprises summing combined torque output of an internal combustion engine, a generator, and an electric traction motor through the vehicle state sensors and communication interfaces.

The step of determining when an independent plausibility check detected output shaft torque is greater than the independent plausibility check desired output shaft torque may comprise the step of comparing the vehicle desired output shaft torque to the detected output shaft torque.

The step of determining the torque output of the hybrid electric vehicle powertrain may comprise the step of fault filtering the compared independent plausibility check detected output shaft torque to the vehicle desired output shaft torque and mitigating torque output or shutting down the hybrid electric vehicle powertrain when detected output shaft torque is greater than desired output shaft torque or a fault in the powertrain control module is detected.

According to a third aspect of the invention there is provided a torque based monitor system to control a torque splitting hybrid electric vehicle powertrain and regenerative brake system including a powertrain control module having a main controller processor comprising an independent plausibility check processor independent of the main controller processor, the independent plausibility check processor performing a monitoring function in a first operating mode including reading a set of vehicle state sensors and communication interfaces shared with the main controller processor and determining when detected output shaft torque is greater than desired output shaft torque, the independent plausibility check processor performing a limiting function of torque output of the hybrid electric vehicle powertrain in a second operating mode by limiting detected output shaft torque to less than desired output shaft torque when detected output shaft torque is greater than desired output shaft torque and the independent plausibility check processor performing a shut down function of the torque output of the hybrid electric vehicle

powertrain in the second operating mode when a fault is detected in the powertrain control module.

The invention will now be described by way of example with reference to the accompanying drawing of which:-

Fig, 1 shows a general torque splitter hybrid electric vehicle configuration;

Fig. 2 shows a schematic diagram of the second generation electronic throttle control powertrain control module and monitor design;

Fig. 3 shows a torque splitter hybrid electric vehicle torque based monitor overview including regenerative brakes;

Fig. 4 shows a partial schematic flow diagram of Fig. 3 and in particular the main controller determination of desired output shaft torque;

Fig. 5 shows a partial schematic flow diagram of Fig. 3 and in particular the IPC determination of desired output shaft torque; and

Fig. 6 shows a partial schematic flow diagram of Fig. 3 and in particular the IPC determination of detected output shaft torque.

With reference to the drawings there is shown a preferred embodiment of the invention. It implements a second generation electronic throttle control (2GETC) in the HEV with an integrated system and process for monitoring output shaft torque and regenerative braking.

The HEV powertrain has three main elements that affect torque output to the transaxle output shaft, the generator, engine, and electric traction motor. There are three main

configurations of the HEV parallel, series, and parallel/series.

A parallel/series HEV ("torque splitting") configuration is shown as the preferred embodiment. This configuration is provided for demonstration and is not intended to limit the use of the present invention to this configuration only.

In Figure 1, the basic components of an HEV are shown. An engine 20, is linked to a first gear set, in the form of a planetary gear set 24 via a one-way clutch 30, having a ring gear 26, a carrier 450, and a sun gear 28.

A generator 32 is linked to a generator brake 22, and is also linked to the first gear set 24. A battery 34 is connected to an electric motor 36 and the generator 32 via an inverter 56.

The electric motor 36 is connected to a second gear set 38. The second gear set 38 has a first gear 90, a second gear 42, and a third gear 44. The first gear set 24 and second gear set 38 are both coupled to a third gear set 46 by a counter 452. The third gear set has a fourth gear 48 and a fifth gear 50. The third gear set 46 is coupled to a drive shaft system 58, ultimately providing torque to drive to a vehicle's wheels 52. This configuration can also include a regenerative braking system 54 linked to the motor 36 and an inverter 56 linked between the battery 39 and the generator 32 as well as between the battery 34 and the motor 36.

A prior art second generation electronic throttle control system (2GETC) is shown in Figure 2. Generally, a powertrain control module (PCM) 60 is connected to and controls all powertrain functions, including a main controller 62 and an independent plausibility check (IPC) 64.

The IPC 64 is a safety feature to independently compare desired and actual torque values via a different calculation path. If a hazardous condition is detected (such as a failure of a system), the PCM 60 mitigates the fault or shuts down the vehicle. The PCM 60, as shown, controls a variety of processes including transmission gear command 70, transmission slip command 72, engine throttle control command 74, fuel flow command 76, and spark timing command 78. The main controller 62 receives vehicle state information from sensor outputs from a variety of vehicle components.

Three pedal position sensors (PPS) 80 outputs to an arbitration PPS 82. The redundant sensors help ensure safe operation. If a discrepancy is detected from any of the three sensors, the arbitration PPS 72 eliminates the output of from the erroneous switch. A wheel torque request process 84 receives the output from the arbitration PPS 82, as well as vehicle speed 92, barometric pressure 90, and cruise wheel torque from the cruise module 94 through communication interfaces. This process determines the desired wheel torque of the operator. A transmission calculation process 96 receives the output from actual transmission gear 86, actual transmission slip 88, wheel torque request 84, and vehicle speed 92. The transmission calculations process 96 outputs the transmission 5 gear command 70 and the transmission slip command 72. An accessory adder process 98 receives torque load information from a vehicle air conditioner 100, vehicle accessories 102, and other added friction variables (e.g., a water pump) 104.

The accessories are basically anything other 10 than drive train load.

A first summation process 106 receives torque trim the output from an idle airflow process 108, the transmission calculations process 96, and the accessory adder 98. The

idle airflow process 108 also outputs desired air mass flow
to the desired airflow process 108. The first summation
process outputs total driver requested torque to the desired
airflow process 108, a desired fuel process 110, and a
desired spark timing process 112. The desired airflow
process 108 then outputs the engine throttle control command
74. The desired fuel process 110 outputs the fuel command
76, and the desired spark process 112 and then outputs the
spark command 78. The IPC 64 receives the output from
several vehicle components as well as from components of the
main controller.

The function of the IPC is to test plausibility of the
system. An IPC accessory adder process 146 receives torque
load information from the vehicle air conditioner 100,
vehicle accessories 102, and added friction variables 104.
The process to determine driver demand 120 receives the
output 5 from the pedal position sensors 80. A process to
determine wheel torque request 130 receives the output from
the main controller's cruise module 94 and the IPC's process
to determine driver demand 120. A process to convert engine
torque 132 receives the output from the process to determine
wheel torque request 130, actual transmission gear 86, and
actual transmission slip 88. A second summation process 134
receives engine torque request from the process to convert
engine torque 132 and EEC torque trim (electronic engine
control) 136.

A compare process 148 receives the total engine torque
request from the second summation process 134 and compares
the value of an estimate of actual engine torque received
from an estimate actual engine torque process 138. The
estimate actual engine torque process 138 receives the
output from the desired fuel process 110, desired spark
process 112, an EEC engine speed 140, an EEC relative
throttle position 142, an EEC actual exhaust gas
recirculating calculation 144, and the IPC accessory adder

process 146. An idle airflow request check 152 receives the output from an EEC desired mass airflow 150. Finally, a fault filter 154 receives the output from the idle airflow request check 152 and the compare process 148.

If a fault is detected, the fault filter 154 sends a vehicle shut down command 156. The next major component of the system is a quizzer 66 as an additional independent monitor to verify proper operation of the PCM 60.

The quizzer 66 sends seed values 68 to the PCM 60 for a variety of variables such as pedal position, vehicle speed, transmission gear, transmission slip, accessories, engine coolant temperature, mass air flow load, spark timing, and air/fuel ratios.

The IPC 64 returns a response 70 and an IPC functionality test 16 is performed. If a PCM 60 fault is detected, the monitor shuts down the vehicle. Applying this monitor scheme to an HEV requires a change from monitoring just engine torque production to estimating and monitoring the output shaft torque production of the entire power train.

Figure 3 provides an overview of a power split HEV torque based monitor method, system, and apparatus (also known as the powertrain control module or PCM). There are similarities to the second generation ETC shown in Figure 2.

This HEV monitor system has an HEV main controller 200, an enhanced HEV independent plausibility check 202, and a quizzer 204.

HEV main controller 200 is connected to various vehicle outputs including the regenerative braking system 54 to determine driver torque demand. The HEV enhanced IPC 202

contains the HEV IPC determination system of a driver torque
demand including regenerative braking 206 and an HEV
estimate of output shaft torque 208.

5   The HEV IPC minimizer system 210 compares desired
output shaft torque 224 from the HEV main controller 200 and
desired output shaft torque from the HEV IPC 224 and outputs
the minimal value as a second desired output shaft torque 18
to an HEV IPC comparison system 212.

10

       The HEV IPC 202 contains the HEV IPC output shaft
torque system 208 that receives various engine outputs from
the vehicle including, the engine 20, generator 32, and
motor 36.

15

       The HEV IPC estimate output shaft torque system 208 has
a process to calculate an output shaft torque 214. Once
calculated, an HEV IPC output shaft torque 196 is sent to
the HEV IPC comparison system 212. The comparison of the
20   second desired output shaft torque 18 and the estimated
output shaft torque 196 is essentially a summation
determination which is outputted to an HEV IPC fault filter
216.

25   The HEV IPC fault filter 216 outputs any faults
detected in the system to an HEV IPC vehicle
shutdown/mitigation (limiting) system 218.

       The mitigation system 218 allows the limiting or
30   prohibition of powertrain output torque when the output
torque 214 is greater than the output torque demanded 210.
Additionally, the HEV IPC 202 determines if the delivered
output shaft torque is within the requested output shaft
torque limits during power on and regenerative braking.
35   Additionally, the HEV torque based monitor system contains
the HEV quizzer 204 to verify functionality of the HEV IPC

202. Similarly, the HEV IPC 202 verifies the functionality of the quizzer 204.

Figure 4 adds more detail to the HEV torque based monitor system's main controller process to determine a desired output shaft torque 224.

The HEV main controller 200 receives from communication interfaces a variety of vehicle state sensory outputs including: vehicle speed 92, pedal position (PPS) 80, barometric pressure 90, and actual transmission gear 86.

The HEV main controller 200 uses these outputs and determines an HEV shaft torque request 400 which is sent to an HEV main controller arbitrator 220. The HEV main controller arbitrator 220 also receives the output from a vehicle cruise control 198. The HEV main controller also has a main controller brake feel map system 228 which receives the output from a brake pedal position switch 226. The HEV main controller brake feel map 228 output is sent to an HEV main controller brake torque management unit 230. This unit also receives the output of an HEV regenerative torque limit system 232.

The HEV main controller brake torque management unit 230 outputs to an HEV main controller foundation brake request system 239 and an HEV main controller regenerative torque request 236. The HEV main 13 controller foundation brake request 234 is sent to a vehicle's brake system (e.g., brake pads) 25B.

Two types of brake torque management configurations are possible. The preferred embodiment is called a series brake configuration. In the series configuration, the HEV main controller brake torque management unit 230 output can go to the HEV main controller regenerative torque request 236

only, the HEV main controller foundation brake request 234
only, or to both in various proportions.

A second configuration is called the parallel brake
management system. This configuration only allows the output
to both in various proportions, i.e., some output will
always go to both brake torque management unit outputs.

The HEV main controller regenerative torque request 236
and the output of the HEV main controller arbitrator 220
feed into a third summation process 222 which outputs the
HEV main controller desired output shaft torque 224.

Figure 5 adds more detail to the HEV torque based
monitor system's IPC system to determine an HEV IPC desired
output shaft torque 244 (see Figure 3). This system is
essentially redundant to the system of the main controller
process to determine HEV IPC desired output shaft torque 224
in Figure 4.

The HEV IPC 206 receives a variety of vehicle state
sensory outputs including: vehicle speed 92, pedal position
(PPS) 80, barometric pressure 90, and actual transmission
gear 86. The 14 HEV IPC 206 uses these outputs and, in turn,
outputs an HEV shaft torque request 420 which is sent to an
HEV IPC arbitrator 240. The HEV IPC arbitrator 240 also
receives the output from the vehicle cruise control 198.

The HEV IPC also has an HEV IPC brake feel map system
248 which receives the output from a brake pedal position
switch 226. The HEV IPC brake feel map 248 output is sent to
an HEV IPC brake torque management unit 250. This unit also
receives the output of the HEV regenerative torque limit
system 232. The HEV IPC brake torque management unit 250
outputs to an HEV IPC foundation brake request system 254
and a HEV IPC regenerative torque request 256. The HEV IPC

foundation brake request 256 is sent to the vehicle's brake
system (e.g., brake pads)258.

Two types of brake torque management configurations are
possible. The preferred embodiment is called a series brake
configuration. In the series configuration, the HEV IPC
brake torque management unit 250 output can go to' the HEV
IPC regenerative torque request 256 only, the HEV IPC
foundation brake request 254 only, or to both in various
proportions.

A second configuration is called the parallel brake
management system. This configuration only allows the output
to both in various proportions, i.e., some output will
always go to both brake torque management unit outputs.

The HEV IPC regenerative torque request 256 and the
output of the HEV IPC arbitrator 240 feed into a forth
summation process 242 which outputs the HEV IPC desired
output shaft torque 244.

The parallel/series HEV configuration requires
enhancement of many other independent plausibility check
(IPC) determinations to obtain the entire vehicle's
powertrain output shaft torque. The output torque of the
engine 20, the generator 32, and the electric traction motor
36 need to be determined individually and then combined to
form a single vehicle output shaft torque.

The prior art second generation ECT's do not address
these necessary enhancements.

Figure 6 shows this HEV IPC output shaft torque system
shown as element 208 in Figure 3. In Figure 6, an IPC HEV
engine torque output calculation system 300 receives
information from vehicle components similar to most second
generation ETC systems. This engine calculation system 300

has an engine estimate load system 316 and an engine load system 318.

The engine estimate load system 316 receives an output for engine speed 310, barometric pressure 90, PPS 80, and exhaust gas recirculation 314. The engine load system 318 receives output for air mass 320 and engine speed 310. The output of the engine estimate load system 316 and the engine load system 318 are inputted into a first MAX system 392 where the higher of the two loads is 16 selected and outputted to an indicated torque calculation system 322 and a loss calculation system 324.

The loss calculation system 324 includes a torque loss determination of accessory devices (such as the air conditioner, water pump, etc.). The output of the indicated torque calculation system 322 and the loss calculation system is sent to a fifth summation process 326 to determine engine brake torque 328.

Engine inertia torque 330 is determine using the following formula:

$$dN/dt(J\text{-eng} + J\text{-carr}) \quad \text{where}$$

d = derivative, N = engine speed, t = time,

J = inertia, eng = engine 20, and carr = carrier 450.

The engine torque brake 328 and the engine inertia torque 330 are inputted into a sixth summation process 406.

The output of this sixth summation process is an engine torque 390. The next HEV IPC system must estimate the torque output of the generator 32. An IPC HEV calculation of generator torque 402 first receives the output from the generator 32 including generator current 332, generator

torque determination by a commercially available system 334, and generator voltage 336. These determinations are inputted into an HEV generator torque map 338. The output from the HEV generator torque map 338 are compared to the generator
5   torque   334 in a second MAX system 340. The greater of the output of 17 the generator map 338 and generator torque 334 is outputted to a seventh summation process 342.

Generator inertia torque 344 is determined using the
10   following formula:

dWs/dt(J-W + J-s)   where

d = derivative, W = generator speed 32,
15

s = sun gear 28, t = time, J = inertia

Generator inertia torque 344 is also inputted into the seventh summation process 342. The output of the seventh
20   summation process 342 is generator torque 302.

Because the engine 20 and the generator 32 are linked to the same first gear system their combined torque to the ring gear 26 must be determined. A ring gear torque 360
25   determination process receives the engine torque 390 and the generator torque 302.

An additional process needed to determine the combined torque of the ring gear 26 is a maximum speed validation
30   process 346. This validation process 346 receives carrier 450 speed 354, sun gear 28 speed 350, ring gear 26 speed 352, and the entire monitor's (PCM's) carrier 450 speed 354 and takes the maximum values and outputs a max carrier 450 speed 356 and a max sun gear speed 358.
35

The ring gear torque 360 is calculated as a function

f {Ts, Ws, Tc, Wc, p}   where

T = torque, W = speed s = sun gear 28,
c = carrier 450, and

p = ratio of the sun gear and ring gear 18.

A derivative ring gear speed 362 must also be
calculated using the following formula:

dWr/dt(J-r)   where

d is the derivative, W = speed, r = ring gear 26,

t = time, and J = inertia.

The output of the derivative ring gear speed 362 and
the ring gear torque 360 is inputted into an eighth
summation process 364 which is in turn outputted into a
first gear ratio calculation process 366 determining the
ratio of the second gear 42 over the first gear 40.

Next, the system must estimate the torque output of the
electric traction motor (motor) 36. The IPC HEV motor torque
output determination system 404 first receives the output
from the motor 36. A motor current 368, a motor torque from
a commercially available source 376, and a motor voltage 372
are inputted into a motor torque map 374. The output from
this map 374 is compared to the motor torque determination
by a commercially available system 376 in a third MAX system
378. The greater of the output of the motor map 374 and the
motor   speed 372 is outputted to a ninth summation process
380.

Motor inertia torque 382 is determined using the
following formula:

dWr/dt(J-mot + J-counter) where

d = derivative, W = motor 36 speed, r = ring gear,

5   t = time, J = inertia, mot = motor 36, and

counter = counter 452

Motor inertia torque 382 is also inputted into a ninth
10   summation process 380. The output of the ninth summation
process 382 is an HEV motor torque 304. The HEV motor torque
304 is inputted into a second gear ratio calculation process
408 and determines the ratio of the second gear 92 over the
third gear 44.
15

Once the estimates of the output torque of the engine
20, generator 32 (first gear ratio calculation process 366),
and motor 36 (second gear ratio calculation process 382) are
determined they are combined into a tenth summation process
20   384.

This system must finally determine an inertia torque of
the second gear 386 using the following formula:

25   dWN/dt(JN)   where

d = derivative, W = motor 36 speed,

N = the second gear 42, t = time, and J = inertia.
30

The output of the tenth summation process 384 and
output of the inertia torque of the second gear 386 are
inputted into an eleventh summation process 388 to provide
the net output shaft torque 196.

CLAIMS

1. An apparatus for a torque based monitor of a torque splitting hybrid electric vehicle powertrain and regenerative brake system in a powertrain control module comprising a main controller, a set of vehicle state sensors, the main controller and the vehicle state sensors being connected through communication interfaces, an independent plausibility check device connected to the vehicle state sensors and the communication interfaces but being independent of the main controller, the check device including a first operating mode comprising a comparison device to determine whether detected output shaft torque is greater than desired output shaft torque and a second operating mode limiting function of a torque output of the hybrid electric vehicle powertrain when a detected output shaft torque is greater than a desired output shaft torque wherein the independent plausibility check device is operable in a second mode of operation comprising a shut down determination of the torque output of the hybrid electric vehicle powertrain when a fault is detected in the powertrain control module.

2. An apparatus as claimed in claim 1 further comprising a quizzing device connected to the independent plausibility check to verify functionality of the independent plausibility check, wherein the quizzing device seeds the independent plausibility check with vehicle state values, receives an independent plausibility check response, performs a functionality test and shuts down the torque output of the hybrid electric vehicle powertrain if a fault is detected.

3. An apparatus as claimed in claim 1 or claim 2 wherein the main controller determines a main controller desired output shaft torque from the vehicle state sensors and the independent plausibility check independently

determines an independent plausibility check desired output shaft torque from the vehicle state sensors.

4.   An apparatus as claimed in any of claims 1 to 3 wherein the independent plausibility check includes a minimiser which determines a vehicle desired output shaft torque as smaller of the main controller desired output shaft torque and the independent plausibility check desired output shaft torque.

5.   An apparatus as claimed in any of claims 1 to 4 wherein the independent plausibility check comprises a device to determine vehicle detected output shaft torque by combining output shaft torques of an internal combustion engine, a generator, and an electric traction motor, all connected to the independent plausibility check through the vehicle state sensors and the communication interfaces.

6.   An apparatus as claimed in claim 5 wherein a compare device compares the vehicle desired output shaft torque to the detected output shaft torque and processed through a fault filter, the fault filter determining mitigation or hybrid electric vehicle shutdown when detected output shaft torque is greater than desired output shaft torque or a powertrain control module fault is detected.

7.   A method for monitoring torque of a torque splitting hybrid electric vehicle powertrain and regenerative braking system with a powertrain control module having a main controller comprising the steps of monitoring a set of vehicle state sensors and communication interfaces through the main controller and determining when main controller detected output shaft torque is greater than main controller desired output shaft torque, monitoring the set of vehicle state sensors and communication interfaces shared with the main controller through an independent plausibility check and determining when independent plausibility check

detected output shaft torque is greater than independent
plausibility check desired output shaft torque, limiting
torque output of the hybrid electric vehicle powertrain when
the detected output shaft torque is greater than desired
5   output shaft torque and shutting down torque output of the
hybrid electric vehicle powertrain when a fault is detected
in the powertrain control module.

8.   A method as claimed in claim 7 further comprising
10   the step of quizzing the independent plausibility check to
verify functionality of the independent plausibility check
processor, including seeding the independent plausibility
check processor with vehicle state values, receiving an
independent plausibility check processor response,
15   performing a functionality test and shutting down torque
output of the hybrid electric vehicle powertrain if a fault
is detected.

9.   A method as claimed in claim 7 or in claim 8
20   wherein determining the desired output shaft torque
comprises the main controller processor determining a main
controller desired output shaft torque from the vehicle
state sensors and the independent plausibility check
processor independently determining an independent
25   plausibility check desired output shaft torque from the
shared vehicle state sensors.

10.   A method as claimed in any of claims 7 to 9
wherein a vehicle desired output shaft torque is determined
30   by comparing the main controller desired output shaft torque
with the independent plausibility check desired output shaft
torque and choosing the smaller of the two.

11.   A method as claimed in any of claims 7 to 10
35   wherein an independent plausibility check detected output
shaft torque is determined and comprises summing combined
torque output of an internal combustion engine, a generator,

and an electric traction motor through the vehicle state
sensors and communication interfaces.

12. A method as claimed in any of claims 7 to 11
wherein determining when an independent plausibility check
detected output shaft torque is greater than the independent
plausibility check desired output shaft torque comprises the
step of comparing the vehicle desired output shaft torque to
the detected output shaft torque.

13. A method as claimed in any of claims 7 to 12
wherein determining the torque output of the hybrid electric
vehicle powertrain comprises the step of fault filtering the
compared independent plausibility check detected output
shaft torque to the vehicle desired output shaft torque and
mitigating torque output or shutting down the hybrid
electric vehicle powertrain when detected output shaft
torque is greater than desired output shaft torque or a
fault in the powertrain control module is detected.

14. An apparatus for a torque based monitor of a
torque splitting hybrid electric vehicle powertrain and
regenerative brake system in a powertrain control module
substantially as described herein with reference to the
accompanying drawing.

15. A method for monitoring torque of a torque
splitting hybrid electric vehicle powertrain and
regenerative braking system with a powertrain control module
substantially as described herein with reference to the
accompanying drawing.

Application No: GB 0126485.2   25   **Examiner:** Peter Mason
Claims searched: 1-15   **Date of search:** 13 May 2002

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Databases searched:

UK Patent Office collections, including GB, EP, WO & US patent specifications, in:

  UK Cl (Ed.T): G3N: NGK2A, NGK2B, NGK2, NGK1V2, NGK1V3, NGK1VX
  G3R: RBR

  Int Cl (Ed.7): B60K: 6/00, 6/02, 6/04, 41/00
  F02D: 41/22, 41/26
  G05D: 17/02

Other: Online: EPODOC, JAPIO, WPI

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Category	Identity of document and relevant passage		Relevant to claims
A	GB 2,316,190 A	(FORD GLOBAL TECHNOLOGIES) See whole document	-
A	JP 2001 333,503 A	(MITSUBISHI MOTORS CORP) See WPI & PAJ Abstracts	-
A	JP 2000 152,412 A	(FUJI HEAVY IND. LTD) See WPI & PAJ Abstracts	-

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