An engine controller having a user-adjustable electronic control unit (ECU) (10) and a remote calibration module (12), and a method for use of the same, is provided for allowing a vehicle operator to precisely regulate the fuel delivery and spark advance of an internal combustion engine. The ECU (10) has outputs for regulating fuel flow rate, spark advance and engine idle speed, inputs adapted for coupling to engine sensors, and a microprocessor for processing information supplied by the sensors, to generate the outputs utilizing mathematical formulas and data tables stored in a read-write memory. The vehicle operator can also control auxiliary hardware such as switches, relays, timers and solenoids. The calibration module (12) cooperates with the ECU (10) and has a display screen (14) and input keys (16) enabling the vehicle operator to modify the fuel delivery and spark advance information and save the modifications.
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Codes used to identify States party to the PCT on the front pages of pamphlets publishing international applications under the PCT.

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+ Any designation of "SU" has effect in the Russian Federation. It is not yet known whether any such designation has effect in other States of the former Soviet Union.
ELECTRONIC ENGINE CONTROLLER HAVING USER-VARIABLE PARAMETERS

Technical Field

The present invention is related to an apparatus for internal combustion engine modification and enhancement wherein a vehicle operator is provided precise control over fuel metering, spark advance and engine idle speed.

Background Art

For as long as there have been vehicles on the road, owners of these vehicles have been modifying engine componentry and enhancing the car's performance and driveability. Before the age of electronics, owners of these vehicles were able to modify the vehicle's engine and enhance performance.

Today, automakers strive for the best compromise between low emissions, high fuel economy, and extended durability, while retaining good performance and driveability. Modern electronic engine controls must be precisely tuned to each application. Manufacturers also minimize the variety of powertrains offered in an attempt to reduce costs. This results in vehicles that are not fully optimized for any one market, much less any individual customer.

For these reasons many people modify their vehicles. Heavy modification is done for off-road racing and problems often arise when attempting engine modification. Any engine configuration has fixed yet interrelated characteristics that limit airflow and output power over all operating conditions. The typical engine controller is programmed using fixed formulas and/or data tables to precisely match the fuel and ignition requirements of the engine. Many modifications
done to the engine will change the airflow characteristics enough to cause a significant mismatch when using the original engine controller.

The prior art suggests replacing the engine controller's fixed programmed formulas and data tables with a modified fixed version to match the new engine configuration. This new program, however, is application specific and affords no more flexibility than the original OEM controller.

The prior art has also taught the use of a portable, or lap-top, computer to interface with the engine controller. While this does provide for greater control capability, the system is inherently undesirable because of its associated operational complexity and expense.

The prior art further proposes an electronic control unit for use in conjunction with the OEM engine control computer. This system uses the spark advance and fuel curves developed by the OEM, but permits the operator to alter the fuel-air mixture and timing at various engine speeds.

Disclosure Of The Invention

The invention is a method and apparatus for regulating the fuel delivery and spark advance of a fuel-injected, spark-ignited, internal combustion engine.

The present invention allows users of vehicles equipped with electronic engine controls to enhance the vehicle engine's performance by replacing the OEM engine control computer with an engine control computer that is user-adjustable, thus improving on the prior art by allowing the vehicle operator to access individual cells in the engine parameter data tables and change the information stored in those cells. The enhancement
occurs at the cell level of the data table, instead of
shifting the entire data table.

Although there is no limit as to how many times the
contents of a cell can be retrieved, modified and
stored, there are certain cells that are unable to be
modified. Cell values are modified by increasing or
decreasing the value in discrete, predetermined steps.
This is to insure the vehicle operator's actions do not
result in unsafe operation or damage to the engine.

When the vehicle operator has completed making
adjustments, the calibration module can be disconnected
from the ECU and stored for later use, without affecting
subsequent engine operation.

Accordingly, it is a general object of the
invention to provide an engine controller for regulating
fuel delivery and spark advance of a vehicle engine
having a plurality of sensors for sensing engine
operating parameters.

It is a further object of the invention to provide
an electronic control unit (ECU) for processing inputs
from sensors and generating outputs utilizing data
tables that are stored in read-write memory.

It is an additional object of the invention to
provide for data tables stored in read-write memory that
are allowed to vary within a predetermined range of
acceptable values.

It is also an object of the invention to provide a
calibration module to be used with the ECU for
displaying engine parameter information and receiving
input from the vehicle operator.

In carrying out the above objects and other objects
of the present invention of an engine controller, a
method is provided for regulating the fuel delivery and
spark advance of a fuel-injected, spark-ignited internal
combustion engine. The method includes the steps of
connecting a calibration module to an ECU, collecting
sensory information, retrieving the fuel delivery and spark advance information from a read-write memory in the ECU and displaying the information to the vehicle operator. The method also includes the steps of modifying the information in predetermined steps within a predetermined range of acceptable values and storing the modified information in the read-write memory of the ECU, whereby the engine's performance is modified. Finally, the method includes the steps of operating the engine so as to evaluate the modifications and disconnecting the calibration module from the ECU if the modifications are acceptable.

A system is also provided for carrying out the above-noted method.

The above objects and other objects and features of the invention will be readily known to one of ordinary skill in the art from the following detailed description of the best modes for carrying out the invention when taken in connection with the accompanying drawings.

Brief Description Of The Drawings

FIG. 1 is a schematic representation of a first embodiment of the present invention;

FIG. 2 is a block diagram of the user-adjustable electronic control unit (ECU) of the present invention;

FIG. 3 is a block diagram of the calibration module of the present invention.

FIG. 4 is a three-dimensional illustration of a data table having discrete values;

FIG. 5 is a three-dimensional illustration of the data table of FIG. 4 with linear interpolation between the discrete values, as utilized by the present invention;

FIG. 6a is a three-dimensional illustration of a fuel overlay table such as that used for modifying the information contained in the fuel delivery data tables;
FIG. 6b is a three-dimensional illustration of a spark overlay table such as that used for modifying the information contained in the spark advance data tables;

FIG. 7 is a flowchart illustrating the general operation of the present invention;

FIG. 8 is a flowchart detailing the display process utilized in the present invention;

FIG. 9 is a flowchart detailing the calibration process utilized in the present invention; and

FIG. 10 is a schematic representation of a second embodiment of the present invention.

Best Modes For Carrying Out The Invention

Referring now to Figure 1, a first embodiment of the invention is shown. This embodiment is for use as a multi-point fuel-injection system. User-adjustable electronic control unit (ECU) 10 replaces the original equipment manufacturer (OEM) engine control computer. Calibration module 12 has display 14 and a plurality of input function keys 16 which allow the vehicle operator to communicate with user-adjustable ECU 10 via cable 18 and connector 19. Wire harness adaptor 20 interfaces user-adjustable ECU 10 and calibration module 12 to OEM harness 22, which in turn is connected to a plurality of engine hardware shown generally by reference numeral 24.

Specifically, engine hardware 24 is comprised of a manifold absolute pressure (MAP) sensor 28, a distributor 30, an air temperature sensor 32, a throttle position sensor 34, a coolant temperature sensor 36 and a plurality of fuel injectors 38 mounted in the individual runners of intake manifold 40. Optional heated exhaust gas-oxygen sensor 26 can be utilized for closed-loop control of the vehicle engine. Closed-loop operation, as is known, provides for enhanced fuel economy and reduced engine emissions.
In the preferred embodiment, the distributor 30 replaces the OEM distributor. The distributor 30 uses inductive sensors and provides engine speed and position information to user-adjustable ECU 10. User-adjustable ECU 10 analyzes these signals, as is known, to identify particular cylinders and support a particular fuel-injection strategy. It should be appreciated that a replacement distributor may not be required.

A block diagram of user-adjustable ECU 10 is shown in Figure 2. As shown, the ECU 10 has a microprocessor and RAM, ROM and EEROM type memories. Sensory information is converted by an analog-to-digital (A/D) converter, and a high-speed timer controls output drivers. The ECU componentry is interconnected by data, address and control buses. It should be noted that there are numerous other electrical circuit schemes which could perform the same function.

A block diagram of calibration module 12 is shown in Figure 3. As shown, the calibration module 12 has a microprocessor, ROM type memory and a display. This componentry is interconnected by data, address and control buses. The microprocessor executes the program, receives input, communicates with the ECU 10 and displays information to the user. It should be noted that there are numerous other electrical circuit schemes which could perform the same function.

User-adjustable ECU 10 has a plurality of data tables stored in a read-write memory. Each table is comprised of a vertical axis and a horizontal axis, with each axis representing a particular engine parameter such as manifold pressure or speed.

There are two types of data tables. Base calibration data tables contain the fuel and spark information used to govern engine operation. The base calibration tables are not accessible to the operator but modifiable through a corresponding overlay data
table. Overlay data tables similarly contain fuel and spark modifier information, but are directly accessible to and modifiable by the operator. Overlay data tables can vary in size as required.

Data table 42 is shown in Figure 4, and is shown three-dimensionally to aid in illustration. Axis 44 of data table 42 is used to represent engine parameter A, and axis 46 is used to represent engine parameter B. Axes 44 and 46 are incrementally divided, or sectioned, to create of plurality of cells that contain data values. To illustrate, let it be assumed that data table 42 contains information that is used for controlling the fuel delivery schedule of an engine. Therefore, engine parameter A would be air density (manifold pressure), and engine parameter B would be engine speed. For each pairing of a specific manifold pressure and a specific engine speed, a cell contains a value representing a specific fuel injection pulse-width, or timing. In the first embodiment, data tables exist for fuel delivery and spark advance.

Data table 42 is shown having discrete values for specific pairings of parameters. A problem exists, however, when a specific air density and engine speed fall between the values on the axes. For example, referring again to Figure 4, assume the air density is 1800 mmHG/K and the engine speed is 2200 RPM. Because these values do not specifically exist on the axes, the injection time for the "next closest" values (1850, 2250 on Figure 4) would be used.

The present invention, however, incorporates linear interpolation in the control strategy. With linear interpolation, an injection time is precisely calculated for any pairing of air density and engine speed. Optimal injection times are thus provided for all operating conditions. Figure 5 shows data table 42 of Figure 4 and illustrates the effect of linear
interpolation. As can be seen, the result is a smoothing of the table of Figure 4.

As noted above, overlay tables exist for fuel and spark modifier information. As in the data tables, linear interpolation is utilized for the overlay tables. Fuel and spark overlay tables are shown three-dimensionally in Figure 6a and Figure 6b, respectively. Overlay table values represent a multiplicative modifier for fuel and an additive modifier for spark. The (1,1,1,1) plane outlined in Figure 6a and the (0,0,0,0) plane outline in Figure 6b represent the "no change" plane (i.e. a 1.00 multiplier for fuel and a 0° adder to the spark advance.) A modifier value above the (0,0,0,0) plane would be a value greater than 1.0, and a value below the plane would be a fractional multiplier. The user is thus able to increment or decrement in predetermined steps. The multiplier is then applied to the corresponding value in the base calibration data table.

With the calibration module 12 connected to the wire harness adaptor 20 via cable 18 and connector 19, and the engine started, calibration module 12 initializes to a real-time display mode and in the preferred embodiment display 14 displays engine speed (RPM), manifold pressure (mm Hg), injector pulse-width (mS), spark advance (°) and the current fuel modifier value. While in display mode, the operator can also view a second screen displaying coolant temperature (°C or °F), air charge temperature (°C or °F), throttle angle (°) and battery voltage (V). It should be appreciated that other types of sensory information can also be displayed in engineering units. The display process is illustrated in Figure 7 and Figure 8. While the present invention utilizes two display mode screens, additional screens may be created to display more information.
Stoichiometry LED 15 of calibration module 12 is illuminated as long as calibration module 12 is connected to wire harness adaptor 20, and changes color to indicate whether the fuel-air mixture is "rich," or "lean." A color-coded key, not specifically illustrated, is located on the front of calibration module 12 in close proximity to stoichiometry LED 15 so that the vehicle operator can quickly associate a particular color with the corresponding type of fuel-air mixture.

The vehicle operator utilizes the input function keys 16 to change from the display mode to the calibration mode. In the calibration mode, the operator can alter, in a user-friendly manner, the fuel, spark and idle speed information that govern engine operation. When the calibration mode is entered, the operator uses the input function keys 16 to retrieve and view the modifier information stored in the fuel and spark overlay data tables. The display 14 informs the operator what parameter is accessed and prompts him on how to execute a modification. The information accessed can be incremented or decremented in discrete, predetermined steps.

As the modifications are made, they are communicated to the random-access memory (RAM) of user-adjustable ECU 10. This storage in the RAM represents a temporary storage, and the modifications will be lost unless formally saved. The temporary storage, however, permits the operator to receive feedback on the effect of the modifications, when possible. This is because the calibration mode, like the display mode, functions in a real-time manner. For example, if the engine is idling and the operator increments the engine idle speed calibration from 750 RPM to 1000 RPM, the operator receives feedback because the engine idle speed will increase to 1000 RPM. However, if the engine is at idle
and the operator alters the spark advance at 5000 RPM and wide-open throttle, the operator would not receive feedback as to the effect of the modification until the engine speed is 5000 RPM with a wide-open throttle.

When the operator has completed the modification process, he can elect to save the modifications, or exit the calibration mode without saving the modifications. If the modifications are not saved, and the ECU 10 is powered down (i.e. ignition turned off) the previous calibration governs engine operation. If the operator wants to retain the modifications, a menu selection writes, the modifications made onto the calibration EEPROM of user-adjustable ECU 10. The entire calibration procedure is illustrated in Figure 7 and Figure 9.

With the desired cell modifications made, the vehicle operator can fully evaluate the effect of all modifications made on the engine's performance. Engine operation is controlled as is known to one skilled in the art.

The present invention also has the capability of controlling auxiliary functions. In addition to the output drivers that are dedicated (i.e. fuel pump driver, injector solenoid driver, etc), the user-adjustable ECU 10 has a plurality of auxiliary output drivers that are available to control auxiliary hardware. For example, these outputs could be used to control emissions hardware, such as an EGR valve or an air pump. By using the auxiliary outputs in such a manner, a vehicle operator could disable the emissions hardware when the vehicle is used in competition racing. The vehicle operator would then enable the emissions hardware for day-to-day use of the vehicle to comply with emissions requirements.

A similar type of fuel delivery schedule control can also be applied to an engine having throttle-body type fuel-injection. Such an embodiment is illustrated
in Figure 10, wherein like-numbered items appear in Figure 1, less 100.

As in the first embodiment, user-adjustable ECU 110 replaces the OEM computer and communicates via cable 118 with calibration module 112, which has a display 114, a stoichiometry LED 115 and a plurality of input function keys 116. In this embodiment, the OEM harness typically is unable to support the conversion to throttle-body fuel injection and is therefore replaced by wire harness adaptor 120, which connects to engine hardware shown generally by reference numeral 124.

Engine hardware 124 is comprised of a manifold absolute pressure (MAP) sensor 128, a distributor 130 having an engine speed and position sensor, an air temperature sensor 132, a throttle position sensor 134, a coolant temperature sensor 136 and a throttle body 140 having fuel injectors 138 as the fuel injecting means. Optional heated exhaust gas-oxygen sensor 126 can be utilized for closed-loop control of the vehicle engine. As in the first embodiment, user-adjustable ECU 110 also has the capability of controlling auxiliary functions such as engine emissions.

It is understood, of course, that while the forms of the invention herein shown and described constitute preferred embodiments of the invention, they are not intended to illustrate all possible forms thereof. It will also be understood that the words used are words of description rather than limitation, and that various changes may be made without departing from the spirit and scope of the invention disclosed.
What is claimed is:

1. An engine controller for regulating the fuel delivery and spark advance of a fuel injected, spark-ignited internal combustion engine having a plurality of sensors for sensing engine operating parameters, said engine controller comprising:
   an electronic control unit (ECU) having outputs for regulating fuel flow rate, spark advance and engine idle speed, inputs adapted for coupling to said sensors, and a microprocessor for processing information supplied by said sensors, to generate said outputs utilizing a plurality of data tables stored in a read-write memory and mathematical formulas; and
   a remote calibration module that cooperates with said ECU, said module having means for displaying information to a vehicle operator and means enabling said vehicle operator to modify and communicate data to said ECU for storage in said data tables.

2. The engine controller of claim 1 wherein said data tables comprise base calibration data tables and corresponding overlay tables, said base calibration data tables being modifiable through the use of said overlay tables, said overlay tables being accessible and modifiable using said remote calibration module by said vehicle operator within a predetermined range of acceptable values.

3. The engine controller of claim 2 wherein said base calibration data tables and said corresponding overlay tables contain information regarding fuel flow rate and spark advance.
4. The engine controller of claim 3 wherein said fuel flow rate and spark advance base calibration data tables and corresponding overlay tables further comprise axes having a plurality of divisions for indicating manifold absolute pressure and engine speed.

5. The engine controller of claim 2 wherein said overlay data tables can vary in size, thereby allowing the user to configure said tables according to each application.

6. The engine controller of claim 1 wherein one of said plurality of sensors is a heated exhaust gas-oxygen sensor, thereby permitting said engine controller to operate in a substantially closed-loop fashion, so as to provide enhanced fuel economy and reduced engine emissions.

7. The engine controller of claim 1 wherein said remote calibration module further comprises a means for indicating the fuel-air mixture, relative to stoichiometry, of said fuel delivery.

8. The engine controller of claim 1 wherein said ECU further comprises outputs for controlling other functions such as engine emissions.
9. A method of controlling the fuel delivery and spark advance of a fuel injected, spark-ignited internal combustion engine having a plurality of sensors for sensing engine operating parameters, using an engine controller having an electronic control unit (ECU) and a calibration module, the method providing:

   connecting said calibration module to said ECU;
   collecting information from said sensors;
   retrieving fuel flow rate and spark advance information and fuel flow rate and spark advance modifier information from said ECU;
   displaying said fuel flow rate and spark advance information and said fuel flow rate and spark advance modifier information data to a vehicle operator;
   altering said fuel flow rate and spark advance information by incrementing or decrementing said information in predetermined steps, within a predetermined range of acceptable values;
   communicating said modifier values to said ECU for temporary storage in a read-write memory, thereby modifying said fuel flow rate and spark advance of said engine, so as to provide feedback to said vehicle operator;
   storing said modifier values in said read-write memory of said ECU;

10. The method of claim 9 further providing:

   operating said engine so as to evaluate said modified fuel flow rate and spark advance of said engine to determine if further modifications are required;

11. The method of claim 9 or claim 10 further providing:

   disconnecting said calibration module from said ECU and storing for later use if said modified fuel flow rate and spark advance are acceptable.
12. An engine controller for regulating the fuel delivery and spark advance of a fuel injected, spark-ignited internal combustion engine having a plurality of sensors including a heated exhaust gas-oxygen sensor for sensing engine operating parameters, said engine controller comprising:

   an electronic control unit (ECU) having outputs for regulating fuel flow rate, spark advance and engine idle speed, outputs for regulating auxiliary functions such as engine emissions, inputs adapted for coupling to said sensors, and a microprocessor for processing information supplied by said sensors, to generate said outputs utilizing mathematical formulas, a plurality of base calibration data tables and a plurality of modifiable overlay data tables, said plurality of base calibration data tables containing fuel flow rate and spark advance information and being stored in a read-write memory, said modifiable overlay data tables containing modifier values and being stored in a read-write memory; and

   a remote calibration module that cooperates with said ECU, said module having a display screen for displaying sensory and fuel flow rate and spark advance information and engine speed information to a vehicle operator, an LED for indicating the fuel-air mixture, relative to stoichiometry, and input function keys enabling said vehicle operator to modify said displayed fuel flow rate and spark advance information and communicate said modifier values to said ECU for storage in said modifiable overlay data tables.
ELECTRONIC CONTROL UNIT

FIG. 2

ROM (Program)  RAM  ROM (Calibr. Overlay Tables)  A/D CONVERTER

DATA BUS

ADDRESS BUS

CONTROL BUS

TO MICROPROCESSOR

O₂ SENSOR  ENG. TEMP.

TO HIGH SPEED TIMER
INJECTION TIME $\mu S$

**FIG. 5**
FUEL OVERLAY TABLE

FIG. 6a
SPARK OVERLAY TABLE

FIG. 6b
START

Collect Sensory Information

Calculate Fuel Delivery and Spark Advance; Calculate Idle Control and Emissions Control

Data From Base Calibration Tables

Modify Fuel Delivery and Spark Advance; Modify Idle Speed and Emissions

Data From User - Variable Overlay Tables

TO/FROM CALIBRATION

Output Fuel, Spark, Idle and Emissions; Output Auxiliary Functions

TO DISPLAY

FIG. 7
DISPLAY PROCESS

FIG. 8
FROM DISPLAY PROCESS

Display Calibration Parameter Name And Prompt To User

Read Modifier Values From Memory and Display To User

Vehicle Performance Acceptable?

Y

N

Alter Modifier Value

Communicate Modifier Value To ECU

View Different Calibration Parameter?

Y

N

Save Changes

N

Use Previous Calibration Values After *Key-off*

N

Save Changes In ECU EEPROM

Y

Return to Display Process (Fig. 8)

FIG. 9
# INTERNATIONAL SEARCH REPORT

## I. CLASSIFICATION OF SUBJECT MATTER

According to International Patent Classification (IPC) or to both National Classification and IPC

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## II. FIELDS SEARCHED

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Documentation Searched other than Minimum Documentation to the extent that such Documents are Included in the Fields Searched 4

## III. DOCUMENTS CONSIDERED TO BE RELEVANT

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<td>US, A, 4,677,558 (BOHMLER ET AL.) 30 June 1987 (See Fig. 1, cols. 1-2).</td>
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<td>US, A, 4,751,633 (HENN ET AL.) 14 June 1988 (See Fig. 1, cols. 4 and 6).</td>
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<td>US, A, 4,908,792 (PRZYBYLA ET AL.) 13 March 1990 (See figs. 1-2, cols. 3 and 5.</td>
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* Special categories of cited documents:

- "A" document defining the general state of the art which is not considered to be of particular relevance.
- "E" earlier document but published on or after the international filing date.
- "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).
- "O" document referring to an oral disclosure, use, exhibition or other means.
- "P" document published prior to the international filing date but later than the priority date claimed.

* "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.

* "X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step.

* "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.

* "Z" document member of the same patent family.

## IV. CERTIFICATION

Date of the Actual Completion of the International Search

05 March 1992

International Searching Authority

ISA/US

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Signature of Authorized Officer

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