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(71) Applicant: **ZF CV SYSTEMS GLOBAL GMBH**  
[CH/CH]; Giacomettistrasse 1, 3006 Bern (CH).

(72) Inventors: **MUTHUKUMARAN, ArunKumar**; H312, VGN Temple Town, Chennai 600077 (IN). **MUTHUPALANIAPPAN, Muthupalaniappan**; Constantinstr. 21, 30177 Hannover (DE).

(74) Agent: **SCHAEFERJOHANN, Volker**; Am Lindener Hafen 21, 30453 Hannover (DE).

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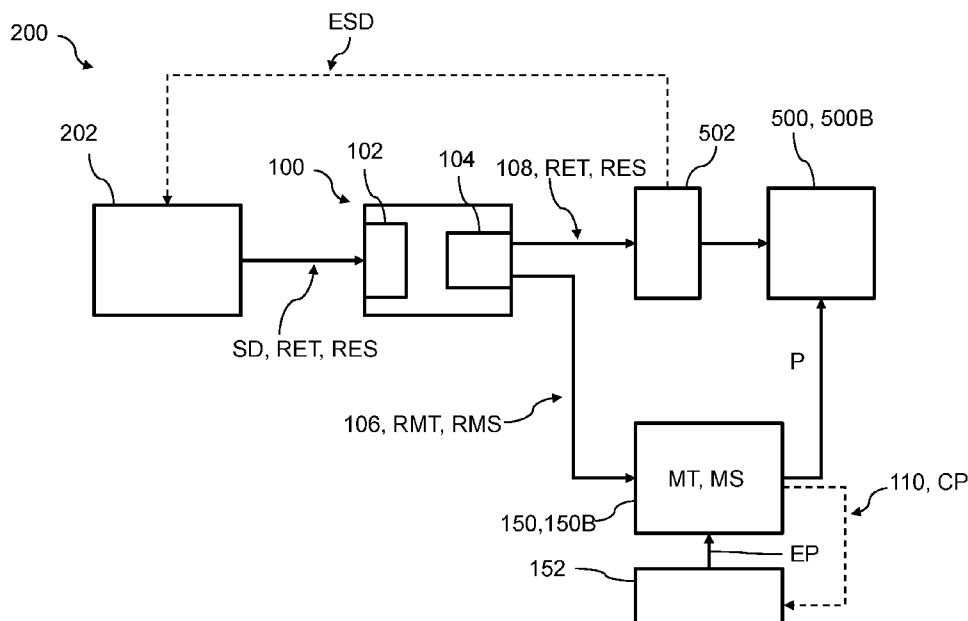


FIG. 3

(57) Abstract: The invention is directed to a control device (100) for controlling an engine (500) during a gear-down shift (DS), the control device (100) comprising a shift ascertaining unit (102) configured to ascertain shift data (SD) indicative of a request to shift a current gear (G) a processing unit (104) configured, upon determining that the ascertained shift data is indicative of a request to downshift the current gear, to generate and provide to an electric motor (150) an electric motor control signal (106) indicative of a required motor torque (RMT) and/or a required motor speed (RMS), wherein the electric motor (150) is configured to be powered by a battery unit (152) and is operatively coupled to the engine (500) and configured to provide to the engine, in response to a reception of the electric motor control signal (106), a power amount (P) necessary to perform the requested downshift (DS).

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Control device and method for operating a control device, transmission control arrangement, motor vehicle and computer program

The present invention is directed to a control device for controlling operation of an engine of a vehicle and to a method for operating said control device. The invention is also directed to a transmission control arrangement, to a motor vehicle and to a computer program.

Increasing air pollution and lack of fossil fuels have encouraged the development of innovative technologies to improve fuel economy and reduce air borne pollutants. The manner of gear shifting is one of the main factors affecting the fuel efficiency of motor vehicles. Potential savings resulted from optimized gear shifting led to introduction of gear shift indicators in passenger vehicles. The gear shifting process in an automated manual or automatic transmission system involves matching of engine speed and controlling of engine torque. This is typically managed by electronic transmission systems that requests an engine controller to realize this by changing fuel quantity. The conventional automated manual transmission (AMT) and automated transmission (AT) systems use engine fuel to control the engine speed/torque required during gear shifting process. This approach consumes fuel for gear shifting which increases fuel consumption and carbon emissions.

Automated manual transmission is a type of transmission for motor vehicles which includes a conventional manual transmission equipped with automatic actuation to operate the clutch and/or shift gears. Automated transmission is a multi-speed transmission used in motor vehicles that does not require any input from the driver to change forward gears under normal driving conditions.

Document DE102007000110A1 describes a controller for controlling a gear change operation of an automated transmission for a vehicle that uses an optimal gear shift in response to vehicle conditions and selects a gear shift line from a shift map in order to improve fuel economy of the vehicle.

In vehicles with automated transmission, when a transmission system determines that the current gear has to be shifted, either upshifted or downshifted, a control unit or controller of the transmission systems provides, to a controller of the engine, an engine torque request or/and an engine speed request indicative of the torque value and/or engine speed value at which the engine should operate during the shifting. In known vehicles, the control of the torque and/or speed of the engine is realized by the engine by controlling a supply of fuel.

This is where the invention comes in, wherein it is an objective of the present invention to improve fuel economy on vehicles with automated transmission.

This objective is achieved in a first aspect of the present invention by a control device for controlling an engine of a vehicle according to claim 1. The control device of the first aspect of the invention comprises a shift ascertaining unit configured to ascertain shift data indicative of a request to shift a current gear. The control device also comprises a processing unit that is configured, upon determining that the ascertained shift data is indicative of a request to downshift a current gear, to generate and provide to an electric motor an electric motor control signal indicative of a required motor torque and/or a required motor speed. The electric motor is configured to be powered by a battery unit and is operatively coupled to the engine of the vehicle. In response to a reception of the electric motor control signal, the electric motor is configured to provide to the engine of the vehicle a power amount necessary to perform the requested downshift.

In conventional automatic or semi-automatic transmission systems, a transmission electronic control unit (ECU) provides a torque or a speed request to an engine ECU in order to synchronize the engine with the transmission system before and after shifting. The inventors have realized, that during a downshifting process, in motor vehicles with automatic transmission, the motor torque and the engine speed increase during a brief amount of time. Typically, in known motor vehicles with automatic transmission, the increase of the motor torque and/or engine speed is achieved by consuming fuel. According to the invention, when the ascertained shift data is indicative of a request to downshift the current gear, the control device is configured to drive operation of an electric motor powered by a battery unit and that is configured to provide the necessary power to increment the motor torque and/or engine speed such that the engine and the transmission system synchronize, i.e. the necessary power amount to perform the requested

downshift. Therefore, the increment of the motor torque and/or engine speed necessary for optimal downshifting is not achieved by consuming fuel, and thus the fuel consumption of the vehicle is reduced. In other words, the battery unit is configured to power the electric motor to achieve the desired engine torque or engine speed for the downshifting process.

Further advantageous developments of the control device of the first aspect of the invention are found in the dependent claims and indicate in detail advantageous possibilities to realize the concept described above within the scope of the object as well as with regard to further advantages.

In the following, development of the control device of the first aspect will be described.

In a development, the shift data is an engine torque request or an engine speed request, analogous to the requests provided by known transmission ECUs for directly controlling the engine. Thus, in this development, term ascertaining is to be understood as receiving shift data, in particular from a transmission ECU. For instance, in a development, the control device can be integrated in the engine ECU. In an alternative embodiment the control device is part of the transmission ECU and the shift ascertainment unit is configured to determine and provide the shift data in accordance with current driving/engine parameters, such as, but not limited to a current gear, a current speed, a current rpm value of the engine, a selected driving mode (sport, eco, etc.). Alternatively, the control device is part of a dedicated gearshift execution controller connected to a transmission ECU for receiving the shift data (e.g., engine torque request, engine speed request, upshift or downshift information, etc.) and connected to the electric motor for providing the electric motor control signal.

In another development, the processing unit is further configured, upon determining that the ascertained shift data is indicative of a request to upshift the current gear, to generate and provide an engine control signal indicative of a required engine torque and/or a required engine speed to the engine of the vehicle, for performing the requested upshift. Additionally, the processing unit is configured and to enable a recharge of the battery unit using a charge power generated by a reduction of the engine torque value and/or an engine speed value associated to the upshift process. The inventors have realized

that during an upshifting process the current engine speed and engine torque are reduced. In this development, the reduction of engine torque and/or speed associated to the upshift process is used by the electric motor, which acts as a generator that receives the kinetic energy from the engine, transforms it into electric power and provides the generated electric power to the battery unit, thereby increasing the efficiency of the engine and further reducing the fuel consumption.

In a preferred development, the processing unit is configured to provide the electric motor control signal to an electric starter motor of the vehicle. The electric starter motor is configured to provide the power amount to the engine. A starter, also referred to as a self-starter, cranking motor, or starter motor, is a device used to rotate or crank an internal-combustion engine so as to initiate the engine's operation under its own power. In this development, there is no specific need for a dedicated electric motor and the control device is configured to control operation of the starter motor for providing the power amount needed for the downshifting process. Preferably, the electric starter motor is also configured to act as a generator that transforms the kinetic energy available at the engine during the upshifting process into electric power to charge the battery unit. The usage of an electric starter motor as generator is quite common in many start stop functionality vehicles. The stator receives energy from the battery and causes rotation of the rotor, which then cranks up the engine. After the engine starts, the crankshaft rotation causes the rotor to rotate, which produces an electric current in the stator and this electric energy is used to recharge the battery.

In yet another development, the control device further comprises a deceleration ascertaining unit that is configured to ascertain deceleration data indicative of a deceleration request, and wherein the processing unit is further configured, upon ascertaining a deceleration request, to enable a recharge of the battery unit using a second charge power generated by a deceleration of the vehicle. Thus, in this development, in addition or alternatively to providing power to the battery unit using the kinetic energy associated to the upshifting process, the control device is configured to control a kinetic energy recovery process of the kinetic energy associated to a deceleration or a braking process. Here again, the kinetic energy available at the engine due to the deceleration process is transformed at the electric motor, acting as a generator, into electric power that is stored at the battery unit and then used for providing the necessary power for carrying out the downshifting process. The deceleration request can be associated to a driver releasing

the accelerator pedal and/or pressing the brake pedal, or can be provided by an external system such as for example an automatic cruise control system requesting deceleration, for instance to maintain a safe distance to vehicles located ahead.

Preferably, in a development, the control device further comprises a battery charge ascertaining unit that is configured to ascertain charge data indicative of a state of charge of the battery unit. In this development, the processing unit is further configured to generate the electric motor control signal in dependence on the ascertained state of charge. Thus, advantageously, the electric motor control signal is only provided when the charge data is indicative of a state of charge compatible with the provision of power to the electric motor, e.g., when the battery unit has sufficient charge stored. If this is not the case, the control device is configured to provide an engine control signal indicative of a required engine torque and/or a required engine speed to the engine of the vehicle for performing the requested downshift using fuel for achieving the required torque or speed increase associated to the downshift process.

In another development, the processing unit is configured to enable the recharge of the battery unit in dependence on the ascertained state of charge of the battery unit. The recharge of the battery unit can be performed using the kinetic energy available at the engine during the upshifting process and/or during the deceleration or braking request, as long as the charge data is indicative of a state of charge that is compatible with further charging. In this development, the battery unit is advantageously protected against overcharging, since the charging process can be interrupted when the current charge state of the battery unit is full or has reached a predetermined maximum charge value.

In particular, it is preferred that energy recuperation for charging the battery unit is allowed only when the battery unit does not have a full charge, and the provision of power from the battery unit to the electric motor is allowed only when the battery unit has enough stored charge. If this is not the case, the request is passed directly to the engine and the increase in engine speed and/or torque is then achieved using fuel.

The proposed control device thus enables a sustainable gear shifting with increased fuel economy.

A second aspect of the present invention is formed by a transmission control arrangement for a vehicle that enables controlling a current gear. The transmission control arrangement of the second aspect of the invention comprises a control device according to the first aspect of the invention as described above. The transmission control arrangement further comprises a transmission control unit that is configured to determine the shift data indicative of a request to shift a current gear using engine status data pertaining to a current operation point of the engine of the vehicle and to provide said shift data to the control device. The transmission control arrangement also includes an electric motor, which is operatively coupled to the engine of the vehicle, and which is configured to receive the electric motor control signal from the control device and to provide to the engine of the vehicle, in response to a reception of the electric motor control signal, the power amount necessary to perform the requested downshift. The transmission control arrangement also comprises a battery unit configured to provide electric power to the electric motor.

Therefore, the transmission control arrangement of the second aspect of the invention shares the advantages of the control device of the first aspect of the invention or of any of its developments. Further advantageous developments of the transmission control arrangement of the second aspect of the invention are found in the dependent claims and indicate in detail advantageous possibilities to realize the concept described above within the scope of the object as well as with regard to further advantages.

In a development, the transmission control arrangement further comprises an engine control unit. In this development, upon determining that the ascertained shift data is indicative of a request to upshift the current gear, the control device is configured to provide an engine control signal to the engine control unit for controlling the engine of the vehicle, the engine control signal being indicative of a required engine torque and/or a required engine speed for performing the requested upshift.

In another development, the battery unit is connected to the electric motor and configured to be charged using a power generated by a reduction of the engine torque value and/or by a reduction of an engine speed value, associated to an upshift process.

In yet another development of the transmission control arrangement of the second aspect, the battery unit is further configured to be charged using a second charge power generated by a deceleration, or a braking of the vehicle.

Preferably, in a development, the electric motor is an electric starter motor of the vehicle.

According to a third aspect of the present invention, a motor vehicle is disclosed. The motor vehicle comprises, in particular, an internal combustion engine (ICE) or a hydrogen powered engine. The motor vehicle of the third aspect of the invention includes a control device according to the first aspect of the invention or a transmission control arrangement according to the second aspect of the invention.

Although ICE are expected to be phased out slowly beginning 2030 they are still gaining traction in some regions. The increasing price of crude oil, stringent emission norms, fuel supply security, and noise pollution have compelled OEMs to shift their focus towards natural gas and hydrogen-based engines which are very similar in function to ICE Engines

A fourth aspect of the present invention is formed by a method for operating a control device for controlling an engine of a vehicle during a shifting process. The method comprises:

- ascertaining, e.g., receiving or determining, shift data indicative of a request to shift a current gear;
- upon determining that the ascertained shift data is indicative of a request to downshift a current gear, generating and providing to an electric motor, an electric motor control signal indicative of a required motor torque and/or a required motor speed, wherein the electric motor is powered by a battery unit and is operatively coupled to the engine of the vehicle and configured to provide to the engine of the vehicle, in response to a reception of the electric motor control signal, a power amount necessary to perform the requested downshift.

The method of the fourth aspect of the invention thus shares the advantages of the control device of the first aspect and of any of its developments.

Further, a fifth aspect is formed by a computer program product comprising instructions which, when executed by a control device according to the first aspect, cause the control device to carry out the method of the fifth aspect. The control device can be part of a transmission ECU, of an engine ECU of a general ECU of the vehicle or can be a dedicated gearshift execution controller.

These and other aspects of the invention will be apparent from and elucidated with reference to the embodiments described hereinafter.

The embodiments of the invention are described in the following on the basis of the drawing in comparison with the state of the art, which is also partly illustrated. The latter is not necessarily intended to represent the embodiments to scale. The drawing is, where useful for explanation, shown in schematized and/or slightly distorted form. With regard to additions to the teaching immediately recognizable from the drawing, reference is made to the relevant prior art. It should be kept in mind that numerous modifications and changes can be made to the form and detail of an embodiment without deviating from the general concept of the invention. The features of the invention disclosed in the description, in the drawing and in the claims may be essential for a further development of the invention, either individually or in any combination. In addition, all combinations of at least two of the features disclosed in the description, drawing and/or claims fall within the scope of the invention.

The general concept of the invention is not limited to the exact form or detail of the preferred embodiments shown and described below or to a subject matter, which would be limited in comparison to the subject matter as claimed in the claims.

For specified design ranges, values within specified limits of the ranges are also disclosed as limit values and thus are arbitrarily applicable and claimable.

The following drawing shows in:

- FIG. 1 a schematic block diagram of a known transmission control arrangement for a motor vehicle;
- FIG. 2 time curves of front axle speed values, gear values, engine torque values and engine speed values associated to a set of upshifting and downshifting processes;
- FIG. 3 a schematic block diagram of a transmission control arrangement including a control device in accordance with a first embodiment of the invention;
- FIG. 4 a schematic block diagram of an alternative transmission control arrangement including a control device in accordance with a second embodiment of the invention;
- FIG. 5 a schematic block diagram of an alternative transmission control arrangement including a control device in accordance with a third embodiment of the invention;
- FIG. 6 a schematic block diagram of a motor vehicle in accordance with an embodiment of the invention;
- FIG. 7 a flow diagram of a method for controlling operation of a control device in accordance with an embodiment of the invention; and
- FIG. 8 a flow diagram of another method for controlling operation of a control device in accordance with an embodiment of the invention.

FIG. 1 shows a schematic block diagram of a known transmission control arrangement 10 for a motor vehicle. The arrangement 10 comprises a transmission electronic control unit (ECU) 11 that receives input data ID1, ID2 indicative of the current engine status and/or other current driving parameter and that is configured to, based on the input data, determine whether a current gear should be varied and to provide, to an engine ECU 12 an engine control signal 108 indicative of a required engine torque RET and/or a required engine speed RES for performing the required shifting process. In the case that a downshift is required, the engine torque value and/or the engine speed value

needs to be increased. This increase in torque/speed is driven by fuel consumption at the engine 13, namely an internal combustion engine or a hydrogen powered engine.

The downshifting und upshifting process and the relation to engine torque and/or engine speed values is discussed with reference to FIG. 2, which show time curves of front axle speed values FAS, in Km/h, gear values G, engine torque values ET in % and engine speed values ES in revolutions per minute (rpm), each associated to a set of upshifting and downshifting processes shown by the On/Off curve.

During the time interval 4-8 seconds, the motor vehicle, which is accelerating as it can be seen by the increasing front axle speed value, as well as by the increasing engine speed value ES, is driving in the eighth gear. The transmission ECU, based on the current driving state and engine state determines that the gear should be incremented and starts a first shifting process at  $t=8$ , namely an upshifting process from the eighth gear to the ninth gear. While upshifting, the engine torque value decreases to 0% and the engine speed is also reduced. This is enabled by the provision of the engine control signal indicative of the required torque/speed necessary for the matching. The same happens during a second upshifting phase at time interval 13.5-15.5 seconds, in which the gear is shifted from the ninth gear to the tenth gear. However, during downshifting, the behaviour of the engine torque values and engine speed values varies. During an downshifting process, e.g. during time intervals 20-21.5 seconds, 27-29 seconds or 32.5-34 seconds, the transmission ECU provides an engine control signal indicative of an increment in the torque value and/or the engine speed. This required increment is currently based on fuel consumption at the engine.

According to the invention, as it will be explained in detail with reference to FIG. 3, FIG. 4 and FIG. 5 below, a control device is configured to enable the provision of electrical power from a battery unit to the engine, via an electric motor, during the downshifting process. Even more preferably, the kinetic energy available due to the reduction of the engine speed  $\Delta S$  and/or engine torque  $\Delta T$  during the upshifting process US can be used to charge the battery unit. This is achieved by operating the electric motor as a generator that transforms the kinetic energy associated to the reduction of the speed/torque to an electric power CP1.

FIG. 3 a schematic block diagram of a transmission control arrangement 200 including a control device 100 in accordance with a first embodiment of the invention. The transmission control arrangement is suitable for controlling a current gear G and comprises a control device 100. The control device 100 includes a shift ascertaining unit 102 that is configured to ascertain, in this particular embodiment to receive, shift data SD indicative of a request to shift a current gear G. Here the shift data SD may include a requested engine torque RET value or a requested engine speed RES value necessary for the required matching during the shifting. The control device further comprises a processing unit 104 that is configured, upon determining that the ascertained (e.g., received) shift data SD is indicative of a request to downshift DS the current gear G, to generate and provide to an electric motor 150 an electric motor control signal 106 indicative of a required motor torque RMT and/or a required motor speed RMS. Here, the electric motor 150 is configured to be powered by a battery unit 152 and is operatively coupled to the engine 500. The electric motor 150 is configured to provide to the engine of the vehicle, in response to receiving the electric motor control signal 106, a power amount P (see also P1, P2, P3 in FIG. 2) necessary to perform the requested downshift DS.

The exemplary arrangement 200 also comprises a transmission control unit 202 that is configured to determine the shift data SD indicative of a request to shift a current gear G, for instance using engine status data ESD pertaining to a current operation point ES, ET of the engine 500 and to provide said shift data SD to the control device 100. The electric motor 150 is operatively coupled to the engine 500 and the battery unit 152 is configured to provide electric power EP to the electric motor. The engine 500 is an internal combustion engine, or, alternatively, a hydrogen powered engine 500B. Preferably, the electric motor 150 is an electric starter motor 150B.

Preferably, in the control device 100 of FIG.1, the processing unit 104 is further configured, upon determining that the ascertained shift data SD is indicative of a request to upshift US the current gear G, to generate and provide an engine control signal 108 indicative of a required engine torque RET and/or a required engine speed RES to the engine 500, in particular to an engine control unit 502, for performing the requested upshift. Additionally, as it was discussed with reference to FIG.2, the processing unit is advantageously configured to enable a recharge 110 of the battery unit 152 using a charge power CP generated by a reduction of the engine torque value  $\Delta T$  and/or an en-

engine speed  $\Delta S$  value associated to the upshift process US. Thus, the upshifting processes result in a charging of the battery unit, whereas the downshifting processes make use of the charge stored in the battery unit to reduce fuel consumption.

Internal experiments using a motor vehicle weighing 31.6 T, with an average fuel consumption of 20 liters per 100 km and 100 gear shifts in 100 km with an average duration per shift of 2 seconds and an average duration of the engine control during shifting of 1 seconds results in an average amount of fuel consumed during shifting (high resolution fuel rate SPN 1600) of approximately 3,95 ml/s, or a total fuel saved in 100 gear shifts of approximately 395 ml, which amounts to approximately 2% in fuel savings.

FIG. 4 shows a schematic block diagram of an alternative transmission control arrangement 200B including a control device 100B in accordance with a second embodiment of the invention. The same reference numbers will be used for those technical features of the arrangement 200B and the control device 100B that have a similar or identical function to those of the arrangement 200 and the control device 100 of FIG. 3. The following discussion will be focused on those technical features distinguishing the arrangement 200B of FIG. 4 from the arrangement 200 of FIG. 3.

In the arrangement 200B, the control device 100B comprises a deceleration ascertaining unit 112 that is configured to ascertain deceleration data AD indicative of a deceleration request AR, and wherein the processing unit 104 is further configured, upon ascertaining a deceleration request AR, to enable a recharge 110 of the battery unit 152 using a second charge power CP2 generated by a deceleration (D, see FIG. 2). For example, the deceleration request can be triggered by a driver lifting the foot from the accelerator pedal or pressing the brake pedal or by an external system such as an adaptive cruise control system.

FIG. 5 is a schematic block diagram of an alternative transmission control arrangement 200C including a control device 100C in accordance with a third embodiment of the invention. The same reference numbers will be used for those technical features of the arrangement 200C and the control device 100C that have a similar or identical function to those of the arrangement 200, 200B and the control device 100, 100B of FIG. 3 and FIG. 4 respectively. The following discussion will be focused on those technical features

distinguishing the arrangement 200C of FIG. 4 from the arrangements 200 and 200B of FIGS. 3 and 4.

The control device 100C further comprises a battery charge ascertaining unit 114 that is configured to ascertain charge data CD indicative of a state of charge SoC of the battery unit 152. The processing unit 104 is further configured to generate the electric motor control signal 106 in dependence on the ascertained state of charge SoC. For example, the electric motor control signal 106 is only provided when the ascertained state of charge indicates that there is enough charge in the battery unit 152. In the cases where the state of charge is indicative of a depleted battery, the processing unit is configured to provide an engine control signal 108 indicative of a required engine torque RET and/or a required engine speed RES to the engine 500 for performing the requested downshift DS. Additionally, the processing unit 104 is configured to enable the recharge 110 of the battery unit 152 in dependence on the ascertained state of charge SoC of the battery unit 152. Thus, an overcharging of the battery is avoided by allowing a charging process, either with the charge power CP or with the second charge power CP2, when the state of charge indicates that the battery can be charged.

FIG. 6 a schematic block diagram of a motor vehicle 1000 in accordance with an embodiment of the invention. The motor vehicle 1000 comprises a transmission control arrangement 200 that includes beside a transmission control unit 202 a control device 100. The control device 100 controls operation of an electric motor 150 that is connected to a battery unit 152 to provide the power amount to the engine 500 that is necessary for performing a downshift process. The transmission (not shown) is connected to the transmission control unit 202 via a corresponding interface circuit. It is also connected via vehicle network bus, e.g. a CAN bus (Controller Area Network) to the engine control device 100.

FIG. 7 a flow diagram of a method 300 for controlling operation of a control device 100 in accordance with an embodiment of the invention. The method comprises, in a step 302, ascertaining (e.g., receiving or determining) shift data SD indicative of a request to shift US, DS a current gear G. The method also comprises, upon determining, in a step 304, that the ascertained shift data SD is indicative of a request to downshift DS a current gear G, generating, in a step 306, and providing to an electric motor 150, in a step 308, an electric motor control signal 106 indicative of a required motor torque RMT

and/or a required motor speed RMS, wherein the electric motor 150 is powered by a battery unit 152 and is operatively coupled to the engine 500 of the vehicle 1000. The method also comprises, in response to a reception of the electric motor control signal 106, providing, in a step 310, a power amount P, P1, P2, P3 necessary to perform the requested downshift DS.

FIG. 8 shows a flow diagram of another method 300b for controlling operation of a control device in accordance with an embodiment of the invention. The method includes, in a step 302, as explained with regard to Fig. 7 above, ascertaining shift data. Upon determining, in a step 312, that the ascertained shift data is indicative of a request to upshift the current gear, the method further includes, in a step 314, generating and providing an engine control signal indicative of a required engine torque and/or a required engine speed to the engine of the vehicle for performing the requested upshift process, and, in a step 316, enabling a recharge of the battery unit using a charge power generated by a reduction of the engine torque value and/or an engine speed value associated to the upshift process.

In summary, the invention is directed to a control device (100) for controlling an engine during a gear-downshift, the control device comprising a shift ascertaining unit configured to ascertain shift data indicative of a request to shift a current gear a processing unit configured, upon determining that the ascertained shift data is indicative of a request to downshift the current gear, to generate and provide to an electric motor an electric motor control signal indicative of a required motor torque and/or a required motor speed, wherein the electric motor is configured to be powered by a battery unit and is operatively coupled to the engine and configured to provide to the engine, in response to a reception of the electric motor control signal, a power amount necessary to perform the requested downshift.

Other variations to the disclosed embodiments can be understood and effected by those skilled in the art in practicing the claimed invention, from a study of the drawings, the disclosure, and the appended claims.

In the claims, the word "comprising" does not exclude other elements or steps, and the indefinite article "a" or "an" does not exclude a plurality.

A single unit or device may fulfill the functions of several items recited in the claims. The mere fact that certain measures are recited in mutually different dependent claims does not indicate that a combination of these measures cannot be used to advantage.

Any reference signs in the claims should not be construed as limiting the scope.

## REFERENCE LIST (PART OF THE DESCRIPTION)

|      |                                      |
|------|--------------------------------------|
| 10   | Transmission control arrangement     |
| 11   | Transmission electronic control unit |
| 12   | Engine electronic control unit       |
| 13   | Engine                               |
| 100  | Control device                       |
| 100B | Control device                       |
| 100C | Control device                       |
| 102  | Shift ascertaining unit              |
| 104  | Processing unit                      |
| 106  | Electric motor control signal        |
| 108  | Engine control signal                |
| 110  | Recharge process                     |
| 112  | Deceleration ascertaining unit       |
| 114  | Battery charge ascertaining unit     |
| 150  | Electric motor                       |
| 150B | Electric starter motor               |
| 152  | Battery unit                         |
| 200  | Transmission control arrangement     |
| 200B | Transmission control arrangement     |
| 200C | Transmission control arrangement     |
| 202  | Transmission control unit            |
| 300  | Method                               |
| 300b | Method                               |
| 302  | Method step                          |
| 304  | Method step                          |
| 306  | Method step                          |
| 308  | Method step                          |
| 310  | Method step                          |
| 312  | Method step                          |
| 314  | Method step                          |
| 316  | Method step                          |
| 500  | Engine                               |
| 500B | Hydrogen powered engine              |

|      |                        |
|------|------------------------|
| 502  | Engine control unit    |
| 1000 | Motor vehicle          |
| AD   | Deceleration data      |
| AR   | Deceleration request   |
| CD   | Charge data            |
| CP   | Charge power           |
| DS   | Downshift process      |
| EP   | Electric power         |
| ES   | Engine speed           |
| ESD  | Engine status data     |
| ET   | Engine torque          |
| FAS  | Front axle speed       |
| G    | Gear                   |
| MS   | Motor speed            |
| MT   | Motor torque           |
| P    | Power amount           |
| RES  | Required engine speed  |
| RET  | Required engine torque |
| RMS  | Required motor speed   |
| RMT  | Required motor torque  |
| SD   | Shift data             |
| US   | Upshift process        |

## CLAIMS

1. A control device (100) for controlling an engine (500) of a vehicle (1000) during a shifting process (US, DS) of a transmission, the control device (100) comprising:
  - a shift ascertaining unit (102) configured to ascertain (*note: receive or determine*) shift data (SD) indicative of a request to shift a current gear (G);
  - a processing unit (104) that is configured, upon determining that the ascertained shift data (SD) is indicative of a request to downshift (DS) the current gear (G), to generate and provide to an electric motor (150) an electric motor control signal (106) indicative of a required motor torque (RMT) and/or a required motor speed (RMS), wherein the electric motor (150) is configured to be powered by a battery unit (152) and is operatively coupled to the engine (500) of the vehicle (1000) and configured to provide to the engine (500) of the vehicle (1000), in response to a reception of the electric motor control signal (106), a power amount (P, P1, P2, P3) necessary to perform the requested downshift (DS).
2. The control device (100) of claim 1, wherein the processing unit (104) is further configured, upon determining that the ascertained shift data (SD) is indicative of a request to upshift (US) the current gear (G), to generate and provide an engine control signal (108) indicative of a required engine torque (RET) and/or a required engine speed (RES) to the engine (500) of the vehicle (1000) for performing the requested upshift (US), and to enable a recharge (110) of the battery unit (152) using a charge power (CP) generated by a reduction of the engine torque value ( $\Delta T$ ) and/or an engine speed ( $\Delta S$ ) value associated to the upshift process (US).
3. The control device (100) of claim 1 or 2, wherein the processing unit (104) is configured to provide the electric motor control signal (106) to an electric starter motor (150B) of the vehicle, wherein the electric starter motor (150B) is configured to provide the power amount (P) to the engine (500).
4. The control device (100B) of any of the preceding claims, further comprising a deceleration ascertaining unit (112) configured to ascertain deceleration data (AD) indicative of a deceleration request (AR), and wherein the processing unit (104) is further configured, upon ascertaining a deceleration request (AR), to enable a recharge (110)

of the battery unit (152) using a second charge power (CP2) generated by a deceleration (D) of the vehicle (100).

5. The control device (100C) of any of the preceding claims, further comprising a battery charge ascertaining unit (114) configured to ascertain charge data (CD) indicative of a state of charge (SoC) of the battery unit (152) and wherein the processing unit (104) is further configured to generate the electric motor control signal (106) in dependence on the ascertained state of charge (SoC).

6. The control device (100C) of claim 2 or 4 and claim 5, wherein the processing unit (104) is configured to enable the recharge (110) of the battery unit (152) in dependence on the ascertained state of charge (SoC) of the battery unit (152).

7. A transmission control arrangement (200) for a vehicle (1000) for controlling a current gear (G), the transmission control arrangement (200) comprising:

- a control device (100, 100B, 100C) according to any of the preceding claims 1 to 6;
- a transmission control unit (202) configured to determine the shift data (SD) indicative of a request to shift a current gear using engine status data (ESD) pertaining to a current operation point (ES, ET) of the engine (500) of the vehicle (1000) and to provide said shift data (SD) to the control device (100, 100B, 100C);
- an electric motor (150, 150B) which is operatively coupled to the engine (500) of the vehicle (1000) and configured to receive the electric motor control signal (106) from the control device (100, 100B, 100C) and to provide to the engine (500) of the vehicle (1000), in response to a reception of the electric motor control signal (106), the power amount necessary (P) to perform the requested downshift (DS); and
- a battery unit (152) configured to provide electric power (EP) to the electric motor.

8. The transmission control arrangement (200) of claim 7, further comprising an engine control unit (502), and wherein, upon determining that the ascertained shift data (SD) is indicative of a request to upshift (US) the current gear (G), the control device (100, 100B, 100C) is configured to provide an engine control signal (108) to the engine control unit (502) for controlling the engine (500) of the vehicle (1000), the engine control signal (108) being indicative of a required engine torque (RET) and/or a required engine speed (RES) for performing the requested upshift (US).

9. The transmission control arrangement (200) of claims 7 or 8, wherein the battery unit (152) is connected to the electric motor (150) and configured to be charged using a power (CP) generated by a reduction of the engine torque value ( $\Delta T$ ) and/or a reduction of an engine speed value ( $\Delta S$ ) associated to an upshift process (US).
10. The transmission control arrangement (200) of any of the claims 7 to 9, wherein the battery unit (502) is further configured to be charged using a second charge power (CP2) generated by a deceleration (D) of the vehicle (1000).
11. The transmission control arrangement (200) of any of the claims 7 to 10, wherein the electric motor (150) is a starter motor (150B) of the vehicle (1000).
12. Motor vehicle (1000), in particular comprising an internal combustion engine (500) or a hydrogen powered engine (500B), the motor vehicle (1000) comprising a control device (100, 100B, 100C) according to any of the preceding claims 1 to 6 or a transmission control arrangement (200) according to any of the preceding claims 7 to 11.
13. Method (300) for operating a control device (100, 100B, 100C) for controlling an engine (500) of a vehicle during a shifting process (US, DS), the method comprising:
- ascertaining (302) shift data (SD) indicative of a request to shift (US, DS) a current gear (G);
  - upon determining (304) that the ascertained shift data (SD) is indicative of a request to downshift (DS) a current gear (G), generating (306) and providing (308) to an electric motor (150), an electric motor control signal (106) indicative of a required motor torque (RMT) and/or a required motor speed (RMS), wherein the electric motor (150) is powered by a battery unit (152) and is operatively coupled to the engine (500) of the vehicle (1000) and configured to provide to the engine (500) of the vehicle, in response to a reception of the electric motor control signal (106), a power amount (P, P1, P2, P3) necessary to perform the requested downshift (DS).
14. Computer program product comprising instructions which, when executed by a control device according to any of the preceding claims 1 to 6 cause the control device to carry out the method of claim 13.

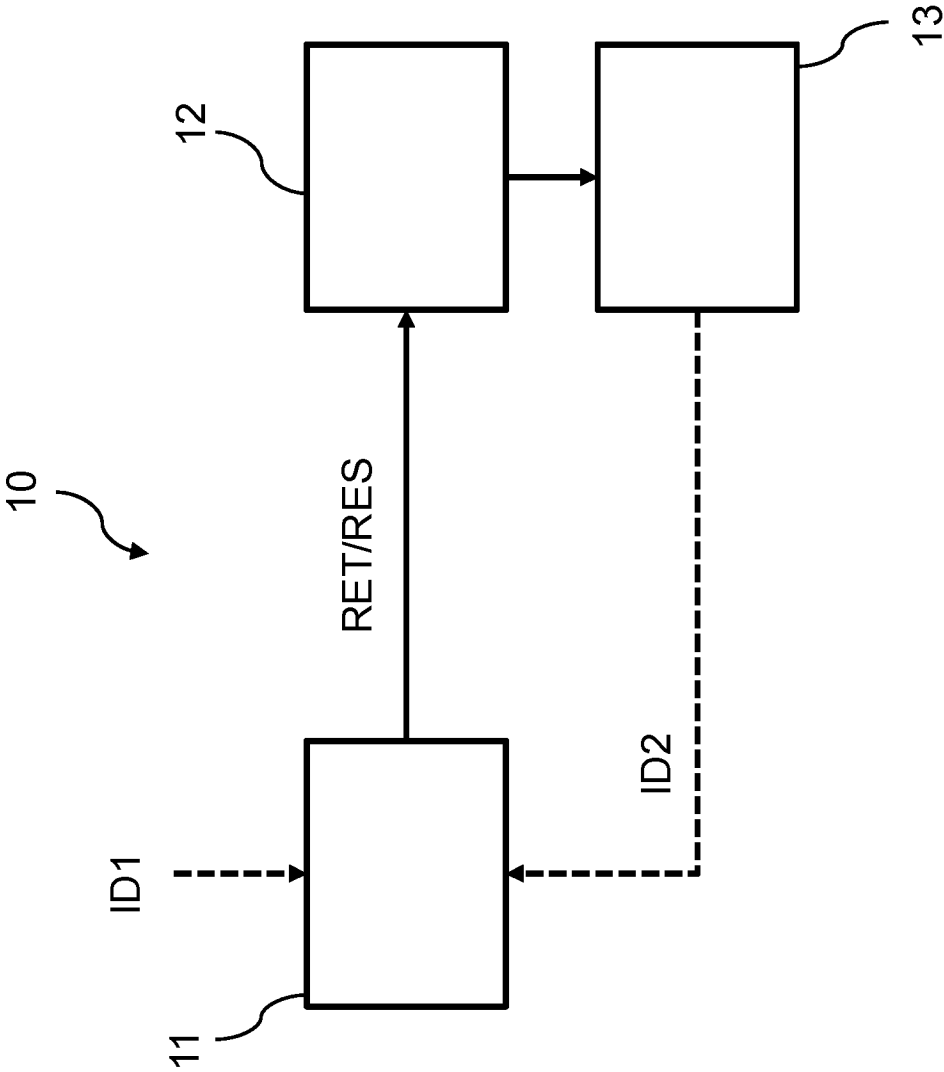


FIG. 1 (Prior Art)

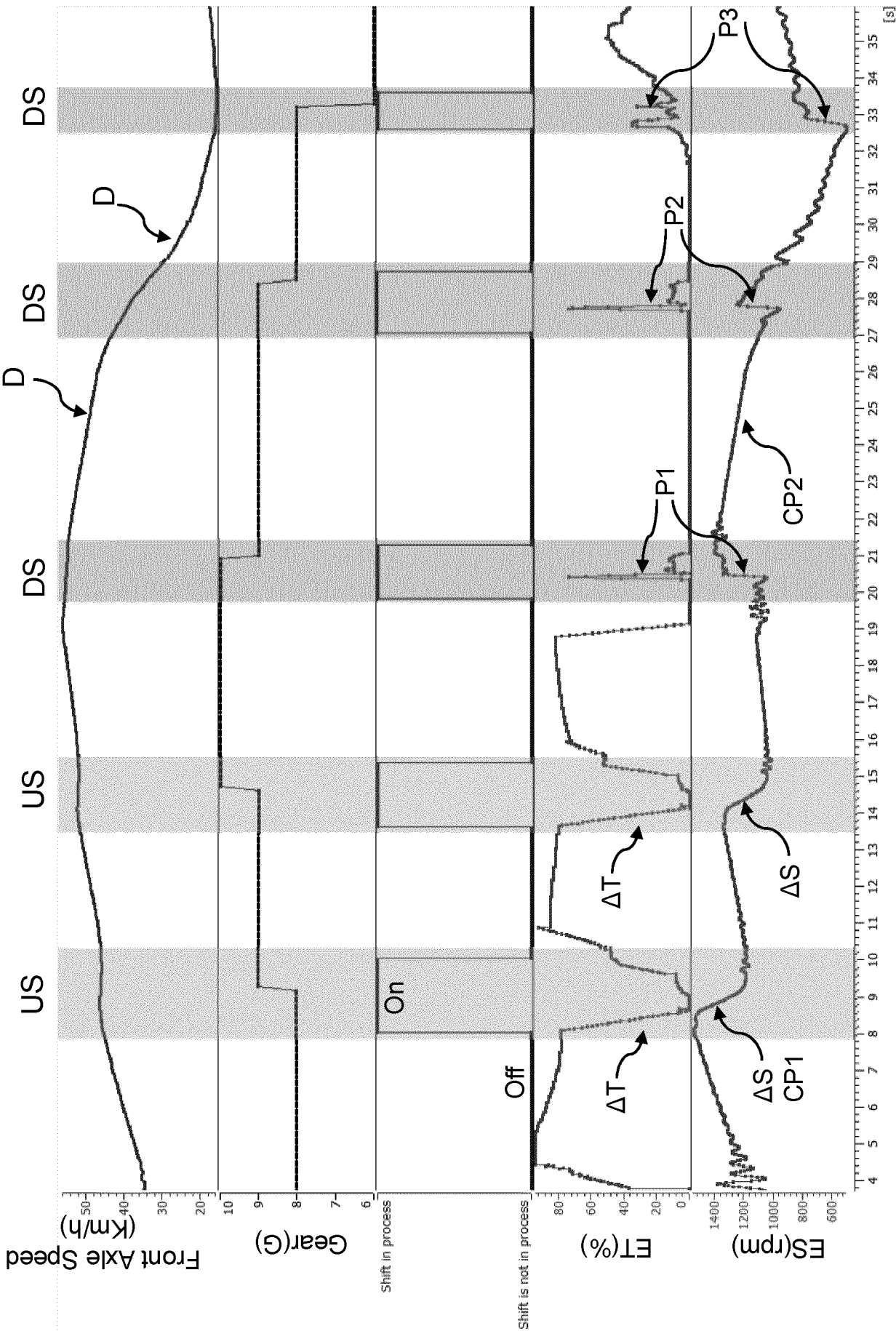


FIG. 2

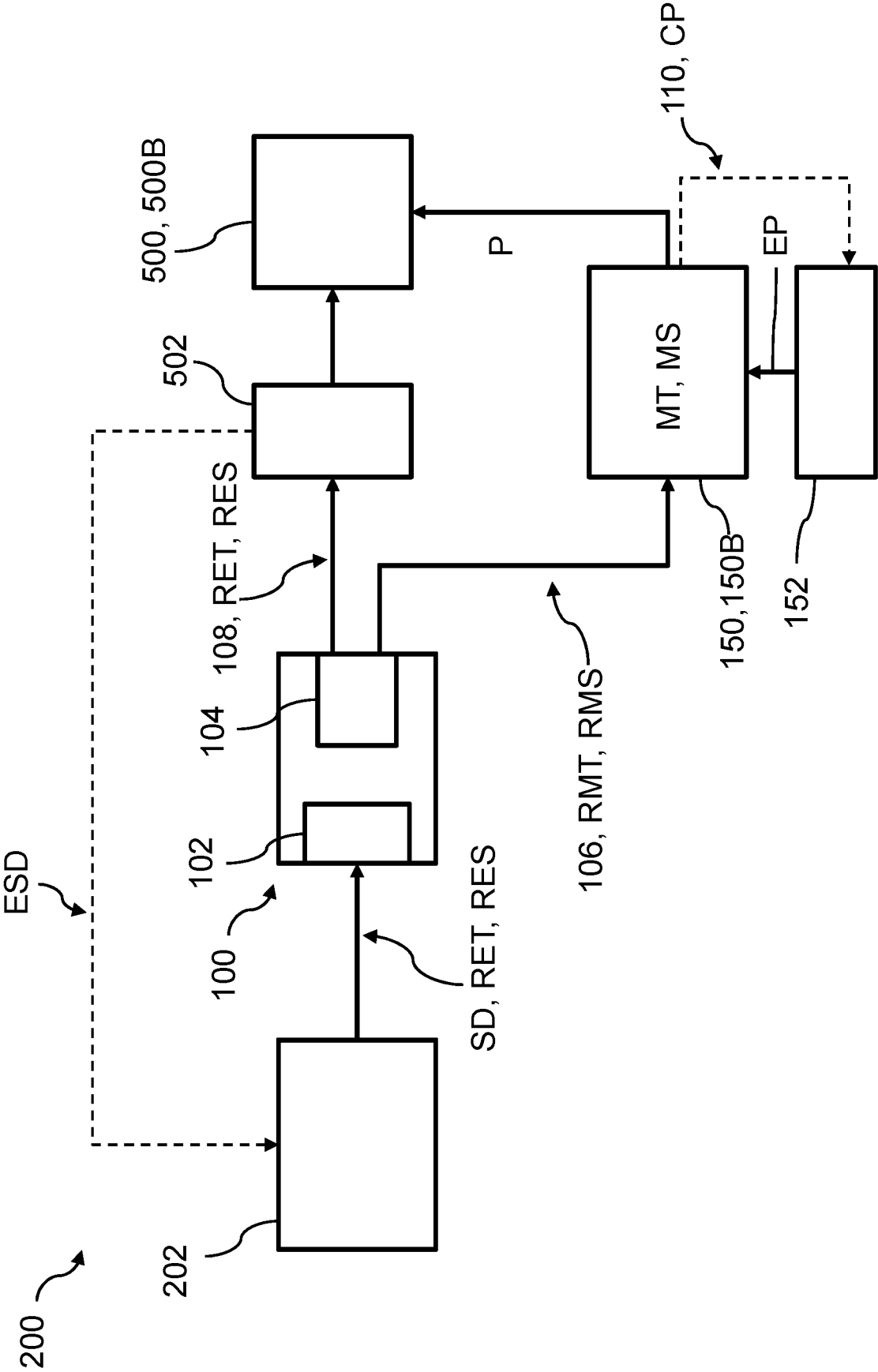


FIG. 3

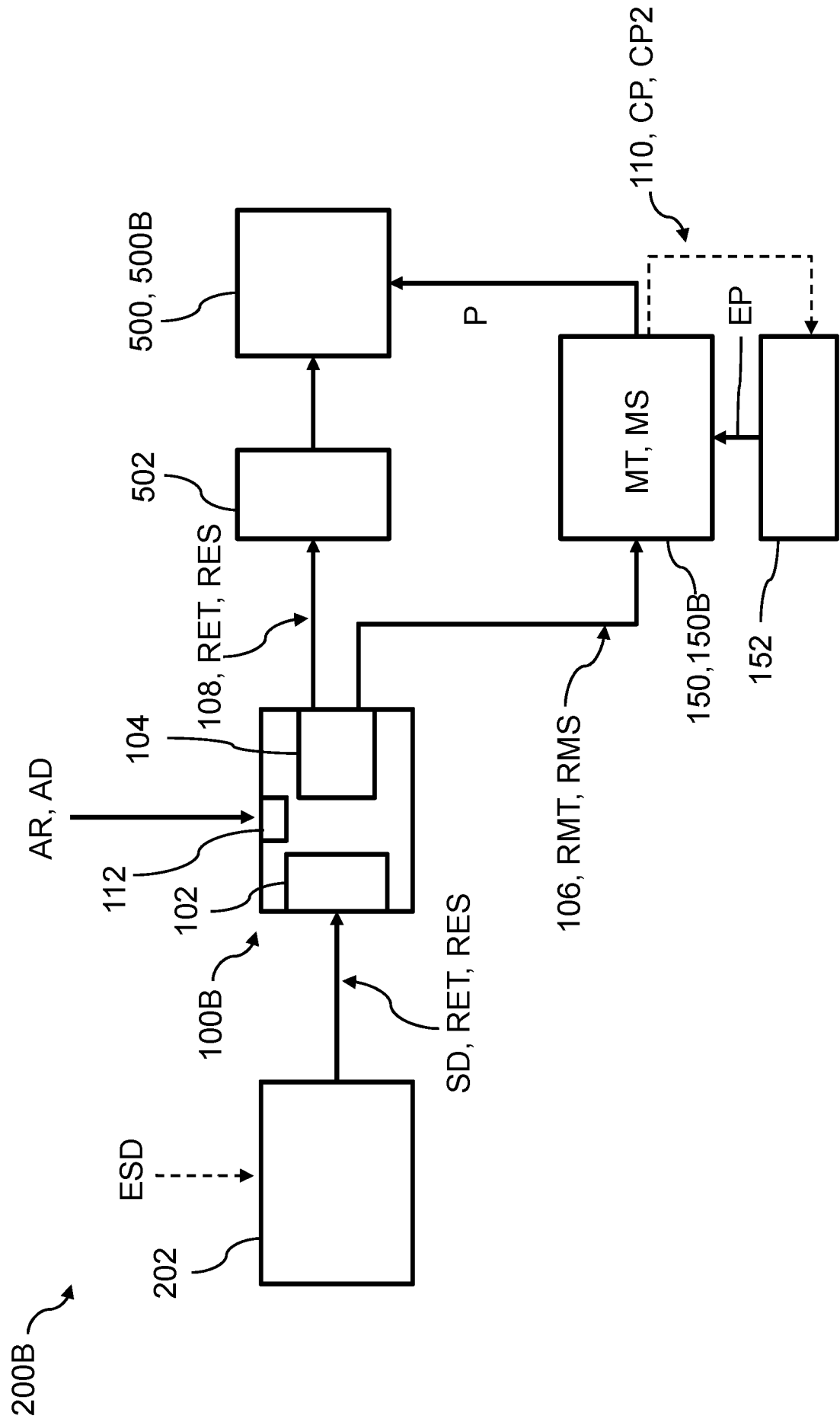


FIG. 4

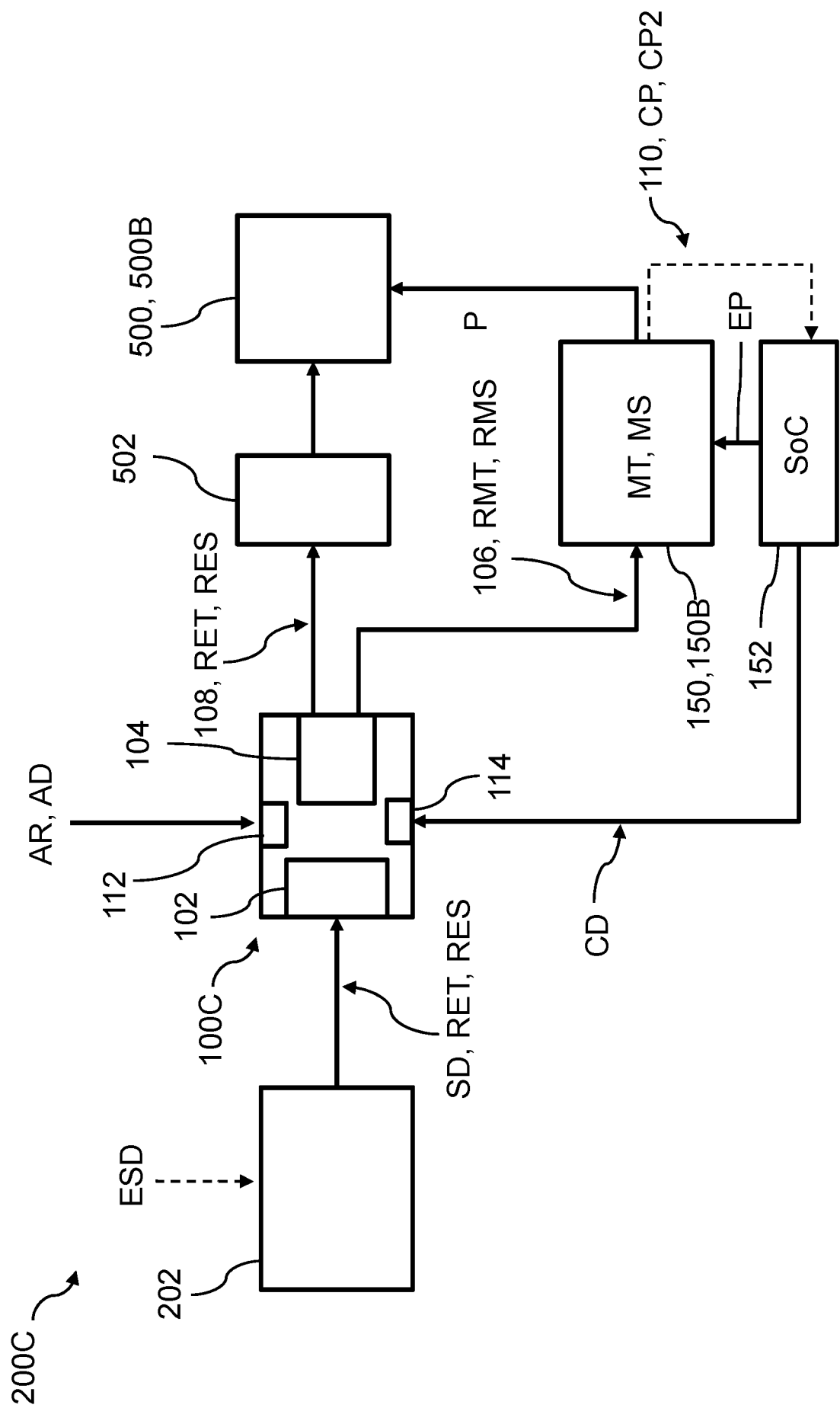


FIG. 5

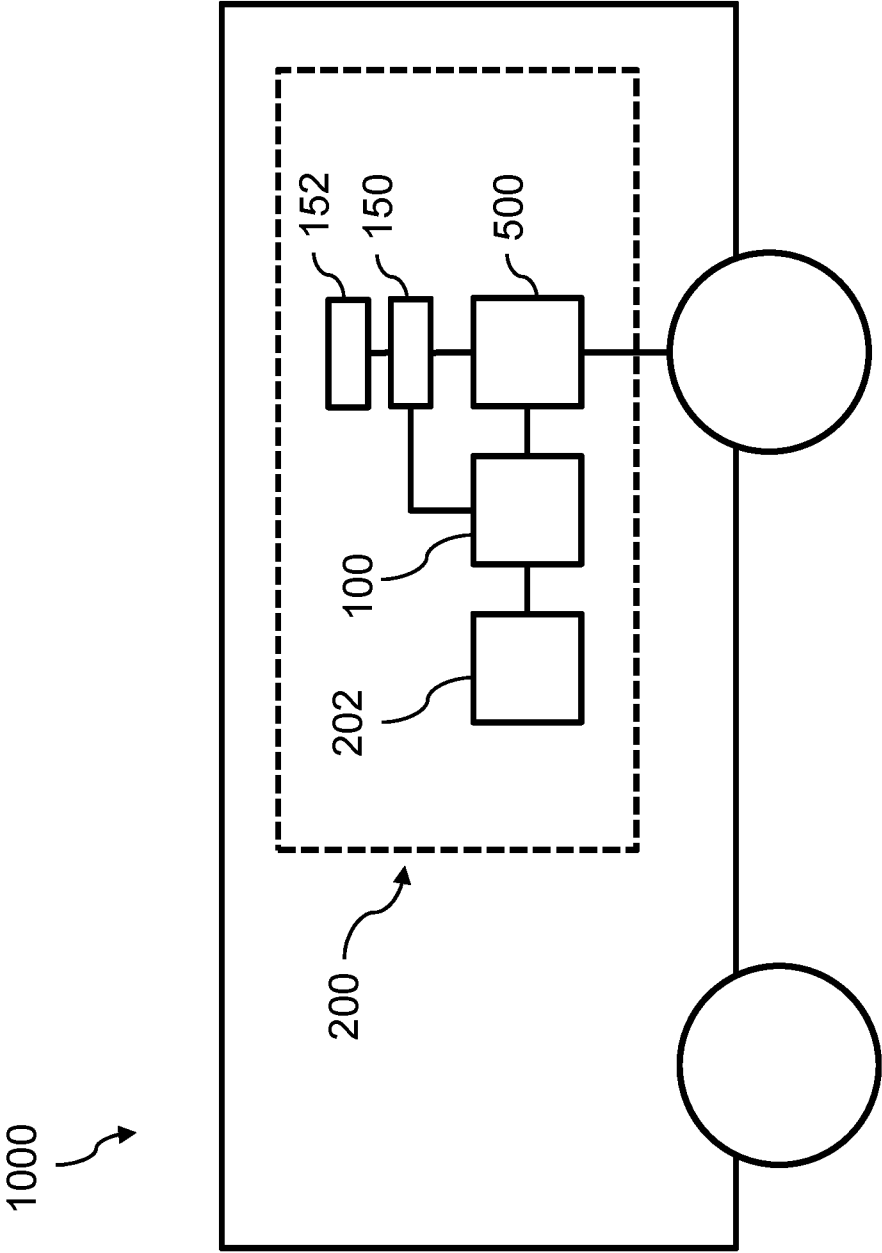


FIG. 6

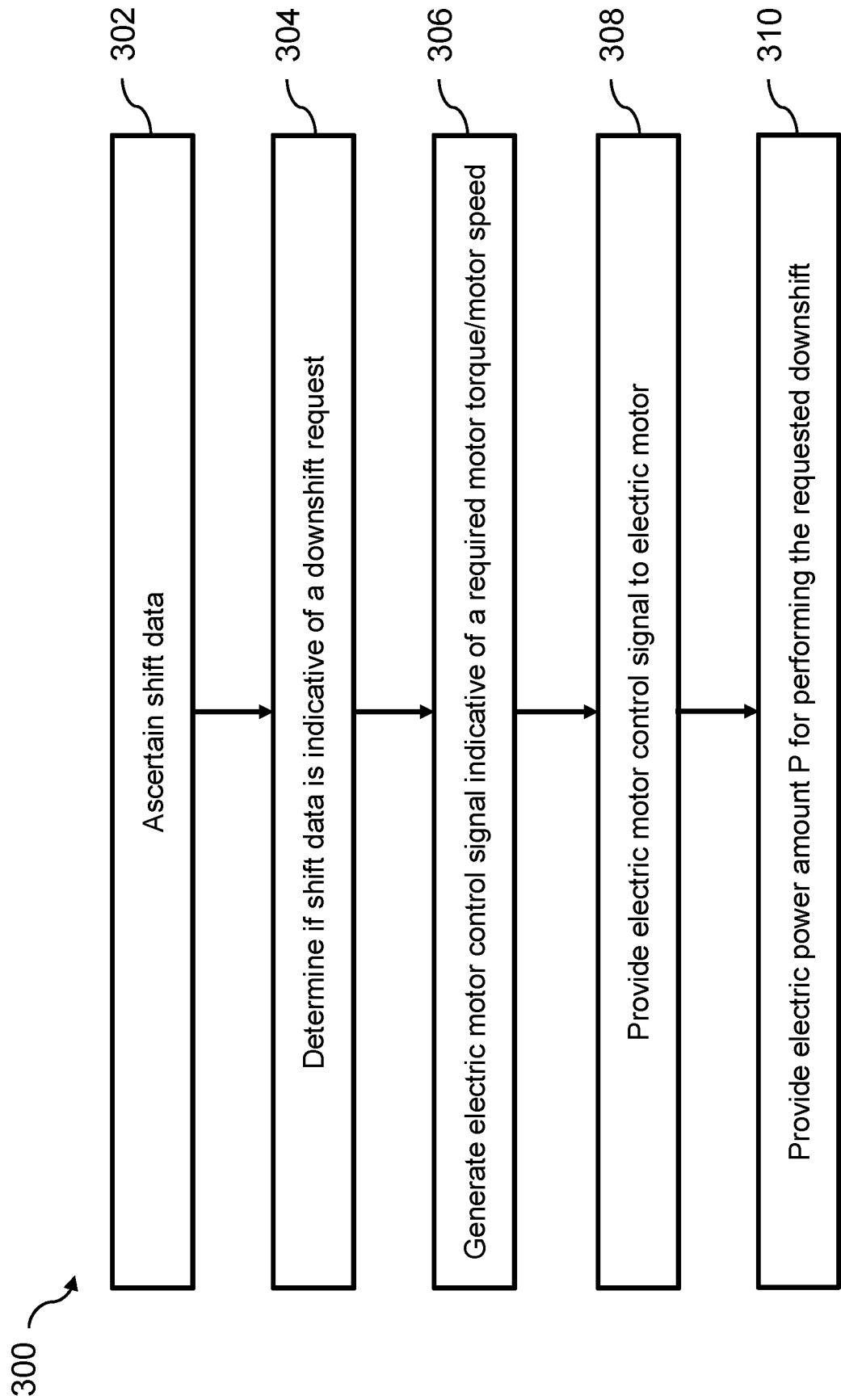


FIG. 7

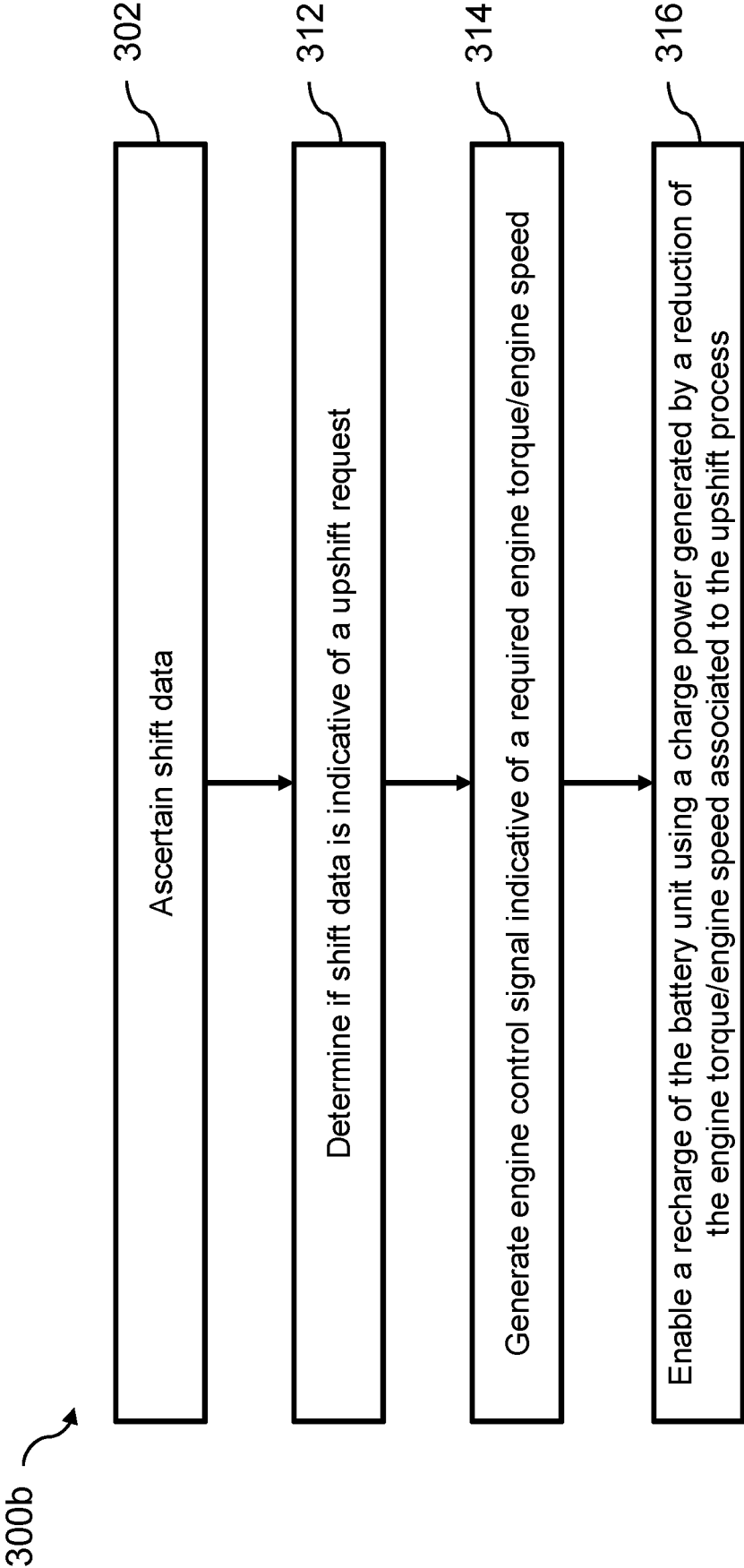


FIG. 8

## INTERNATIONAL SEARCH REPORT

International application No  
PCT/EP2024/064015

| <b>A. CLASSIFICATION OF SUBJECT MATTER</b><br>INV. B60K6/485 B60W30/19 F16H63/50<br>ADD. F16H61/04                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |                                                                                                                                                 |                                                                      |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------------------------------------------------------------------------------------------------------------------------------------------|----------------------------------------------------------------------|
| According to International Patent Classification (IPC) or to both national classification and IPC                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    |                                                                                                                                                 |                                                                      |
| <b>B. FIELDS SEARCHED</b><br>Minimum documentation searched (classification system followed by classification symbols)<br>B60K B60W<br><br>Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched<br><br>Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)<br><br>EPO-Internal, WPI Data                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                           |                                                                                                                                                 |                                                                      |
| <b>C. DOCUMENTS CONSIDERED TO BE RELEVANT</b>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                 |                                                                      |
| Category*                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                            | Citation of document, with indication, where appropriate, of the relevant passages                                                              | Relevant to claim No.                                                |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | WO 2015/179482 A1 (CUMMINS INC [US])<br>26 November 2015 (2015-11-26)<br>paragraphs [0008] - [0010], [0025];<br>figure 1<br>-----               | 1 - 14                                                               |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | CN 101 612 936 A (FORD GLOBAL TECH LLC)<br>30 December 2009 (2009-12-30)<br>claims 3, 13, 17, 18; figure 3<br>-----                             | 1 - 14                                                               |
| X                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                    | DE 10 2009 045485 A1 (BOSCH GMBH ROBERT<br>[DE]) 14 April 2011 (2011-04-14)<br>paragraphs [0005] - [0007], [0010],<br>[0014]; figure 1<br>----- | 1 - 3, 7, 8,<br>11 - 14                                              |
| <input type="checkbox"/> Further documents are listed in the continuation of Box C. <input checked="" type="checkbox"/> See patent family annex.                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                     |                                                                                                                                                 |                                                                      |
| <p>* Special categories of cited documents :</p> <p>"A" document defining the general state of the art which is not considered to be of particular relevance</p> <p>"E" earlier application or patent but published on or after the international filing date</p> <p>"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)</p> <p>"O" document referring to an oral disclosure, use, exhibition or other means</p> <p>"P" document published prior to the international filing date but later than the priority date claimed</p> <p>"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention</p> <p>"X" document of particular relevance;; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone</p> <p>"Y" document of particular relevance;; the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art</p> <p>"&amp;" document member of the same patent family</p> |                                                                                                                                                 |                                                                      |
| Date of the actual completion of the international search<br><br>22 July 2024                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                        |                                                                                                                                                 | Date of mailing of the international search report<br><br>10/09/2024 |
| Name and mailing address of the ISA/<br>European Patent Office, P.B. 5818 Patentlaan 2<br>NL - 2280 HV Rijswijk<br>Tel. (+31-70) 340-2040,<br>Fax: (+31-70) 340-3016                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                 |                                                                                                                                                 | Authorized officer<br><br>Gubovits, János                            |

INTERNATIONAL SEARCH REPORT

Information on patent family members

International application No  
PCT/EP2024/064015

| Patent document<br>cited in search report | Publication<br>date | Patent family<br>member(s) | Publication<br>date |
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