(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 4 417 802 A1

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
21.08.2024 Bulletin 2024/34

(21) Application number: **23157231.4**

(22) Date of filing: **17.02.2023**

(51) International Patent Classification (IPC):
F02D 19/08 *(2006.01)* ***F02D 41/26*** *(2006.01)*

(52) Cooperative Patent Classification (CPC):
F02D 19/084; F02D 19/087; F02D 41/266;
F02D 41/34; F02D 41/40; F02D 2200/0611

(84) Designated Contracting States:
AL AT BE BG CH CY CZ DE DK EE ES FI FR GB GR HR HU IE IS IT LI LT LU LV MC ME MK MT NL NO PL PT RO RS SE SI SK SM TR
Designated Extension States:
BA
Designated Validation States:
KH MA MD TN

(71) Applicant: **StepOne Tech Oy**
33960 Pirkkala (FI)

(72) Inventors:
- **Hölttä, Miika**
  33960 Pirkkala (FI)
- **Härkönen, Risto**
  33960 Pirkkala (FI)

(74) Representative: **Boco IP Oy Ab**
Kansakoulukatu 3
00100 Helsinki (FI)

(54) SYSTEM AND METHOD FOR ADJUSTING FUEL INJECTION CHARACTERISTIC OF AN ELECTRONICALLY FUEL INJECTED COMBUSTION ENGINE

(57) A system for adjusting fuel injection characteristic of an electronically fuel injected combustion engine (100), comprising a conversion control assembly (200). A conversion control unit (201) is configured to determine applicable ethanol conversion instructions corresponding to fuel ethanol content in accordance with an ethanol conversion map, and to determine applicable optimization correction instructions corresponding to current engine speed and engine load, in accordance on an optimization map. The conversion control unit (201) is further configured to apply applicable ethanol conversion instructions and applicable optimization correction instructions to the original injector pulse signal (110a) so as to obtain a corrected injector pulse signal (204a), and transmit the corrected injector pulse signal (204a) to the fuel injectors (101). The conversion control unit (201) is further configured to determine engine speed and engine load based on original injector control signal (110a) produced by an ECU of the engine.

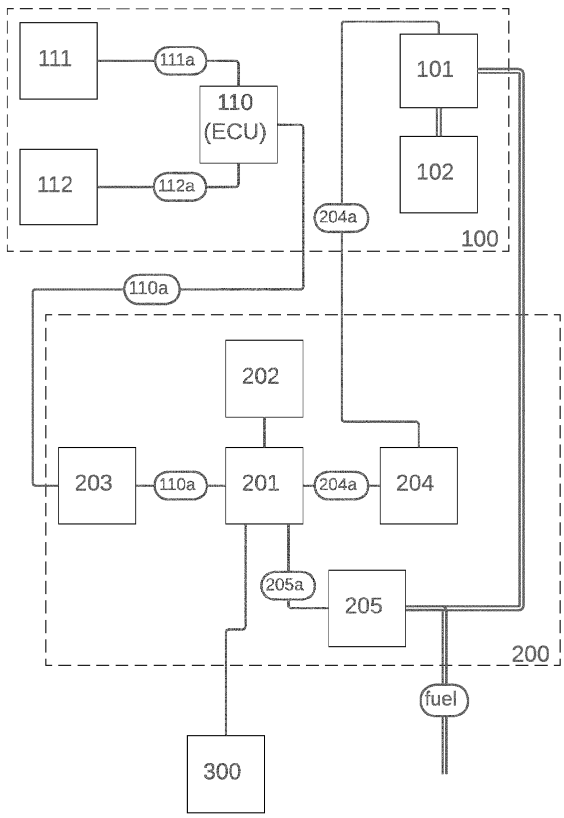

Fig. 1

EP 4 417 802 A1

Description

FIELD OF THE DISCLOSURE

[0001] The present disclosure is related to a system and method for adjusting the amount of fuel injected into a combustion cylinder of an electronically injected combustion engine. More particularly, the present disclosure concerns such a system and method, in which the amount of fuel is adjusted based on both an ethanol content of the fuel and on a separate optimization map, which can be provided for achieving desired operational characteristic of the combustion engine.

BACKGROUND OF THE DISCLOSURE

[0002] Commercially available ethanol conversion kits conventionally have an ethanol sensor determining ethanol content of the fuel and a control unit through which an injector signal from the ECU is transmitted to the fuel injectors. Typically, the duration of the injector pulse signal is increased based on how much ethanol the fuel contains, so as to compensate for the smaller energy content of ethanol.

[0003] Some of the commercially available kits provide further possibilities to control the fuel injection characteristics. To this end, additional wiring between the control unit and sensors of the engine is provided so as to obtain information regarding engine speed and load. In such a case the control unit is wired typically to a crankshaft position sensor and a sensor indicative of engine load (e.g., MAP, MAF, TPS).

BRIEF DESCRIPTION OF THE DISCLOSURE

[0004] An object of the present disclosure is to provide a system and a method for adjusting fuel injection characteristics of an electronically fuel injected combustion engine, allowing improved ease of installation, while simultaneously achieving ethanol conversion and engine optimization capabilities.

[0005] The object of the disclosure is achieved by a system and a method, which are characterized by what is stated in the independent claims. The preferred embodiments of the disclosure are disclosed in the dependent claims.

[0006] The disclosure is based on the idea of determining engine load and engine speed based on an original injector pulse signal generated by the ECU, as opposed to directly obtaining information of engine load end engine speed from corresponding separate sensors, such as ones already included in the combustion engine.

[0007] An advantage of arrangements according to the present disclosure is that the need for separate, dedicated wiring or other communication regarding the engine load and engine speed is eliminated.

[0008] According to a first aspect of the present disclosure, a system for adjusting fuel injection characteristic of an electronically fuel injected combustion engine is provided. The system comprises an electronically fuel injected combustion engine.

[0009] Such an electronically fuel injected combustion engine, in turn, comprises fuel injectors for injecting fuel into respective combustion cylinders of the combustion engine. Most suitably, the engine and fuel injectors are ones intended for uses with gasoline fuel. For example, the fuel injectors may be provided as any of the conventional arrangements including a direct injection system or an indirect injection system.

[0010] The engine further comprises an engine speed sensor configured to produce an engine speed signal indicative of engine speed. For example, such an engine speed sensor may be provided as any of the conventional arrangements, including a crankshaft speed or position sensor of well-known types in the art, and a camshaft speed or position sensor of well-known types in the art.

[0011] The engine further comprises at least a manifold air sensor configured to produce a manifold air signal indicative of engine load. For example, such a sensor could be provided as a manifold air pressure sensor, mass airflow sensor or a throttle position sensor.

[0012] The engine further comprises an ECU unit operationally coupled to said engine speed sensor, manifold air sensor and fuel injectors. Particularly, the ECU unit is configured to generate original injector pulse signals, at least during an open-loop control mode, so as to control fuel injector timing and duration in accordance with a pre-determined fuel map based on at least the engine speed signal and the manifold air signal.

[0013] The system further comprises a conversion control assembly, which in turn comprises a conversion control unit and a memory storage unit. For example, the conversion control unit may comprise a microprocessor coupled or integrated to the memory storage unit. Moreover, the memory storage unit comprises computer readable instructions embodied thereon, executable by the conversion control unit. The execution of the instructions by the conversion control causes it to perform adjustment fuel injection characteristic of an electronically fuel injected combustion engine, as described in more detail hereafter.

[0014] The conversion control assembly further comprises an ECU connector operationally coupled to the conversion control unit and configured to receive original injector pulse signals form the ECU unit. Preferably, the ECU connector comprises one or more suitable plugs or sockets, which can be coupled to an output of the ECU unit, so as to receive the original injector pulse signals generated by the ECU. Suitably, the ECU connector also comprises respective wiring for conducting the original injector pulse signals to the conversion control unit.

[0015] The conversion control assembly further comprises an injector connector operationally coupled to the conversion control unit and configured to transmit corrected injector pulse signals from the conversion control unit to the fuel injectors. Preferably, the injector connector comprises one or more suitable plugs or sockets, which can be coupled to respective inputs of the fuel injectors so as to conduct the corrected injector pulse signals to the fuel injectors. Suitably, the injector connector also comprises respective wiring for conducting the corrected injector pulse signals form the conversion control unit.

[0016] The conversion control assembly further comprises a fuel ethanol sensor operationally coupled to the conversion control unit and configured to produce a fuel ethanol signal indicative of fuel ethanol content. For example, such a fuel ethanol sensor may be provided in connection with a fuel line feeding the fuel injectors. Suitably, the fuel ethanol sensor may comprise respective wiring for conducting the fuel ethanol signal to the conversion control unit.

[0017] Particularly, an ethanol conversion map is stored in the memory storage unit. The ethanol conversion map comprises ethanol conversion instructions corresponding to various fuel ethanol contents. That is, such ethanol conversion instructions indicate how much the conversion control unit increases durations of the original injector pulses, based on fuel ethanol content, so as to compensate for the lower energy content of ethanol. In practise, such ethanol conversion instructions may be provided, for example, as a table indicating a duration increase as percentage of or multiplier coefficient for an original injector pulse duration for various fuel ethanol contents.

[0018] Moreover, an optimization map is stored in the memory storage unit. The optimization map comprises optimization correction instructions corresponding to specific engine speeds and engine loads. That is, such optimization instructions indicate how much the conversion control unit alters durations of the original injector pulses, based on engine speed and engine load, so as to adjust fuel injection characteristics in a desired manner. In practise, such optimization instructions may be provided as a table comprising a first axis having columns corresponding to engine speed, a second axis having rows corresponding to engine load, and cells corresponding to intersections of the rows and columns.

[0019] For example, engine load on the first axis may be represented as durations of original injector pulse signals, or as percentage of full load. In a similar manner, engine speed on the second axis may be represented, e.g., as periods of original injector pulse signals, frequency of original injector pulse signals or as revolutions of the crankshaft per minute (RPM).

[0020] Each cell may indicate a duration change (e.g., as a percentage of or a multiplier coefficient for an original injector pulse signal, or as an absolute value of duration change), for various combinations of engine load and engine speed. The cell values of the optimization map may be provided so as to achieve desired fuel injection characteristics, e.g., one or more of improved fuel efficiency, improved power output, improved torque output, a more even power or torque output throughout engine speed, optimizing power or torque output for a given engine speed, etc.

[0021] Furthermore, the conversion control unit is configured to

obtain the original injector pulse signal via the ECU connector;

obtain the fuel ethanol signal from the fuel ethanol sensor;

determine applicable ethanol conversion instructions corresponding to the fuel ethanol content based on the ethanol conversion map;

determine applicable optimization correction instructions corresponding to current engine speed and engine load, based on the optimization map;

apply applicable ethanol conversion instructions and applicable optimization correction instructions to the original injector pulse signal so as to obtain a corrected injector pulse signal, and

transmit the corrected injector pulse signal to the fuel injectors via the injector connector.

[0022] Particularly, the conversion control unit is further configured to determine engine speed based on a period between successive original injector pulse signals, and to determine engine load based on a duration of the original injector control signal.

[0023] That is, the conversion control assembly is able to determine both engine speed and engine load base on the original injector pulse signal. Consequently, installation of such a system is greatly facilitated, as it eliminates the need for separate connectors and/or wiring associated to the engine speed sensor and manifold air sensor.

[0024] In an embodiment according to the first aspect of the present disclosure, the system further comprises a user device operationally coupled to the conversion control unit. For example, such a user device may be provided as dedicated device, or alternatively, as a personal computer or a mobile device. Such a personal computer or mobile device may be installed with dedicated software so as to be configured to perform functionalities discussed in more detail below. Moreover, the user device may be couped to the conversion control unit with a wired or wireless connection. The conversion control assembly may then be additionally provided with a corresponding interface for establishing communication with the user device.

[0025] Moreover, the system is configured to execute an engine load calibration cycle. Such an engine load calibration cycle may be initiated either by a user or the system itself. During the engine load calibration cycle, the system is further configured to send an idle load request via the user device and receive an idle load acknowledgement via the user device. For example, the idle load request may be displayed as a message on the user device, prompting the user run the engine at idle load, suitably for a given period of time. Subsequently, the idle load acknowledgement could be sent by the user with the user device. The system is further configured to identify a minimum original injection pulse duration from original injection pulse signals received via the ECU connector between the idle load request and the idle load acknowledgement

[0026] During the engine load calibration cycle, the system is also configured to send a full load request via the user device, and to receive a full load acknowledgement via the user device. In a similar manner, the full load request may be displayed as a message on the user device, prompting the user run the engine at full load, suitably execute one or more full throttle acceleration with the associated vehicle. Subsequently, the full load acknowledgement could be sent by the user with the user device. The system is further configured to identify a maximum original injection pulse duration from original injections pulse signals received via the ECU connector between the full load request and the full load acknowledgement.

[0027] It should be noted that the idle load request and the full load request need not be separate requests but may be sent jointly as a single request. Correspondingly, the idle load acknowledgement and the full load acknowledgement need not be separate acknowledgements but may be sent jointly as a single acknowledgement.

[0028] The conversion control unit is then configured to determine, advantageously during normal operation of the engine, engine load based on the duration of the original injector control signal with relation to the minimum original injector pulse duration and the maximum original injector pulse duration. That is, the engine load calibration allows the system to determine durations of original injector pulse signals corresponding to an idle load and full load, respectively, which are specific to the engine and associated equipment being used. Consequently, such an arrangement allows the system to determine engine load more precisely without the need for additional connectors and/or wiring associated to the manifold air sensor.

[0029] Preferably, but not necessarily, during the engine load calibration cycle, the system is further configured to determine an engine specific load range between an idle load corresponding to the minimum original injector pulse duration and a full load corresponding to the maximum original injector pulse duration. Based on the determined engine specific load range, the system is further configured to modify the optimization map, such that engine loads of the optimization map are normalized with respect to the engine specific load range.

[0030] Consequently, the optimization map can be adapted to match the spectrum of original injector pulse signal durations corresponding to the specific engine and associated equipment being used. That is, the engine load columns of the optimization map may be scaled to match the load range.

[0031] For example, a column of the optimization map corresponding to minimum engine load could be associated with the original injector pulse signal duration corresponding to idle load, whereas a column of the optimization map corresponding to full engine load could be associated with the original injector pulse signal duration corresponding to full load. This ensures that all of the engine load columns in the optimization map reside within the operating region of the specific engine, i.e., no columns of the optimization map are wasted. The remaining columns residing between the idle load column and the full load column could then be scaled, e.g., by evenly spacing apart or by being set at predetermined intervals. This, in turn, allows for improved resolution of the optimization map with regard to engine load, and provides for more accurate optimization of injector characteristics.

[0032] It should be noted that any one of identifying the minimum and maximum original injector pulse durations, determining engine specific load range, and modifying the optimization maps may be performed either by the conversion control unit, the user device, or jointly by both. Moreover, further modification of the optimization map may naturally be performed by the user.

[0033] Preferably, but not necessarily, the system is further configured to execute an engine speed calibration cycle. Such an engine speed calibration cycle may be initiated either by a user or the system itself. During the engine speed calibration cycle, the system is further configured to send an idle speed request via the user device and to receive an idle speed acknowledgement via the user device. For example, the idle speed request may be displayed as a message on the user device, prompting the user run the engine at idle speed, suitably for a given period of time. Subsequently, the idle speed acknowledgement could be sent by the user with the user device. The system is further configured to identify a minimum engine speed from a longest period between successive original injector pulse signals received via the ECU connector between the idle speed request and the idle speed acknowledgement.

[0034] During the engine speed calibration cycle, the system is also configured to send a full speed request via the user device, and to receive a full speed acknowledgement via the user device. In a similar manner, the full speed request may be displayed as a message on the user device, prompting the user run the engine at full speed. Subsequently, the full speed acknowledgement could be sent by the user with the user device. The system is further configured to identify a maximum engine speed from a shortest period between successive original injector pulse signals received via the ECU connector between the full speed request and the speed load acknowledgement.

[0035] It should be noted that the idle speed request and the full speed request need not be separate requests but may be sent jointly as a single request. Correspondingly, the idle speed acknowledgement and the full speed acknowledgement need not be separate acknowledgements but may be sent jointly as a single acknowledgement.

[0036] Moreover, the requests associated to the engine load calibration cycle and the engine speed calibration cycle may be sent jointly, and correspondingly, the acknowledgements associated to the engine load calibration cycle and the engine speed calibration cycle may be sent jointly. That is, the engine load calibration cycle and the engine speed calibration cycle may be performed simultaneously.

[0037] Further during the engine speed calibration cycle, the system is configured to determine an engine specific speed range between an idle speed corresponding to the minimum engine speed and a full speed corresponding to the maximum engine speed. The system is also configured to modify the optimization map such that engine speeds of the optimization map are normalized with respect to the engine specific speed range.

[0038] Consequently, the optimization map can be adapted to match the spectrum of original injector pulse signal periods corresponding to the specific engine and associated equipment being used. That is, the engine speed rows of the optimization map may be scaled to match the engine speed range.

[0039] For example, a row of the optimization map corresponding to minimum engine speed could be associated with the original injector pulse signal period corresponding to idle speed, whereas a row of the optimization map corresponding to full engine speed could be associated with the original injector pulse signal period corresponding to full speed. This ensures that all of the engine speed rows in the optimization map reside within the operating region of the specific engine, i.e., no rows of the optimization map are wasted. The remaining rows residing between the idle speed row and the full speed row could then be scaled, e.g., by evenly spacing apart or being set at predetermined intervals. This, in turn, allows for improved resolution of the optimization map with regard to engine load, and provides for more accurate optimization of injector characteristics.

[0040] It should be noted that any one of the identification of the minimum and maximum engine speeds, determination of the engine speed range and the modification of the optimization map may be performed either by the conversion control unit, the user device, or jointly by both. Moreover, further modification of the optimization map may naturally be performed by the user.

[0041] It should be noted that the first aspect of the present disclosure encompasses any combination of two or more embodiments, or variants thereof, as discussed above.

[0042] According to a second aspect of the present disclosure, a method for adjusting fuel injection characteristic of an electronically fuel injected combustion engine is provided. Most suitably, the engine and fuel injectors are ones intended for use with gasoline fuel.

[0043] The method comprises a step of providing a conversion control assembly, which conversion control assembly, in turn, comprises a conversion control unit a memory storage unit an ECU connector an injector connector, and a fuel ethanol sensor operationally coupled to the conversion control unit and configured to produce a fuel ethanol signal indicative of fuel ethanol content. The conversion control unit has been discussed in more detail above in connection to the first aspect of the present disclosure.

[0044] The method further comprises a step of operationally coupling the conversion control unit and the ECU unit with the ECU connector, so as to enable the conversion control unit to receive original injector pulse signals from the ECU unit. For example, this could be done by coupling the ECU connector (or plugs/sockets associated thereto) to an injector output of the ECU unit.

[0045] The method further comprises a step of operationally coupling the conversion control unit and the fuel injectors with the injector connector, so as to enable the conversion control unit to transmit corrected injector pulse signals to the fuel injector. For example, this could be done by coupling injector connector (or plugs/sockets associated thereto) with corresponding inputs of the fuel injectors.

[0046] The method further comprises a step of providing an ethanol conversion map stored in the memory storage unit, the ethanol conversion map comprising ethanol conversion instructions corresponding to various fuel ethanol contents. The ethanol conversion map and the ethanol conversion instructions have been discussed in more detail above, in connection with the first aspect of the present disclosure.

[0047] The method further comprises a step of providing an optimization map stored in the memory storage unit, the optimization map comprising optimization correction instructions corresponding to specific engine speeds and engine loads. The optimization map and the optimization instructions have been discussed in more detail above, in connection with the first aspect of the present disclosure.

[0048] During operation of the engine, the conversion control unit obtains the fuel ethanol signal indicative of fuel ethanol content from the fuel ethanol sensor and determines determining applicable ethanol conversion instructions corresponding to the fuel ethanol content based on the ethanol conversion map. The conversion control unit also obtains the original injector pulse signal via the ECU connector and determines applicable optimization correction instructions corresponding to current engine speed and engine load based on the optimization map. The conversion control unit then applies applicable ethanol conversion instructions and applicable optimization correction instructions to the original injector pulse signal so as to obtain a corrected injector pulse signal, and transmits the corrected injector pulse signal to the fuel injectors via the injector connector.

[0049] Moreover, during normal operation of the engine, the conversion control unit determines engine speed based on a period between successive original injector pulse signals, and engine load based on a duration of the original injector pulse signal. That is, the conversion control unit does not directly utilise the engine speed sensor nor the manifold air sensor of the engine.

[0050] In an embodiment according to the second aspect of the present disclosure, the method further comprises the steps of providing a user device operationally coupled to the conversion control unit. The user device is discussed in more detail above in connection with the first aspect of the present invention.

[0051] The method may further comprise a step of executing an engine load calibration cycle. An idle load request is sent via the user device and an idle load acknowledgement is received via the user device, as discussed in more detail above in connection with the first aspect of the present disclosure. A minimum original injection pulse duration is then identified from original injection pulse signals received via the ECU connector between the idle load request and the idle load acknowledgement.

[0052] In addition, a full load request is sent via the user device, and a full load acknowledgement is received via the user device, as discussed in more detail above in connection with the first aspect of the present disclosure. A maximum original injection pulse duration is then identified from original injection pulse signals received via the ECU connector between the full load request and the full load acknowledgement.

[0053] Consequently, during operation, engine load is determined based on the duration of the original injector pulse signal with relation to the minimum original injector pulse duration and the maximum original injector pulse duration. Most suitably, this is done during normal operation of the engine, i.e., outside the engine load calibration cycle.

[0054] Preferably, but not necessarily, the engine load calibration cycle, further comprises determining an engine specific load range between an idle load corresponding to the minimum original injector pulse duration and a full load corresponding to the maximum original injector pulse duration. Consequently, the optimization map may then be modified, such that engine loads of the optimization map are normalized with respect to the engine specific load range. It is noted that determining the engine specific load range and modifying the optimization map have been discussed above in further detail in connection with the first aspect of the present disclosure.

[0055] Preferably, but not necessarily, the method may further comprise a step of executing an engine speed calibration cycle. In the engine speed calibration cycle, an idle speed request is sent via the user device, and an idle speed acknowledgement is received via the user device. Subsequently a minimum engine speed is determined from a longest period between successive original injector pulse signals received via the ECU connector between the idle speed request and the idle speed acknowledgement.

[0056] Additionally, in the engine speed calibration cycle, a full speed request is sent via the user device and a full speed acknowledgement is received via the user device. Subsequently a maximum engine speed is determined from a shortest period between successive original injector pulse signals received via the ECU connector between the full speed request and the speed load acknowledgement.

[0057] An engine specific speed range between an idle speed corresponding to the minimum engine speed and a full speed corresponding to the maximum engine speed is then determined. and the optimization map is modified such that engine speeds of the optimization map are normalized with respect to the engine specific speed range.

[0058] It is noted that the engine speed calibration cycle has been discussed above in further detail in connection with the first aspect of the present disclosure.

[0059] It is further noted that the second aspect of the present disclosure encompasses any combination of two or mor embodiments, or variants thereof, as discussed above.

BRIEF DESCRIPTION OF THE DRAWINGS

[0060] In the following the disclosure will be described in greater detail by means of preferred embodiments with reference to the accompanying drawings, in which

Fig. 1 is a schematic illustration of a system for adjusting fuel injection characteristic of an electronically fuel injected combustion engine.

DETAILED DESCRIPTION OF THE DISCLOSURE

[0061] Fig. 1 schematically depicts a schematic illustration of a system for adjusting fuel injection characteristic of an electronically fuel injected combustion engine 100. The system comprises an engine 100, which in turn comprises a combustion cylinder 102. Fuel is injected into the combustion cylinder 102 with a fuel injector 101 coupled in communication with a fuel line. Although Fig. 1 illustrates a single fuel injector 101 and a single combustion cylinder 102 for the purpose of clarity, the present disclosure may readily be implemented with an engine having multiple combustion cylinders 102, with multiple corresponding fuel injectors 101.

[0062] The engine 100 further comprises an ECU unit 110 which generates, at least during open-loop control, original injector pulse signal 110a based on an engine speed signal 111a obtained from an engine speed sensor 111 (e.g., crank shaft position sensor) and manifold air signal 112a obtained from a manifold air sensor (e.g., MAP-, MAF, or TPS sensor) in accordance with a predetermined fuel map. Naturally, the ECU unit 110 may be coupled with a multitude of other sensors and be configured to control other equipment and aspects (e.g., ignition) of the engine.

[0063] In typical arrangements of the prior art, the ECU unit 110 directly controls the fuel injectors 102, among others.

[0064] However, as depicted in Fig. 1, in arrangements according to the present disclosure, the system comprises a conversion control assembly 200. The original injector pulse signal 110a, generated by the ECU unit 110, is fed to the conversion control assembly 200 via the ECU connector 203. The conversion control assembly 200 then generates, based on the original injector pulse signal 110a, a corrected injector pulse signal 204a, which is sent to the fuel injector 101 via the injector connector 204. Notably, the corrected injector pulse signal is generated based on the original injector pulse signal 110a, without the engine speed signal 111a and the manifold air signal 112a. That is, neither the engine speed sensor 111 nor the manifold air sensor 112 are coupled to the conversion control unit 200.

[0065] As mentioned, the conversion control assembly 200 comprises the ECU connector 203 for receiving the original injector pulse signal 110a from the ECU unit 100, and the injector connector 204 for transmitting the corrected injector pulse signal 204a to the fuel injector 101. The conversion control unit further comprises a conversion control unit 201 and a memory storage unit 202 operationally coupled to each other. That is, the conversion control unit 201 may access and modify the contents of the memory storage unit 202.

[0066] The conversion control unit 201 is further operationally coupled to the ECU connector 203 for receiving the original injector pulse signal 110a therefrom, and to the injector connector 204 for transmitting the corrected injector pulse signal 204a thereto. Fig. 1 illustrates an arrangement in which the conversion control assembly 200 is coupled in series between the ECU unit 100 and the fuel injector 101, although the conversion control unit 200 could alternatively be coupled in parallel.

[0067] The conversion control assembly 200 further comprises a fuel ethanol sensor 205 coupled in communication with the fuel line, and configured for producing a fuel ethanol signal 205a indicating a fuel ethanol content of the fuel within the fuel line. For example, the fuel ethanol sensor 205 may be coupled with the fuel line in series or in parallel. The conversion control unit 201 is also operationally coupled to the fuel ethanol sensor 205 so as to obtain the fuel ethanol signal 205a.

[0068] The conversion control unit 201 is configured to determine engine load and engine speed based on the original injector pulse signal 110a. Then, based on the determined engine load and engine speed, the control unit 201 further determines applicable optimization instructions in accordance with an optimization map stored in the memory storage unit 202.

[0069] The conversion control unit 201 is further configured to determine fuel ethanol content based on the fuel ethanol signal 205a provide by the fuel ethanol sensor 205. Then, based on the determined fuel ethanol content, the control unit 201 further determines applicable ethanol conversion instructions in accordance with an ethanol conversion map stored on the memory storage unit 202.

[0070] As the conversion control unit 201 has established appropriate applicable optimization instructions and ethanol conversion instructions, the control unit obtains a corrected injector pulse signal 204a by applying said optimization instructions and ethanol conversion instructions to the original injector pulse signal 110a. The corrected injector pulse signal 204a is then transmitted to the fuel injector 101. Moreover, a corresponding corrected injector pulse signal 204 is generated for each of the original injector pulse signals 110a generated by the ECU unit 110, at least during open loop control thereof.

[0071] As depicted in Fig. 1, the system may a user device 300 operationally coupled to the conversion control assembly 200, suitably the conversion control unit 201 thereof. The user device 300 may be used to perform an engine load calibration cycle, and/or an engine speed calibration cycle, where the user is prompted to run the engine in a pre-described manner and subsequently acknowledge that such an engine run has been completed. The user device 300 (or the conversion control unit 201) can then modify the optimization map such that the engine speed (corresponding to periods of the original injector pulse signals 110a) and engine loads (corresponding to durations of original injector pulse signals 110a) durations exhibited therein match an operating range of the specific engine in question.

[0072] Alternatively, or in addition, the user device 300 may be used to modify either or both of the optimization map and the ethanol conversion map.

LIST OF REFERENCE NUMERALS

[0073]

100	combustion engine
101	fuel injectors
102	combustion cylinder
110	ECU unit
110a	original injector pulse signal
111	engine speed sensor
111a	engine speed signal
112	manifold air sensor
112a	manifold air signal
200	conversion control assembly
201	conversion control unit
202	memory storage unit
203	ECU connector
204	injector connector
204a	corrected injector pulse signal
205	fuel ethanol sensor
205a	fuel ethanol signal
300	user device

Claims

1. A system for adjusting fuel injection characteristic of an electronically fuel injected combustion engine (100), comprising:

an electronically fuel injected combustion engine (100), in turn comprising:

- fuel injectors (101) for injecting fuel into respective combustion cylinders (102) of the combustion engine (100);
- an engine speed sensor (111) configured to produce an engine speed signal (11a) indicative of engine speed;
- at least a manifold air sensor (112) configured to produce a manifold air signal (112a) indicative of engine load, and
- an ECU unit (110) operationally coupled to said engine speed sensor (111), manifold air sensor (112) and fuel injectors (101), the ECU unit (110) being configured, at least during an open-loop control mode, to generate original injector pulse signals (110a) so as to control fuel injector timing and duration in accordance with a pre-determined fuel map based on at least the engine speed signal and the manifold air signal;

a conversion control assembly (200), in turn comprising:

- a conversion control unit (201);
- a memory storage unit (202);
- an ECU connector (203) operationally coupled to the conversion control unit (201) and configured to receive original injector pulse signals (110a) form the ECU unit (110);
- an injector connector (204) operationally coupled to the conversion control unit (201) and configured to transmit corrected injector pulse signals (204a) from the conversion control unit (201) to the fuel injectors (101), and
- a fuel ethanol sensor (205) operationally coupled to the conversion control unit (201) and configured to produce a fuel ethanol (205a) signal indicative of fuel ethanol content,

wherein an ethanol conversion map is stored in the memory storage unit (202), the ethanol conversion map comprising ethanol conversion instructions corresponding to various fuel ethanol contents,
wherein an optimization map is stored in the memory storage unit (202), the optimization map comprising optimization correction instructions corresponding to specific engine speeds and engine loads,
wherein the conversion control unit (201) is configured to:

- obtain the fuel ethanol signal (205a) from the fuel ethanol sensor;
- determine applicable ethanol conversion instructions corresponding to the fuel ethanol content based on the ethanol conversion map;
- obtain the original injector pulse signal (110a) via the ECU connector (203);
- determine applicable optimization correction instructions corresponding to current engine speed and engine load, based on the optimization map;
- apply applicable ethanol conversion instructions and applicable optimization correction instructions to the original injector pulse signal (110a) so as to obtain a corrected injector pulse signal (204a), and
- transmit the corrected injector pulse signal (204a) to the fuel injectors (101) via the injector connector (204),

characterized in that the conversion control unit (201) is further configured to:

- determine engine speed based on a period between successive original injector pulse signals (110a), and
- determine engine load based on a duration of the original injector control signal (110a).

2. The system according to claim 1, **characterized by** further comprising a user device (300) operationally coupled to the conversion control unit (201),

wherein the system is configured to execute an engine load calibration cycle, during which the system is further configured to:

- send an idle load request via the user device (300);
- receive an idle load acknowledgement via the user device (300);
- identify a minimum original injection pulse duration from original injection pulse signals (110a) received via the ECU connector (203) between the idle load request and the idle load acknowledgement;
- send a full load request via the user device (300);
- receive a full load acknowledgement via the user device (300), and
- identify a maximum original injection pulse duration from original injections pulse sig-

nals (110a) received via the ECU connector (203) between the full load request and the full load acknowledgement, and

wherein the conversion control unit (201) is configured to determine engine load based on the duration of the original injector control signal (110a) with relation to the minimum original injector pulse duration and the maximum original injector pulse duration.

3. The system according to claim 2, **characterized in that**, during the engine load calibration cycle, the system is further configured to

- determine an engine specific load range between an idle load corresponding to the minimum original injector pulse duration and a full load corresponding to the maximum original injector pulse duration, and
- modify the optimization map, such that engine loads of the optimization map are normalized with respect to the engine specific load range

4. The system according to claim 2 or 3, **characterized in that** the system is further configured to execute an engine speed calibration cycle, during which the system is further configured to:

- send an idle speed request via the user device (300);
- receive an idle speed acknowledgement via the user device (300);
- identify a minimum engine speed from a longest period between successive original injector pulse signals (110a) received via the ECU connector (203) between the idle speed request and the idle speed acknowledgement;
- send a full speed request via the user device (300);
- receive a full speed acknowledgement via the user device (300), and
- identify a maximum engine speed from a shortest period between successive original injector pulse signals (110a) received via the ECU connector (203) between the full speed request and the speed load acknowledgement, and

wherein the system is further configured to determine an engine specific speed range between an idle speed corresponding to the minimum engine speed and a full speed corresponding to the maximum engine speed,
wherein the system is further configured to modify the optimization map such that engine speeds of the optimization map are normalized with respect to the engine specific speed range

5. A method for adjusting fuel injection characteristic of an electronically fuel injected combustion engine (100), comprising the steps of:

providing a conversion control assembly (200), comprising:

- a conversion control unit (201);
- a memory storage unit (202);
- an ECU connector (203);
- an injector connector (204), and
- a fuel ethanol sensor (205) operationally coupled to the conversion control unit (201) and configured to produce a fuel ethanol signal (205a) indicative of fuel ethanol content,

operationally coupling the conversion control unit (201) and the ECU unit (110) with the ECU connector (203), so as to enable the conversion control unit (201) to receive original injector pulse signals (110a) from the ECU unit (110);
operationally coupling the conversion control unit (201) and the fuel injectors (101) with the injector connector, so as to enable the conversion control unit (201) to transmit corrected injector pulse signals (204a) to the fuel injector (101);
providing an ethanol conversion map stored in the memory storage unit (202), the ethanol conversion map comprising ethanol conversion instructions corresponding to various fuel ethanol contents;
providing an optimization map stored in the memory storage unit (202), the optimization map comprising optimization correction instructions corresponding to specific engine speeds and engine loads, and
during operation of the engine, with the conversion control unit:

- obtaining the fuel ethanol signal (205a) indicative of fuel ethanol content from the fuel ethanol sensor (205);
- determining applicable ethanol conversion instructions corresponding to the fuel ethanol content based on the ethanol conversion map;
- obtaining the original injector pulse signal (110a) via the ECU connector (203);
- determining applicable optimization correction instructions corresponding to current engine speed and engine load based on the optimization map;
- applying applicable ethanol conversion instructions and applicable optimization correction instructions to the original injector pulse signal (110a) so as to obtain a cor-

rected injector pulse signal (204a), and
- transmitting the corrected injector pulse signal (204a) to the fuel injectors (101) via the injector connector (204),

characterized by, during operation of the engine, with the conversion control unit:

- determining engine speed based on a period between successive original injector pulse signals (110a), and
- determining engine load based on a duration of the original injector pulse signal (110a).

6. The method according to claim 5, **characterized by** further comprising the steps of:

providing a user device (300) operationally coupled to the conversion control unit (201),
executing an engine load calibration cycle, said engine load calibration cycle further comprising the steps of:

- sending an idle load request via the user device (300);
- receiving an idle load acknowledgement via the user device (300);
- identifying a minimum original injection pulse duration from original injection pulse signals (110a) received via the ECU connector (203) between the idle load request and the idle load acknowledgement;
- sending a full load request via the user device (300);
- receiving a full load acknowledgement via the user device (300), and
- identifying a maximum original injection pulse duration from original injection pulse signals (110a) received via the ECU connector (203) between the full load request and the full load acknowledgement, and

wherein, during operation, engine load is determined based on the duration of the original injector pulse signal (110a) with relation to the minimum original injector pulse duration and the maximum original injector pulse duration.

7. The method according to claim 6, **characterized in that**, the engine load calibration cycle, further comprises the steps of:

- determining an engine specific load range between an idle load corresponding to the minimum original injector pulse duration and a full load corresponding to the maximum original injector pulse duration, and
- modifying the optimization map, such that engine loads of the optimization map are normalized with respect to the engine specific load range

8. The method according to claims 6 or 7, **characterized by** further comprising the steps of:

executing an engine speed calibration cycle, said engine speed calibration cycle further comprising the steps of::

- sending an idle speed request via the user device (300);
- receiving an idle speed acknowledgement via the user device (300);
- identifying a minimum engine speed from a longest period between successive original injector pulse signals (110a) received via the ECU connector (203) between the idle speed request and the idle speed acknowledgement;
- sending a full speed request via the user device (300);
- receiving a full speed acknowledgement via the user device (300), and
- identifying a maximum engine speed from a shortest period between successive original injector pulse signals (110a) received via the ECU connector (203) between the full speed request and the speed load acknowledgement, and

determining an engine specific speed range between an idle speed corresponding to the minimum engine speed and a full speed corresponding to the maximum engine speed,
modifying the optimization map such that engine speeds of the optimization map are normalized with respect to the engine specific speed range

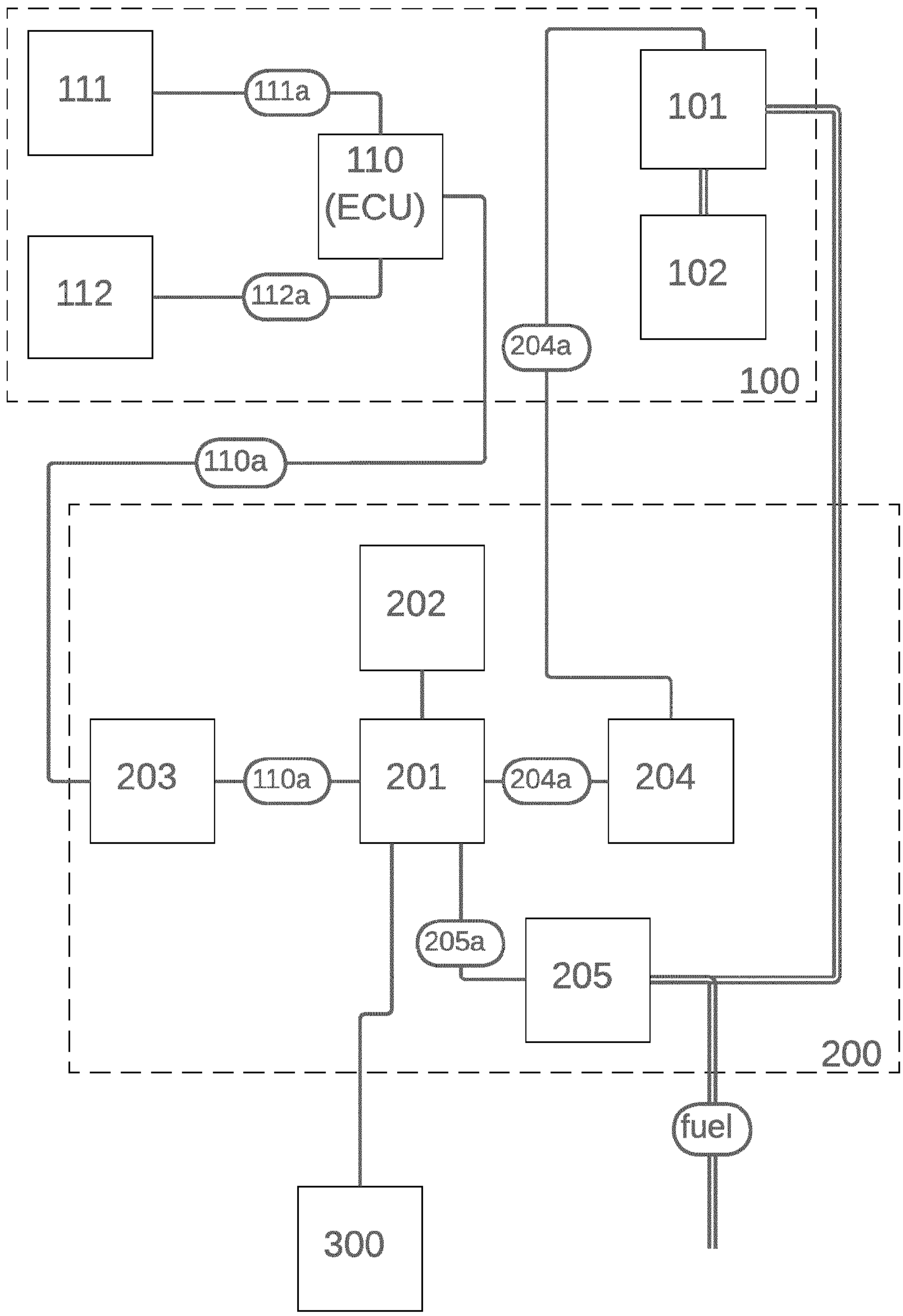
111
111a
110
(ECU)
112
112a
101
102
204a
100
110a
202
203
110a
201
204a
204
205a
205
200
fuel
300

Fig. 1

Europäisches Patentamt
European Patent Office
Office européen des brevets

EUROPEAN SEARCH REPORT

Application Number
EP 23 15 7231

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
X	US 2008/255753 A1 (SPIVAK PAUL [US]) 16 October 2008 (2008-10-16) * paragraphs [0015], [0017], [0022], [0024], [0027], [0028], [0034], [0035]; claim 1; figures 1-3 * -----	1-8	INV. F02D19/08 F02D41/26
Y	US 2021/079867 A1 (HARKONEN RISTO [FI] ET AL) 18 March 2021 (2021-03-18) * paragraphs [0036] - [0039]; claims 1-19; figures 1-10 * -----	1,5	
Y	WO 2012/120312 A1 (MOBILIZER LTD; ZYLA EDWARD [GB]; HOWARTH MARK [GB]) 13 September 2012 (2012-09-13) * claims 1-18; figures 1,2 * -----	1,5	
			TECHNICAL FIELDS SEARCHED (IPC)
			F02D

The present search report has been drawn up for all claims

1

Place of search	Date of completion of the search	Examiner
The Hague	15 August 2023	Boye, Michael

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
Y : particularly relevant if combined with another document of the same category
A : technological background
O : non-written disclosure
P : intermediate document

T : theory or principle underlying the invention
E : earlier patent document, but published on, or after the filing date
D : document cited in the application
L : document cited for other reasons
....
& : member of the same patent family, corresponding document

EPO FORM 1503 03.82 (P04C01)

ANNEX TO THE EUROPEAN SEARCH REPORT ON EUROPEAN PATENT APPLICATION NO.

EP 23 15 7231

This annex lists the patent family members relating to the patent documents cited in the above-mentioned European search report. The members are as contained in the European Patent Office EDP file on
The European Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

15-08-2023

Patent document cited in search report	Publication date	Patent family member(s)	Publication date
US 2008255753 A1	16-10-2008	NONE	
US 2021079867 A1	18-03-2021	US 2021079867 A1	18-03-2021
		US 2021079868 A1	18-03-2021
WO 2012120312 A1	13-09-2012	EP 2683929 A1	15-01-2014
		GB 2488814 A	12-09-2012
		US 2013345951 A1	26-12-2013
		WO 2012120312 A1	13-09-2012

EPO FORM P0459

For more details about this annex : see Official Journal of the European Patent Office, No. 12/82