United States Patent

Suda et al.

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[54] **FUEL INJECTION CONTROLLING SYSTEM FOR INTERNAL COMBUSTION ENGINE**

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[73] Assignee: **Hitachi, Ltd.,** Tokyo, Japan

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Sept. 11, 1968 Japan....................................43/64960

[52] **U.S. Cl.**..........................**123/32 EA,** 123/139 E, 123/119
[51] **Int. Cl.**...**F02m 51/02**
[58] **Field of Search**..............123/32, 32 E, 32 EI, 119, 139 E

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Primary Examiner—Laurence M. Goodridge
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[57] **ABSTRACT**

A fuel injection controlling system for internal combustion engines, wherein the various conditions of the internal combustion engine are converted to signal currents, these signal currents are superimposed upon a timing signal current, the magnitude of which corresponds to a lapse of time, and then supplied to an input terminal of a current level detecting circuit so that there is produced an output pulse signal of which the duration is related to the quantity of fuel required by the internal combustion engine, and a fuel injection valve is opened in accordance with said output pulse signal thereby to control the quantity of fuel supplied to the internal combustion engine.

12 Claims, 12 Drawing Figures

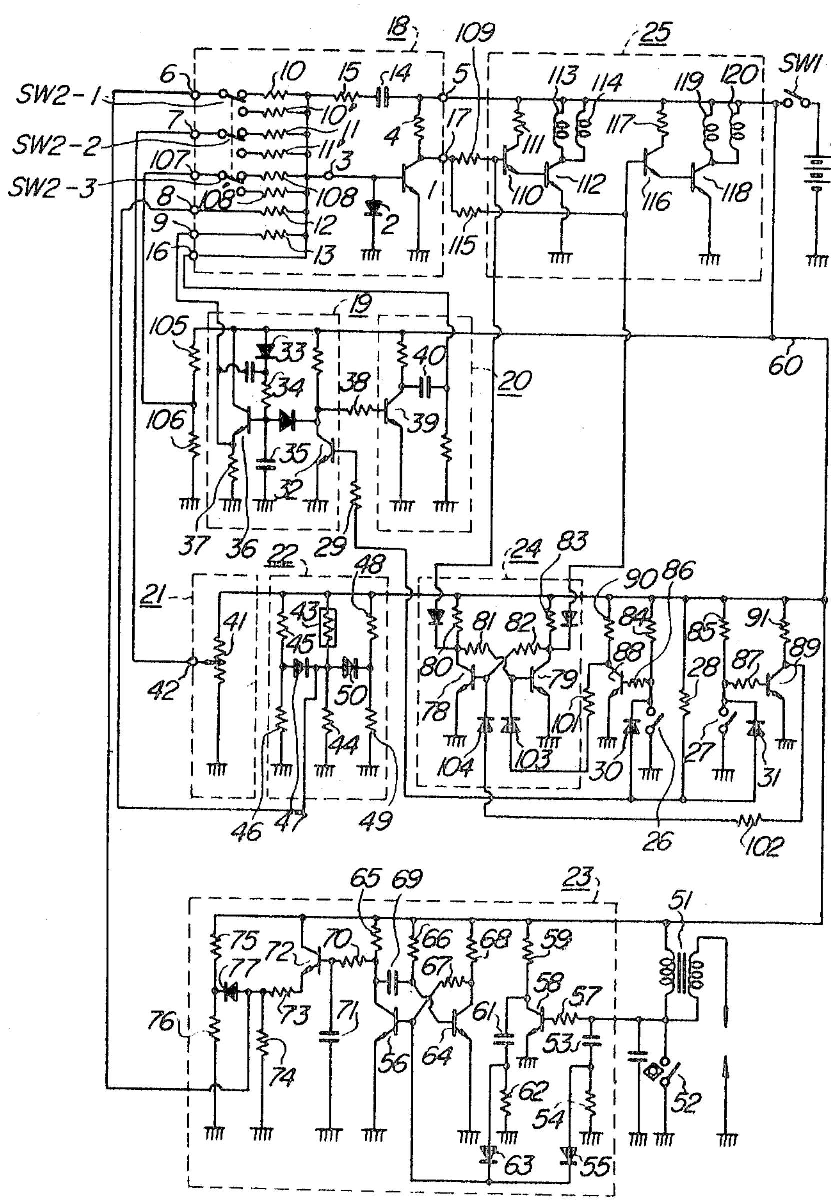

FIG. 1a

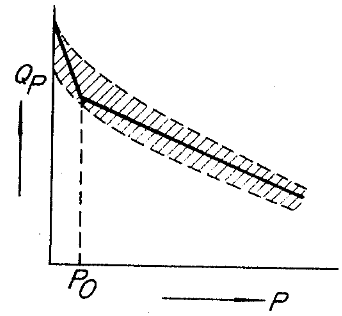

FIG. 1b

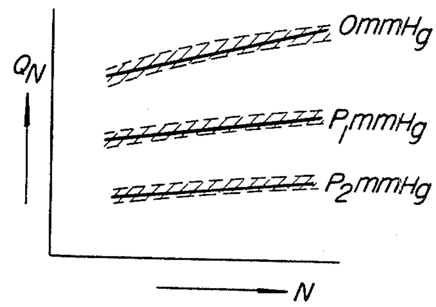

FIG. 1c

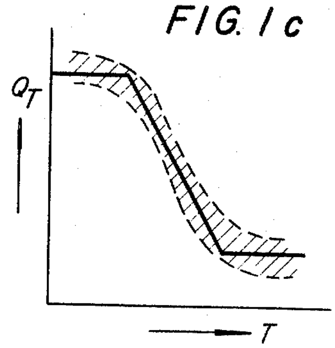

FIG. 2a

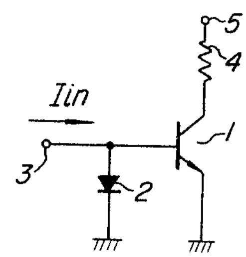

FIG. 2b

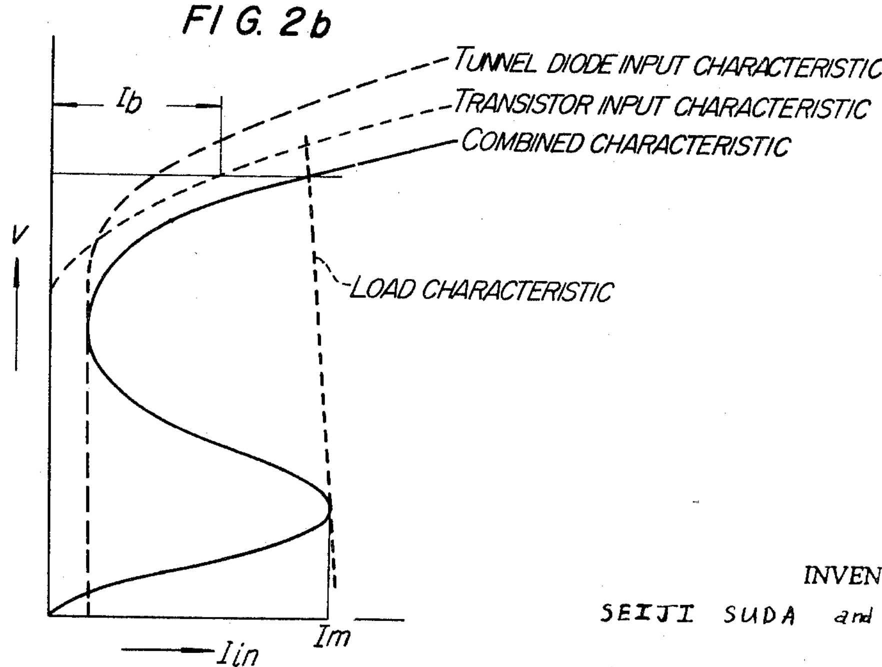

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FIG. 3a

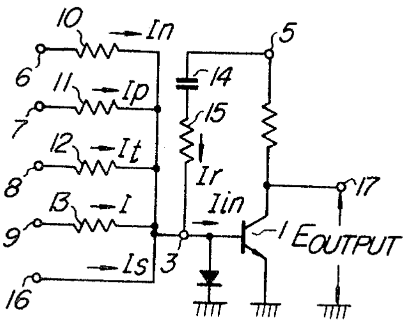

FIG. 3b

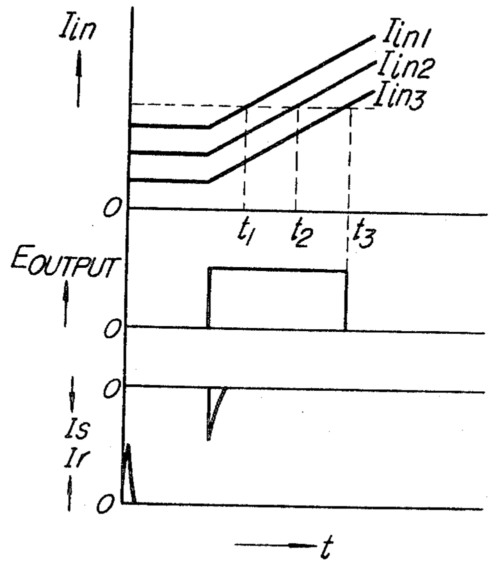

FIG. 5a

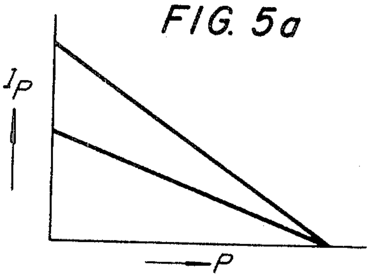

FIG. 5b

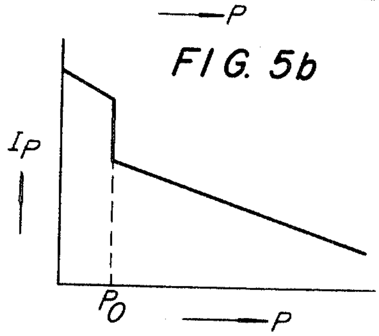

FIG. 6a

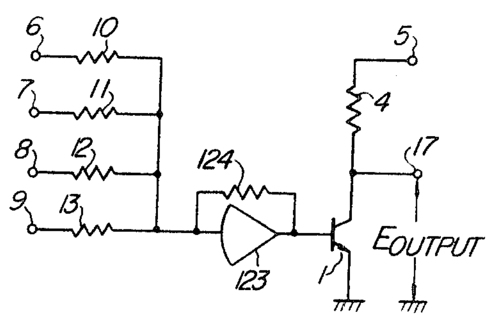

FIG. 6b

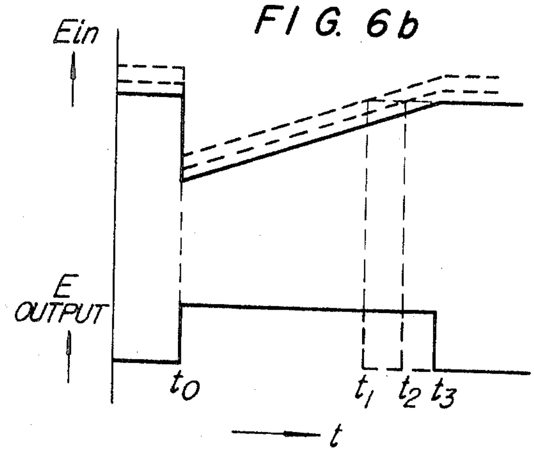

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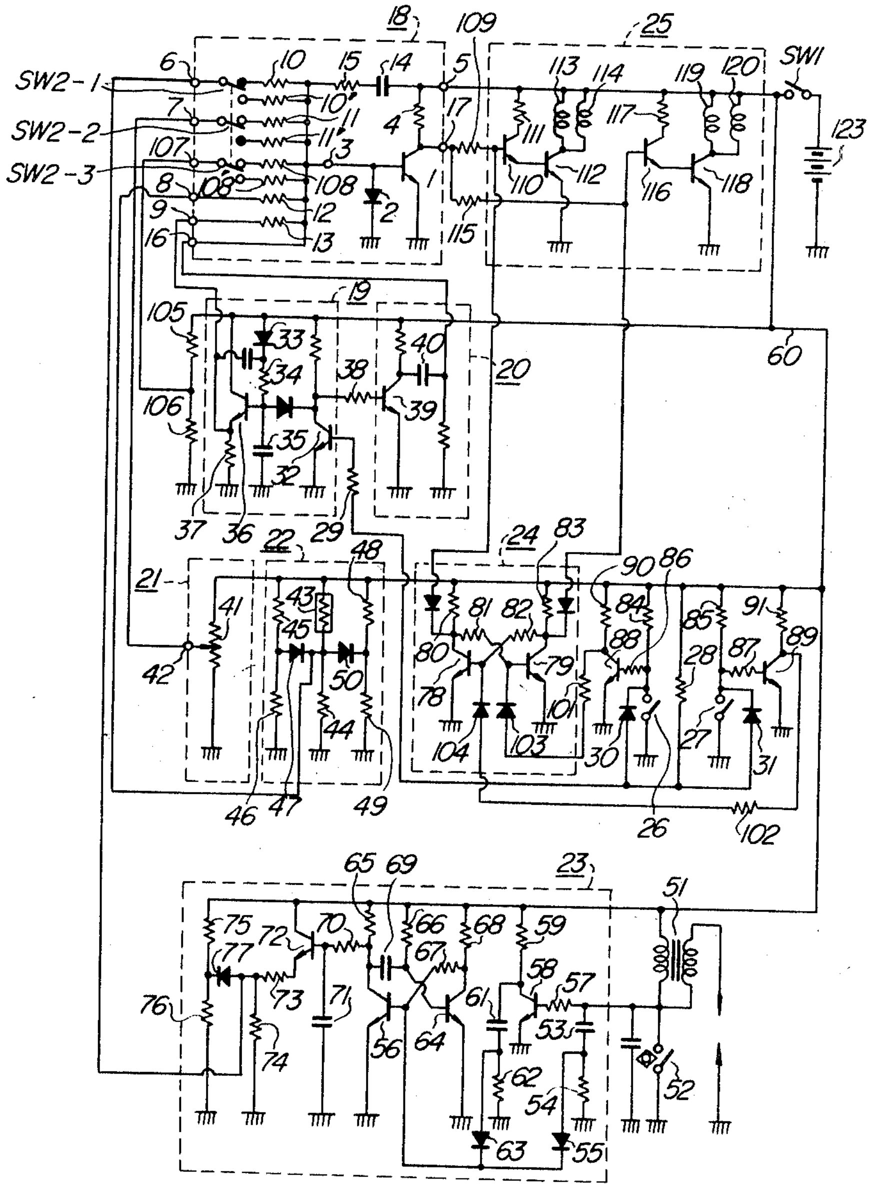
FIG. 4



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FUEL INJECTION CONTROLLING SYSTEM FOR INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a fuel injection controlling system for internal combustion engines which is adapted to control the quantity of fuel to be supplied, and more particularly it pertains to improvements in or relating to a system of electrically controlling the quantity of fuel to be injected.

2. Description of the Prior Art

Among the conventional methods of supplying fuel to an internal combustion engine are the methods of sucking out fuel by making use of a negative pressure existing in a suction pipe and the method of injecting fuel by means of an injection nozzle. In the latter method, the quantity of fuel to be supplied can be accurately controlled in correspondence to the quantity of fuel required by the internal combustion engine so that the efficiency of the internal combustion engine is enhanced to provide an increased output torque and the quantity of harmful exhaust gas is decreased. Thus, this method is effectively utilized as means for supplying fuel to the internal combustion engine for an automobile.

In most of the injection-type fuel feed systems, the various conditions of the internal combustion engine are imparted to electric elements in order that an electrical signal having a magnitude corresponding to the quantity of fuel to be supplied to the internal combustion engine may be produced by making use of a change in the time constant of a time-constant circuit constituted by such electric elements or a potential variation in a voltage divider circuit, and an electromagnetic valve is actuated in accordance with the electrical signal thus produced, thereby controlling the quantity of fuel which is injected by an injection nozzle. A typical example of such systems is a method opening an electromagnetic valve by means of an electrical signal having a required duration which is produced by the use of a monostable flip-flop circuit. In this method, the values of the capacitor and resistor serving as timing means in the monostable flip-flop circuit are varied in accordance with the conditions of the internal combustion engine thereby to change the duration of the output. Such a system is disclosed in the U.S. Pat. No. 2,941,519 to Zechnall et al., filed Dec. 1, 1958, and U.S. Pat. No. 3,051,152 to Paule et al., filed Sept. 17, 1958, for example. In this system, however, a limitation is put on the conditions of the internal combustion engine from which the quantity of fuel is to be determined, since difficulty is encountered in an attempt to constitute the timing means by a number of electric elements in the monostable flip-flop circuit. In order to determine the quantity of fuel from a number of conditions, it will become necessary to resort to the use of a complicated composite mechanism.

Another example is a system designed so that the various conditions of the internal combustion engine are converted to resistance values, a signal voltage is provided by an operational means (voltage divider circuit) which is constituted by connecting a combination of said resistance values between power source lines, and that the open duration of an electromagnetic valve is controlled in accordance with the signal voltage thus provided. Such system is disclosed in U.S. Pat. No. 3,240,191, to Wallis, filed May 29, 1963, for example. With the system using operational means as described above, however, it is very difficult to change the resistance characteristics corresponding to the various conditions of the internal combustion engine since the absolute values of such resistances have effect on the entire voltage distribution. Thus, this makes it difficult to achieve the matching between various types of internal combustion engines to which such system as described above is applied. For internal combustion engines for automobiles, such matching difficulty constitutes a great disadvantage from the standpoint of mass production.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide a system capable of controlling the quantity of fuel to be supplied by effecting an operation with respect to electric signals corresponding to the various conditions of an internal combustion engine in a very simple manner.

Another object of the present invention is to provide such a system that can be matched to a plurality of types of internal combustion engines having different characteristics merely by making minor adjustments or design changes.

The system according to the present invention is characterized in that the various conditions of an internal combustion engine from which the required quantity of fuel is determined are converted to independent electric signals respectively, a time signal is produced which corresponds to the lapse of time from the moment when the crankshaft reaches a predetermined position, these signals are combined with each other and then supplied to a discriminator circuit to produce an output signal having a time width corresponding to the required quantity of fuel, and an electromagnetic valve is operated in accordance with the output signal thus produced.

Other objects, features and advantages of the present invention will become apparent from the detailed description of the preferred embodiments taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE INVENTION

FIG. 1*a* is a graph showing the relationship between the negative pressure in the manifold and the quantity of fuel to be supplied;

FIG. 1*b* is a graph showing the relationship between the rotational frequency of the engine and the quantity of fuel to be supplied, with the negative pressure in the manifold maintained constant;

FIG. 1*c* is a graph showing the relationship between the engine temperature and the quantity of fuel to be supplied;

FIG. 2*a* is a circuit diagram showing an example of discriminator means according to the present invention;

FIG. 2*b* is a view showing the input current characteristics of said discriminator means;

FIG. 3*a* is a circuit diagram showing an example of arithmetic operating means according to the present invention;

FIG. 3*b* is a view showing the characteristics thereof;

FIG. 4 is a circuit diagram showing the fuel injection controlling system for internal combustion engines according to an embodiment of the present invention;

FIGS. 5*a* and 5*b* are views showing characteristic curves useful for explaining variations of fuel feed characteristics with the negative pressure in the manifold, respectively;

FIG. 6*a* is a circuit diagram showing another example of discriminator means according to the present invention; and

FIG. 6*b* is a view showing the characteristic curves thereof.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The preferred quantity Q_p of fuel to be supplied in terms of the negative pressure P in the manifold of the internal combustion engine is as shown in FIG. 1*a* from which it will be seen that the quantity Q_p in terms of the negative pressure P is represented by a continuous characteristic curve. However, it is difficult to change the supplied fuel quantity Q_p along such a characteristic curve. In practice, therefore, such a characteristic is approximated by polygonal line. The negative pressure P in the manifold depends upon the opening degree of the throttle valve and the rotational frequency N of the internal combustion engine. At a predetermined rotational frequency N, if the negative pressure P in the manifold is low, then it is required that the opening degree of the throttle valve be increased to provide an increased output. In this region, therefore, the characteristic is made such that the supplied fuel quantity Q_p is so selected as to produce a maximum output in disregard of fuel cost. In case the negative pressure P in the manifold is high, however, the opening degree of the throttle valve is low. In this region, therefore, the characteristic is modified so that the supplied fuel quantity Q_p is selected to make the fuel cost the lowest possible. The modification point corresponds to the bent P. of the polygonal line. Thus, the characteristic is divided into a power region and an economic region, with this bent point as a boundary.

Referring now to FIG. 1*b*, there is shown the characteristic of the proper supplied fuel quantity Q_N in terms of rotational frequency N of the engine. This characteristic also changes in the form of a curve in terms of the rotational frequency N, with the manifold negative pressure P as parameter. In practice, however, it is difficult to achieve control along such curve. Therefore, it is approximated by straight line.

FIG. 1*c* shows the characteristic of supplied fuel quantity Q_t in terms of engine temperature T. THis characteristic is also approximated by a polygonal line since in some temperature region the quantity Q_t is proportional to the engine temperature while in the opposite end regions there occur saturation characteristics.

In order to control the quantity Q of fuel to be supplied in the injection-type fuel feed system, two methods are conceivable, that is, a method to change the quantity of fuel to be injected per unit of time and a method to change the duration of the fuel injection. In order to control such changes with the aid of an electromagnetic valve, the latter method turns out to be advantageous. The system according to the present invention may be applied to such a control.

In such method, the quantity Q of fuel to be supplied and the opening duration *t* of the electromagnetic valve are in substantially linear relationship with each other. If the supplied fuel quantity Q is represented in terms of duration *t*, then it may be considered that the duration *t* is represented by a function including as independent variables the manifold negative pressure P, rotational frequency N and temperature T.

$$t=f_1(P)+f_2(N)+f_3(T) \quad (1)$$

From manifold negative pressure P_O corresponding to each bent point, f_1, f_2 and f_3 vary as follows:

When $P \geqq P_O$,

$$f_1(P)=r_1P+S_1 \quad (2)$$

$$f_2(N)=a_1N+b_1 \quad (3)$$

When $P<P_O$,

$$f_1(P)=r_2P+S_2 \quad (4)$$

$$f_2(N)=a_2N+b_2 \quad (5)$$

When $P \gtreqless P_O$ and $T_O \leqq T \leqq T_1$,

$$f_3(T)=kT+k' \quad (6)$$

where T_O represents the temperature corresponding to the low-temperature bent point and T_1 indicates the temperature corresponding to the high-temperature bent point.

In accordance with the present invention, the aforementioned manifold negative pressure *P*, rotational frequency *N* and temperature *T* are converted to signal currents from which it is attempted to determine the opening duration *t* of the electromagnetic valve.

Description will now be made of the principle of an embodiment of the present invention, with reference to FIGS. 2*a*, 2*b* and 3*a*, 3*b*.

Referring to FIG. 2*a*, there is shown a discriminator circuit comprising an NPN-transistor **1** and a tunnel diode **2** connected between the base electrode and the emitter electrode of the transistor **1** in the same polarity and in parallel with the latter, wherein the base electrode of the transistor **1** is connected with an input terminal **3**, and the collector electrode thereof is connected with a power source terminal **5** through a load resistor **4**. The operation of this discriminator circuit will be explained with reference to FIG. 2*b*. If an input current I_{in} arriving at the input terminal **3** is increased, then the overall current is enabled to flow through the tunnel diode **2** because of the fact that the tunnel diode represents a very low internal impedance when the input current I_{in} is lower than the maximum value I_m of the tunnel diode **2**, so that the current is not caused to flow in the base electrode of the transistor **1**. Thus, the nonconductive state is established between the emitter and the collector of the transistor. However, if the input current I_{in} exceeds the maximum value I_m, then the tunnel diode **2** is caused to enter the negative region so that the current flowing therethrough is decreased with the result that the terminal voltage builds up. Consequently, the potential at the base electrode of the transistor **1** increases to cause a current I_b to flow between the base electrode and the emitter electrode. Thus, the conductive state is established between the emitter electrode and the collector electrode so that a collector current is caused to flow so that an output signal is obtained across the load resistor **4**.

In accordance with one embodiment of the present invention, an attempt is made to effect operation with respect to the optimum quantity of fuel to be supplied to the engine from the various signal currents by making use of the aforementioned characteristic.

FIG. 3*a* is a circuit diagram showing an example of operational means adapted to form an output signal corresponding to a required duration *t* by imparting the various conditions of the internal combustion engine to the discriminator circuit described above in connection with FIGS. 2*a* and 2*b*. Numeral **6** represents a signal input terminal corresponding to the rotational frequency *N* of the engine, **7** a signal input terminal corresponding to the manifold negative pressure *P*, **8** a signal input terminal corresponding to the temperature *T*, and **9** a signal input terminal corresponding to the lapse of time. These signal input terminals are connected in common to the input terminal of the discriminator circuit through the resistors **10**, **11**, **12** and **13** respectively. A capacitor **14** and resistor **15** constitute a differentiating circuit which is connected in series between the power source terminal **5** and the input terminal **3**. This differentiating circuit is provided for the purpose of imparting to the input terminal **3** a preparation signal current I_r having such a magnitude as to establish the conductive condition between the emitter and the collector electrodes of the transistor **1** when the power source is turned on. Numeral **16** represents a reset signal input terminal for imparting a negative trigger voltage to the transistor **1** to establish the nonconductive condition between the emitter and the collector electrodes of the transistor **1** when it is desired that the fuel injection be started. This reset signal input terminal is also connected with the input terminal **3**. An output signal is taken from between an output terminal **17** connected with the collector electrode transistor **1** and the ground.

Next, the operation of the foregoing arrangement will be described with reference to FIG. 3*b*. First of all, upon application of the power source voltage to the power source terminal **5**, the preparation current I_r is caused to flow into the input terminal **3** through the capacitor **14** and resistor **15** so that a current having a sufficient magnitude to establish the conductive state between the emitter and the collector electrodes of the transistor **1** is caused to flow into the base electrode thereof. At this point, the potential at the collector electrode is so low that no output signal is available from the output terminal **17**. Subsequently, if the engine is rotated by starter means (not shown), then a negative pulselike reset current I_s is supplied from the input terminal **16** to the input terminal **3** when it is desired that the fuel injection be initiated. This reset current I_s reduces the current flowing in the input terminal **3** so that the potential at the base electrode of the transistor **1** is decreased, while at the same time resetting the tunnel diode **2**. Thus, the base current of the transistor **1** is interrupted so that the nonconductive condition is established between the emitter and the collector electrodes thereof. As a result, the potential at the collector electrode increases, and thus an output signal E_{output} appears at the output terminal **17**. At the same time, a sawtooth wave signal voltage which increases with the lapse of time is applied to the signal input terminal **9** so that a time-lapse signal current I_v is caused to flow through tHe input terminal by way of resistor **13**. Further, voltages corresponding to the various conditions of the engines are applied to the other signal input terminals 6, 7 and 8, and signal currents I_n, I_p and I_t are supplied to the input terminal 3 through the resistors 10, 11 and 12 respectively. Because of the very low input impedance of the input terminal 3, these signal currents are algebraically combined with each other so that there is obtained a combined current I_{in} which in turn flows in the input terminal 3. Such combined current I_{in} is selected to be lower than the maximum value I_m of the tunnel diode 2. The combined current I_{in} increases with an increase of the time-lapse signal current I_v, but when it is in the region below the maximum value I_m, it is caused to flow to the ground through the tunnel diode 2, so that no current is made to flow in the base electrode of the transistor 1. Thus, the nonconductive condition is established between the emitter and the collector electrodes, and therefore in such region, the output signal available at the output terminal 17 is preserved. After the lapse of predetermined time t, however, the combined current I_{in} flowing in from the input terminal 3 exceeds the maximum value I_m of the tunnel diode 2, so that the internal impedance of the tunnel diode 2 is increased with the result that the terminal voltage is increased. Consequently, the potential at the base electrode of the transistor increases to enable a base current to flow therein so that the conductive condition is established between the emitter and the collector electrodes. Thus, the potential at the collector electrode decreases so that the output signal at the output terminal disappears. By operating the fuel injection control value in accordance with the output signal available at the output terminal 17, therefore, it is possible to feed fuel for the aforementioned duration t. This duration t depends upon the magnitudes of the signal currents I_n, I_p and I_t which depend upon the conditions of the engine, and therefore the quantity Q of fuel to be supplied can be controlled to correspond to the required fuel quantity by changing these signal currents in accordance with predetermined characteristics. That is, since the time-lapse signal current I_v varies at a constant gradient irrespective of the conditions of the engine whereas the composite current I_{in} flowing in the input terminal 3 varies like I_{in1}, I_{in2}, I_{in3}, . . ., the duration t in which the maximum value I_m of the tunnel diode 2 is reached varies like t_1, t_2, t_3. . . .

Referring now to FIGS. 5*a* and 5*b*, description will be made of the present invention as embodied under the following conditions.

a. Injection is simultaneously effected with respect to respective two cylinders of a four-cylinder, four-stroke-type engine.

b. Injection timing is set such that the injection is started by means of primary current interrupter contact associated with a firing coil and additionally provided with two contacts when these contacts are made.

c. A sawtooth wave voltage which builds up with the lapse of time is used as a signal to detect time variations.

d. It is assumed that the required fuel feed characteristics of the engine are as shown in FIGS. 1*a*, 1*b* and 1*c*, and that such characteristics can easily be changed.

In FIG. 4, numeral 18 represents the aforementioned operational circuit, 19 a sawtooth wave generating circuit adapted for providing a time-lapse signal, and 20 a reset circuit adapted to provide a negative trigger voltage in synchronism with the generation of the sawtooth wave. Numeral 21 indicates a circuit for detecting a negative pressure in the engine suction manifold, which consists of a combination of a diaphragm and a potentiometer type resistor, 22 an engine temperature detecting circuit, and 23 a circuit for detecting the rotational frequency of the engine. Numeral 24 denotes a selector circuit for selecting that one of the electromagnetic valves to which the output signal of the operational circuit is to be supplied, and 25 a switching circuit for flowing a driving current through the electromagnetic valve thus selected.

These circuits will be described in further detail below. The sawtooth wave generating circuit 19 is constituted by a bootstrap circuit. When either one of timing contacts 26 and 27 is made, a current which has been flowing through a resistor 29 by way of a resistor 28 is now made to flow to the ground through diode 30 or 31, so that a transistor 32 is rendered nonconductive. At this point, a capacitor 35 begins to be charged through a diode 33 and a resistor 34. As a result, the potential at the base electrode of a transistor 36 is increased so that the conductivity between the collector and the emitter electrodes thereof is increased. Thus, an increasing current is caused to flow from the emitter electrode to a resistor 37, so that the potential at the emitter electrode builds up gradually. By virtue of the fact that the transistor 32 is rendered nonconductive when the sawtooth wave generating circuit 19 starts the generation of the sawtooth wave, the reset circuit 20 is adapted to establish the conducting state between the emitter and the collector electrodes of a transistor 39 by connecting the collector electrode of the transistor 32 with the base electrode of the transistor 39 through a resistor 38, and impart a negative trigger voltage to the reset signal input terminal 16 of the operational circuit by discharging charges stored at a capacitor 40 when the transistor 39 is in the nonconducting state. The engine manifold negative pressure detecting circuit 21 is constituted by the diaphragm adapted for movement in accordance with the manifold negative pressure and potentiometer type resistor 41 actuated by the diaphragm, wherein a voltage which builds up with an increase in the manifold negative pressure is obtained at a slidable contact 42. The engine temperature detecting circuit 22 is constituted by a series circuit of a temperature-sensitive element 43 and resistor 44, wherein a signal voltage is obtained at the connection point of the series circuit. In the case where as temperature-sensitive element 43 use is made of a thermistor, the resistance value of the temperature-sensitive element 43 decreases with temperature increase, while the potential at the output point thereof increases. The lowest voltage is clamped by resistors 45 and 46 and diode 47, and the highest voltage is clamped by resistors 48 and 49 and diode 50. Thus, there is obtained the characteristic represented by the polygonal line in FIG. 1*c*. The engine rotational frequency detecting circuit 23 is constructed by the use of a monostable flip-flop circuit which is triggered with the aid of a breaker contact 52 for interrupting the primary current flowing through a firing coil 51, in order to reduce the pulsation of the output voltage and improve the response characteristic. The voltage at the connection point between the firing coil 51 and the breaker contact 52 builds up when the contact 52 is in the open state. This voltage is differentiated by a capacitor 53 and resistor 54 and then imparted to the base electrode of a transistor 56 of the monostable flip-flop circuit through a diode 55. Further, this voltage is imparted to the base electrode of a transistor 58 through a resistor 57, thus establishing the conductive condition between the emitter-collector electrodes of the transistor 58. The collector electrode of the transistor 58 is connected with a conductor 60 through a resistor 59 and also grounded through a capacitor 61 and resistor 62. Thus, if the voltage which has been imparted to the base electrode of the transistor 58 becomes extinct due to the closure of the breaker contact 52, then the transistor 58 is rendered nonconductive so that the potential at the collector electrode thereof increases. This voltage variation is differentiated by a capacitor 61 and resistor 62, and then imparted to the base electrode of the aforementioned transistor 56 through a diode 63. The transistor 56 constitutes the monostable flip-flop circuit together with a transistor 64, resistors 65, 66 and 68 and capacitor 69. The transistor 56 is rendered nonconductive when the monostable flip-flop circuit is in the stable state, and it has its collector electrode connected with an integrating circuit constituted by a resistor 70 and capacitor 71. At this capacitor 71, there occurs a voltage of which the magnitude corresponds to the rotational frequency N of the engine. This voltage is applied to the base electrode of a transistor 72 to change the conductivity between the emitter and the collector electrodes thereof so that a voltage appearing at the connection point between resistors 73 and 74 connected in series with each other is varied in accordance with the rotational frequency N of the engine.

Series resistors **75** and **76** constitute a clamping circuit together with a diode **77**, which is adapted to clamp the maximum value of the voltage appearing at said connection point. The selector circuit **24** consists of a bistable flip-flop circuit constituted by transistors **78** and **79** and resistors **80, 81, 82** and **83**. The transistors **78** and **79** are connected in such a manner as to be controlled by the aforementioned timing contacts **26** and **27**. Those terminals of the contacts **26** and **27** which are opposite to the grounded ones are connected with the conductor **60** through resistors **84** and **85** respectively, and also with the base electrodes of transistors **88** and **89** through resistors **86** and **87** respectively. The transistors **88** and **89** have their emitter electrodes grounded and the collector electrodes thereof connected with the conductor **60** through resistors **90** and **91** and further with the base electrodes of the transistors **78** and **79** of the aforementioned bistable flip-flop circuit through resistors **101, 102** and diodes **103, 104** respectively. Thus, the transistors **78** and **79** are rendered conductive by the fact that their base electrodes are biased at a high voltage when one of the contacts **26** and **27** is closed so that one of the transistors **88** and **89** is rendered nonconductive. Description will now be made of the operational circuit **18**. The quantity of fuel to be supplied which depends upon the engine manifold negative pressure P and rotational frequency N differs between when the manifold negative pressure P is $P \geq P_0$ and when $P < P_0$. Therefore, the gradient of the characteristic is changed by changing the resistors **10, 11** to resistors **10', 11'** which are connected with input terminals **6** and **7** through switches SW2–1 and SW2–2 which are operated when the manifold negative pressure P is equal to P_0. The state shown in the drawing corresponds to that in which the manifold negative pressure P is $P \geq P_0$. The values of the resistors **10** and **11** are selected to be lower than those of the resistors **10'** and **11'**, and the gradient of the characteristic is so set up that variations in the current flowing in the input terminal **3** become greater as compared with those in the manifold negative pressure, as shown in FIG. 5*a*. By changing the values of the resistors, the gradient of the characteristic is changed as described above, but the absolute value is also varied at the same time. If it is left as it is, the quantity of injected fuel in terms of the manifold negative pressure P is changed in a jumping manner when $P = P_0$. Such phenomenon is undesirable. Therefore, the design is made such that this jumping phenomenon is prevented by switching from a resistor **108** to a resistor **108'** a bias current flowing in the input terminal **3** through a switch SW2–3 from an input terminal **107** to which is applied a fixed bias voltage available from the connection point between the series resistors **105** and **106** as input. The output terminal **17** of the operational circuit **18** is coupled to the base electrode of a transistor **110** through a resistor **109**. The transistor **110** which is adapted to serve as amplifier has its collector electrode connected with the conductor **60** through a resistor **111** and its emitter electrode connected with the base electrode of a transistor **113** for driving an electromagnetic valve. The collector electrode of the transistor **112** is connected with the conductor **60** through electromagnetic coils **113** and **114**, and the emitter electrode thereof is grounded. On the other hand, the output terminal **17** is connected with the base electrode of a transistor **116** through a resistor **115**. This transistor **116** which is also adapted to serve as amplifier has its collector electrode connected with the conductor **60** through a resistor **117** and its emitter electrode connected with the base electrode of a transistor for driving an electromagnetic valve. The collector electrode of the transistor **118** is connected with the conductor **60** through electromagnetic coils **119** and **120**, and the emitter electrode thereof is grounded. Further, the base electrodes of the two amplifier transistors **110** and **116** are connected with the collector electrodes of the transistors **78** and **79** of the aforementioned discriminator circuit **24** through diodes **121** and **122** respectively. SW1 is a power source switch connected between the conductor **60** and a battery **123**.

Next, the operation of the present system will be fully described. First of all, by closing the power source switch SW1, the voltage of the battery is applied to the entire circuit arrangement so that the latter is brought into the active state. In the operational circuit, when the voltage at the power source terminal **5** builds up, the preparation current I_r is caused to flow in the input terminal **3** through the capacitor **14** and resistor **15** to render the transistor **1** conductive so that no output voltage appears at the output terminal **17**. Thus, none of the transistors **110** and **116** can be rendered conductive, and therefore the electromagnetic valves remain closed. At the same time, signal voltages corresponding to the engine manifold negative pressure P, rotational frequency N and temperature T and imparted to the input terminals **6, 7** and **8** respectively, so that currents corresponding to these voltages are supplied to the input terminal **3**. When the engine is started, either one of the timing contacts **26** and **27** is made at a point of time when it is desired that the fuel injection be initiated. In case the timing contact **26** is made for example, the bias current which has been flowing from the conductor **60** to the transistor **32** through the resistors **28** and **29** is now caused to flow to the ground through the diode **30** and timing contact **26**, so that the transistor **32** is rendered nonconductive. As a result, the potential at the collector electrode of the transistor **32** increases to render the transistor **39** conductive so that the electric charges which have been stored at the capacitor **40** are discharged to the input terminal **16** of the operational circuit **18**. The polarity of the current resulting from this discharge is negative, and therefore the current I_{in} flowing in the input terminal **3** is reduced so that the transistor **1** is rendered nonconductive and the tunnel diode **2** is shifted to the characteristic region below the maximum value I_m. When the transistor **1** is rendered nonconductive, the potential at the collector electrode thereof increases, with the result that an output voltage appears at the output terminal **17**. Such state corresponds to that in which the timing contact **26** is closed. When this timing contact **26** is closed, the transistor **88** is rendered nonconductive, so that the potential at the collector electrode thereof increases, with the result that the potential at the base electrode of the transistor **79** incorporated in the selector circuit **24** is increased so that the transistor **79** is rendered conductive. Thus, the amplifier transistor **116** provided in the switching circuit **25** has its base electrode grounded through the diode **122**. At this point, the transistor **78** which constitutes the bistable flip-flop circuit together with the transistor **79** is in the nonconducting state, and the amplifier transistor **110** is rendered conductive with an output voltage appearing at the output terminal **17** of the operational circuit **18**. Further, the transistor **112** is also rendered conductive to flow a current through the electromagnetic coils **113** and **114** so that the valve is opened to make the fuel injection possible. Simultaneously, the transistor **32** is rendered nonconductive with the result that the potential at the collector electrode thereof increases so that the capacitor **35** begins to be charged so that the terminal voltage thereof is increased to shift the transistor **36** from the nonconducting state to the conducting state. Thus, the potential at the emitter electrode of the transistor **36** is gradually increased in accordance with a lapse of time. This time-lapse signal voltage is imparted to the input terminal **9**, resulting in a current which flows to the input terminal **3** through the resistor **13**. In case the current I_{in} which is a combination of the signal current corresponding to the various conditions of the engine and the time-lapse signal current is lower than the maximum value I_m of the tunnel diode **2**, then all the input currents I_{in} are made to flow to the ground through the tunnel diode **2**, and thus in this region the transistor **1** is maintained in the nonconducting state so that the fuel injection is continued. However, if the input current I_{in} exceeds the maximum value I_m of the tunnel diode **2**, then the latter is brought into the negative region so that the internal impedance thereof increases to increase the terminal voltage. As a result, the potential at the base electrode of the transistor **1** is increased so that the conductive condition is established between the emitter and the collector electrodes thereof. At this point, the output voltage at the output terminal **17** becomes extinct. Thus, the transistors **110** and **112** are rendered nonconductive so that the currents flowing through the electromagnetic coils **113** and **114** are interrupted. Consequently, the valve is closed to interrupt the fuel injection. The time t in which the fuel injection is ended corresponds to that in which the input current I_{in} reaches the maximum value I_m of the tunnel diode **2**. It depends upon the signal current which varies depending upon the various conditions of the engine. In this way, the quantity of injected fuel turns out to be a proper one which meets the various conditions of the engine.

When the crank shaft of the engine is rotated to a certain degree, the timing contact **26** is broken and subsequently the other timing contact **27** is made. Thus, the fuel-injecting operation is performed in a manner similar to that described above. In this case, the transistor **78** of the selector circuit **24** is rendered nonconductive while the transistor **79** is made conductive, so that the electromagnetic coils **119** and **120** are energized to open the valve.

In the foregoing embodiment, use was made of NPN-transistors, but it will be readily apparent to those skilled in the art that it is also possible to use PNP-transistors.

Description will now be made of the case where use is made of an operational amplifier, with reference to FIGS. **6a** and **6b**. This operational amplifier is of the ordinary type, and therefore detailed description thereof will be omitted. Applied to the signal input terminals are signal voltages which are obtained in accordance with the various conditions of the engine, and they are so set up as to decrease with increases in the rotational frequency N of the engine, the manifold negative pressure P and the temperature T. Further, the sawtooth wave voltage applied to the time-lapse signal input terminal **9** is one which rapidly drops to a negative voltage of a high magnitude upon the initiation of the input and thereafter gradually changes toward zero. Numeral **123** represents an operational amplifier, and **124** resistor.

In the aforementioned setup, normally the transistor **1** is rendered conductive with an input signal voltage which is obtained depending upon the various conditions so that no output voltage is available at the output terminal **17**. However, if a negative voltage of a high magnitude is imparted to the time signal input terminal **39** at a point of time t_0 when it is desired that the fuel injection be started, then the summed value becomes lower than the barrier voltage of the transistor **1** so that the latter is rendered nonconductive with the result that an output voltage appears at the output terminal **17**. On the other hand, if the summed value becomes higher than the barrier voltage of the transistor **1** as a result of the gradual decrease of the time-lapse signal voltage, the transistor **1** is then rendered conductive so that the output voltage at the output terminal **17** becomes extinct. The time is changed like t_1, t_2, t_3 depending upon the magnitude of the input signal voltage corresponding to the various conditions, and thus the quantity of fuel to be supplied can be controlled as in the aforementioned embodiment.

We claim:

1. A fuel injection controlling system for internal combustion engines having a fuel control apparatus including an electromagnetic valve for controlling the amount of fuel delivered by the fuel supply for the engine comprising:
   - first means for generating a plurality of signal currents each being independent from one another having a magnitude corresponding to a respective condition from which the quantity of fuel to be supplied to said engine is determined;
   - second means for producing an output signal corresponding to an algebraic summation of the magnitudes of said independent signal currents; and
   - third means responsive to said output signal produced by said second means for controlling the opening duration of said electromagnetic valve, to thereby feed the proper quantity of fuel to said engine.

2. A fuel injection controlling system according to claim **1**, wherein said first means includes a first circuit means for producing independent condition signal currents corresponding to the respective conditions of the engine operation, a second circuit means for independently producing a timing signal current which varies with a lapse of time from the starting point of fuel injection and a third circuit means for resetting the value of said timing signal current to a predetermined level at each starting point of the fuel injection and said second means includes an input terminal with a low input impedance for simultaneously receiving said independent signal currents, and an output terminal for producing said output signal corresponding to said algebraic summation, and wherein said third means includes a discriminator means for comparing the output signal produced by said second means with a predetermined discriminating level and for closing said electromagnetic valve at a desired time after the initiation of fuel injection, when said output signal produced by said second means reaches said predetermined level.

3. A fuel injection controlling system according to claim **2**, wherein each of said first circuit means and said second circuit means includes a circuit having an output terminal for producing a voltage corresponding to the relevant condition and a resistor connected between said output terminal of said circuit and said input terminal of said second means, said resistor having a relatively high resistance higher than said input impedance of said second means.

4. A fuel injection controlling system according to claim **3**, further including means for changing the resistance values of said resistors in response to a predetermined value of the negative pressure in the manifold of the engine.

5. A fuel injection controlling system according to claim **4**, further including a correction means for correcting for a discontinuity in an input signal when said resistance values are changed.

6. A fuel injection controlling system according to claim **2**, wherein said discriminator means comprises a transistor, the input terminals of which are constituted by the base-emitter electrodes thereof, and a tunnel diode connected between the base-emitter electrodes of said transistor in the same polarity therewith, whereby the transistor of said discriminator means which is normally in its conducting state is rendered nonconductive at the beginning of the fuel injection and is rendered conductive when an input current reaches said predetermined level.

7. A fuel injection system according to claim **6**, wherein the input terminals of said discriminator means are connected with the power source for said system through a capacitor so that a preparation current is supplied therethrough whereby said transistor in said discriminator means becomes conductive when said power source voltage is imparted thereto.

8. A fuel injection system according to claim **2**, wherein said second means comprises an operation amplifier connected in series with said third means.

9. A fuel injection system according to claim **8**, further including respective resistors for supplying said independent condition signals produced from said first means to said operational amplifier.

10. A fuel injection controlling system according to claim **1**, wherein said first means comprises a negative pressure detector, an engine temperature detector, and a circuit for detecting the rotational frequency of said engine, each detector circuit producing an independent signal corresponding to a separate engine parameter.

11. A fuel injection controlling system according to claim **10**, wherein said engine temperature detector comprises a thermistor-resistor series circuit the output of which is connected to a nonlinear clamping circuit whose output is, in turn, fed to said second means, whereby a signal representative of a nonlinear temperature sensitive characteristic is provided by said first means.

12. A fuel injection controlling system according to claim **11**, wherein said rotational frequency detector comprises a monostable multivibrator responsive to the interruption of pri-

mary current flowing through a firing circuit, an integrating circuit connected in series with said monostable multivibrator and a clamping circuit connected in series with said integrating circuit, whereby a signal representative of the rotational speed of said engine will be delivered to said second means.

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