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[54] **FUEL INJECTION SYSTEM CONTROLLED BY THE AMOUNT OF AIR DRAWN IN DURING THE SUCTION STROKE**

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[52] **U.S. Cl.**.. **123/32 EA**, 123/119 R, 123/139 AW

[51] **Int. Cl.**........................ **F02m 51/00**, F02d 5/02

[58] **Field of Search**.................... 123/32 EA, 119 R, 123/139 AW

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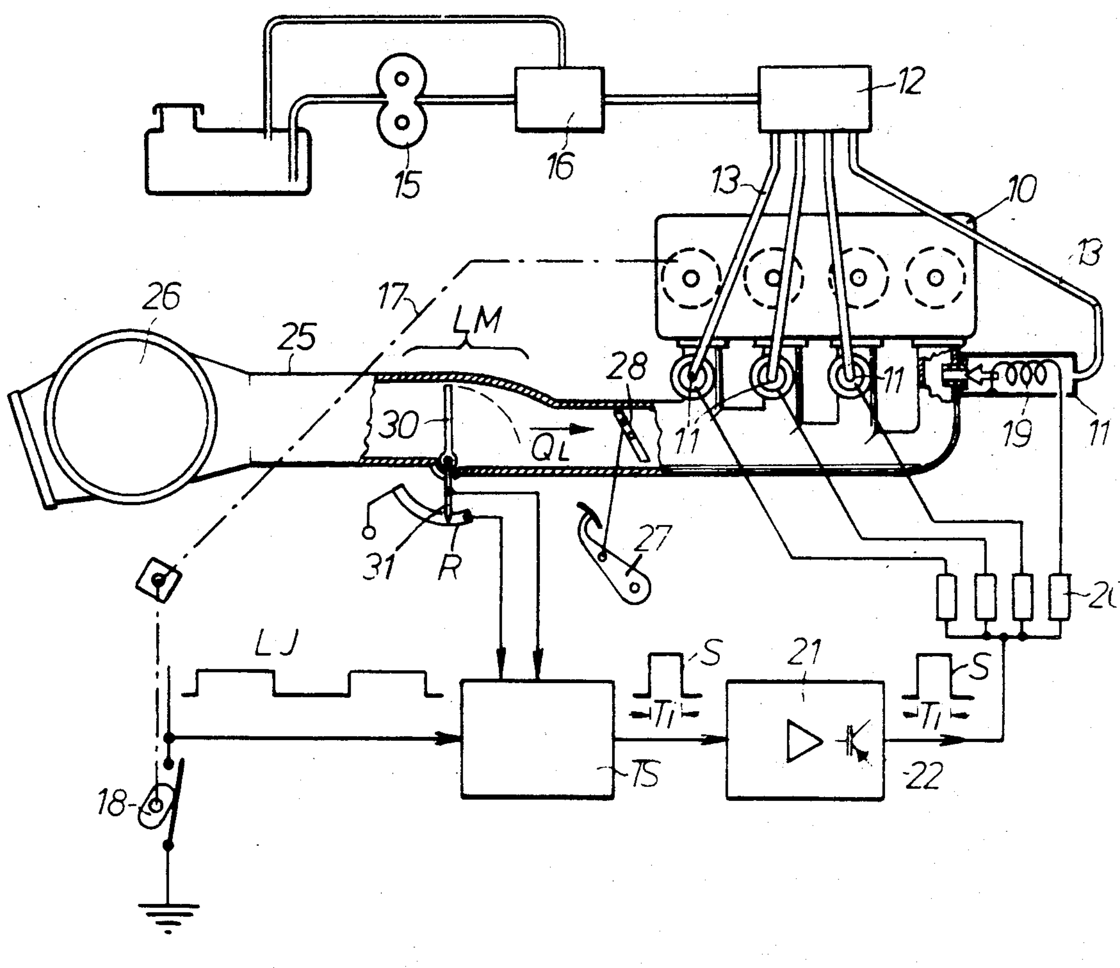
[57] **ABSTRACT**

The position of a static plate used to measure the amount of air sucked through the intake manifold controls the wiper of a potentiometer that is connected to control either the rate of charging or of discharging of a capacitor that is charged in synchronism with the rotation of the engine crank shaft. The length of time that the capacitor or inductor takes to discharge determines the length of time that the fuel injection valve is open.

24 Claims, 15 Drawing Figures



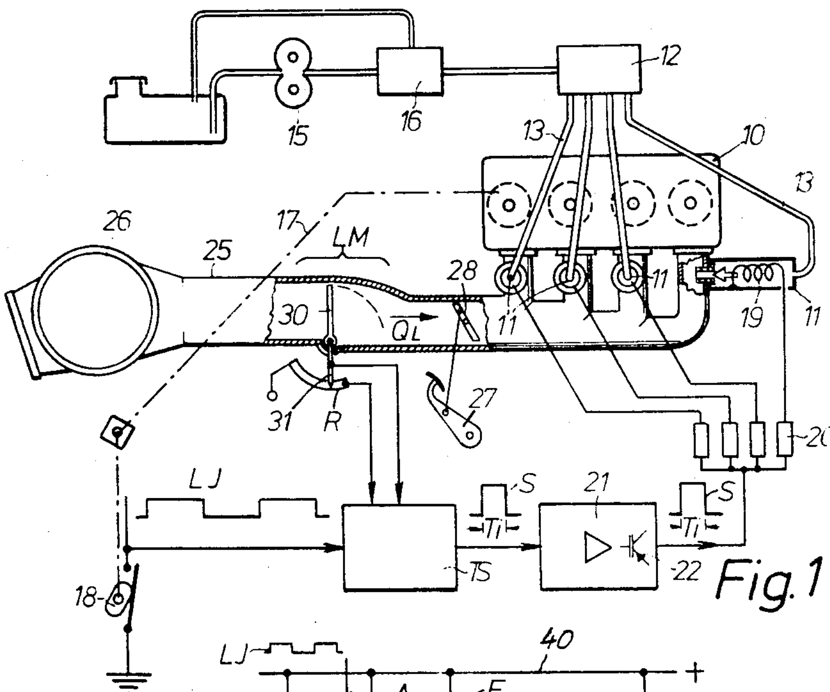


Fig.1

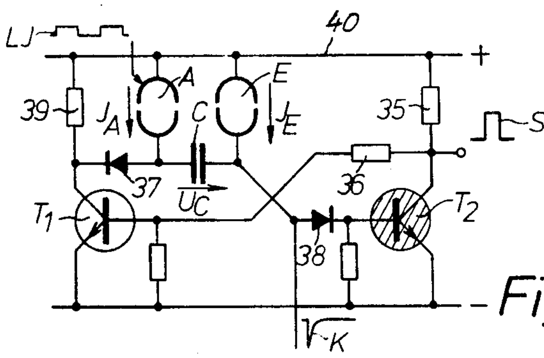


Fig.2

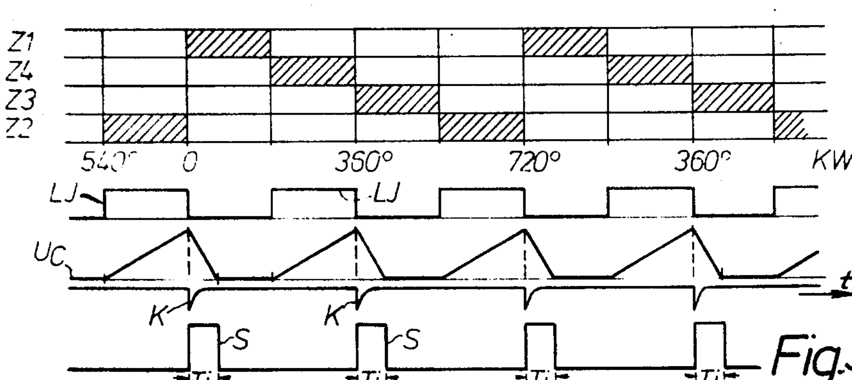


Fig.3

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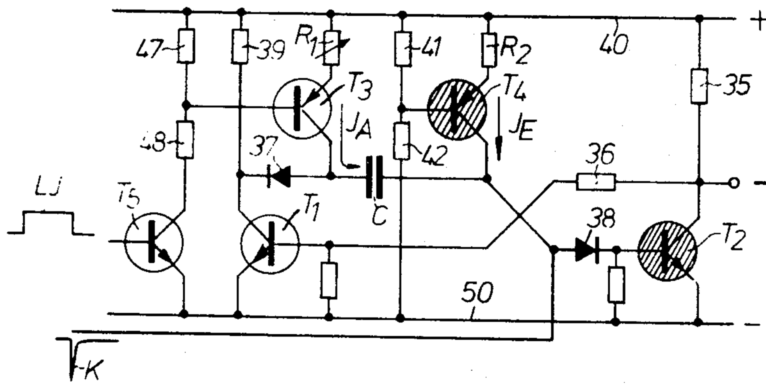

Fig. 4

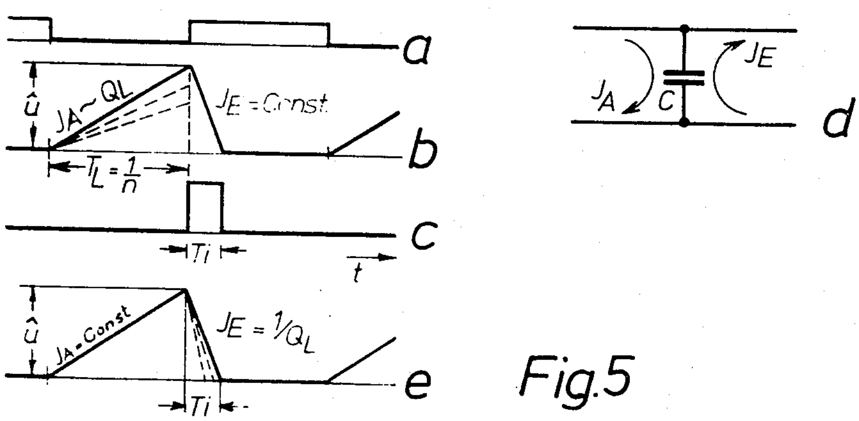

Fig.5

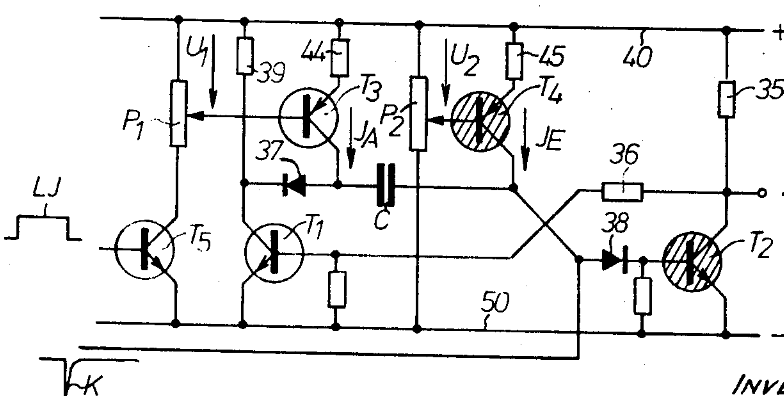

Fig.6

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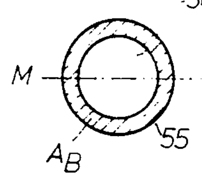

Fig. 7a

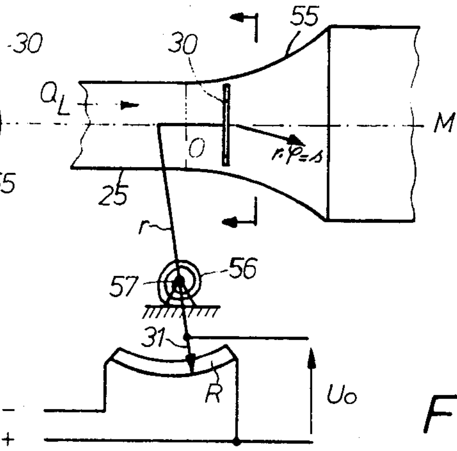

Fig. 7

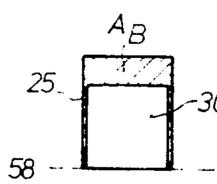

Fig. 8a

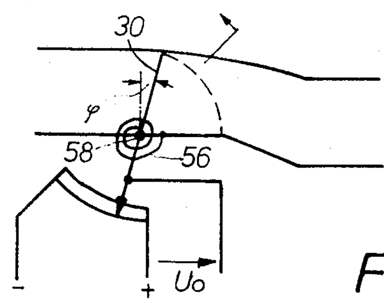

Fig. 8

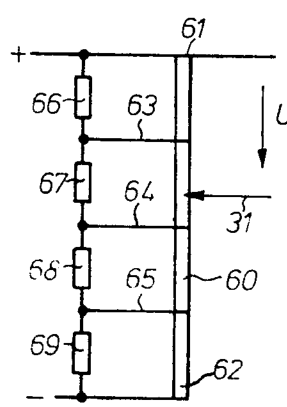

Fig. 9

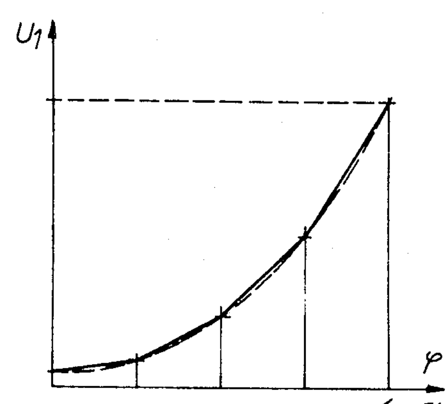

Fig. 10

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FUEL INJECTION SYSTEM CONTROLLED BY THE AMOUNT OF AIR DRAWN IN DURING THE SUCTION STROKE

BACKGROUND OF THE INVENTION

The invention relates to an electrically controlled, intermittently operating, fuel injection arrangement for internal combustion engines having an electromagnetic fuel spray valve for each cylinder of the engine. A power output transistor is connected in series with the solenoid that operates the fuel injection valves, a transistor switch being connected to the input of the output transistor and operated in synchronism with the rotation of the engine crank shaft so that the transistor switch is triggered for a period of time that occurs simultaneously with the opening of a fuel injection valve and which determines how long the valve is kept open, the period of time being determined by the discharge time of a capacitor or inductor that is previously stored with energy at a predetermined rate.

An important advantage of electrically controlled fuel injection arrangements of this kind is that the quantity of fuel injected into a cylinder can be very exactly suited to the amount of air supplied to the cylinder during the suction stroke and that, consequently, with efficient operation of the engine, the timing can be set so that the exhaust contains a minimum amount of harmful components.

With fuel injection arrangements of the prior art, the quantity of air that is sucked in is not directly measured, but is instead obtained by an inductive pressure sensor, which is positioned downstream of the throttle valve in the intake manifold to measure the pressure there. The inductance of an iron core solenoid connected to the sensor varies in accordance with the pressure changes and determines the period of time that a multivibrator remains in the unstable state, which latter is triggered in synchronism with the rotation of the engine crank shaft. Because of the largely speed dependent flow resistance, the amount of fuel, which is controlled by the sensor and which is injected before the working stroke, must be modified in dependence on the engine speed, for which purpose these known fuel injection arrangements incorporate relatively costly electronic circuits.

SUMMARY OF THE INVENTION

An object of the invention is an appreciably simpler electronic control of the length of the fuel injection valve opening pulse in a fuel injection arrangement of the kind described in the first paragraph of the preceding section.

The invention consists essentially of electric storage means, electric circuit means connected to the electric storage means and having a first state during which electric energy is added to the electric storage means and a second state during which electric energy is removed from the electric storage means, and a fuel injection valve is opened for the period of time required to remove electric energy from the electric storage means, this period of time being dependent on the amount of energy stored and on the rate at which this energy is removed, air meter means associated with the intake manifold of the engine for providing a quantity representative of the time average of the amount of air sucked through the engine intake manifold, and wherein the electric circuit means includes transducer

means for making, in dependence on this quantity, an electric parameter of the electric storage means proportional to the amount of air drawn in during each suction stroke of the engine, so that this period of time is proportional to the amount of air drawn in during each suction stroke.

In the region between idling and maximum engine speed and load the air supplied to the cylinder varies approximately in the ratio of 1 : 40. Since it would be difficult to obtain so large a range with an electric storage means that varied in accordance with this ratio, the arrangement of the invention, which directly converts a signal corresponding to the time average of the amount of air drawn through the intake manifold into an electric parameter of the storage means that varies in proportion with the amount of air sucked in during each intake stroke, offers an appreciably better accuracy.

The novel features which are considered as characteristic for the invention are set forth in particular in the appended claims. The invention itself, however, both as to its construction and its method of operation, together with additional objects and advantages thereof, will be best understood from the following description of specific embodiments when read in connection with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** schematically shows the fuel injection arrangement of the invention;

FIG. **2** is a circuit diagram showing the principles of the invention;

FIG. **3** shows the plot of various voltages against time that occur at different points in the circuit shown in FIG. **2**;

FIG. **4** is a circuit diagram of a form of the invention based upon the circuit of FIG. **2**;

FIGS. *5a–d* show the plot of various voltages against time during the charging and discharging cycles of the circuit shown in FIG. **4**;

FIG. **6** is a circuit diagram of another form of the invention based upon the circuit shown in FIG. **2**;

FIGS. **7**, **7*a***, **8**, and **8*a*** show two different embodiments of the static plate that can be used with the fuel injection arrangement of the invention;

FIG. **9** shows the exponential potentiometer that can be used with the invention; and

FIG. **10** shows the exponential change in voltage obtained with the potentiometer shown in FIG. **9**.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. **1**, the illustrated fuel injection arrangement of the invention is intended for a four cylinder, four stroke, internal combustion engine **10**. The arrangement essentially comprises four electromagnetic fuel injection spray valves **11** that are connected by respective fuel conveying pipes **13** to a distributor **12**, and an electric motor driven fuel pump **15**, a pressure regulator **16** that keeps the fuel at a constant pressure, and an electronic control (to be described) that a triggering means or signal generator **18**, which is coupled to the engine cam shaft rotating synchronously with the crank shaft, operates twice during each complete rotation of the crank shaft to produce one rectangular valve opening pulse S. These pulses cause the valves **11** to open. The period T_i of the pulse S determines the open time of the valve 11 and therefore the amount of fuel that is forced out of a valve at a nearly constant pressure of 2 atmospheres. The magnet coils 19 of the fuel injection spray valves 11 are connected in series with respective decoupling resistors 20, which latter are connected in common to the output of an amplification and power output stage 21. The stage 21 contains at least one power transistor 22, the emitter collector path of this transistor being connected in series with the decoupling resistors 20 and the magnet coils 19, which latter are connected at one end to ground.

With external auto ignition gasoline engines of the kind illustrated the amount of air sucked into a cylinder during a single suction stroke determines the amount of fuel that can be completely burned during the following power stroke. If the engine is to be used efficiently, little air should remain after the power stroke. In order to obtain the desired stoichiometric ratio between air and fuel, there is provided in the intake manifold, between the filter 26 and the throttle valve 28, an air meter LM, which essentially comprises a static plate 30 and an adjustable resistor R of which the movable tap 31 is coupled to the static plate, these components together constituting adjusting means. The position of the throttle valve is controlled by an accelerator 27. The air meter LM operates in conjunction with a transistor switch TS, the output of which delivers the control pulse S for the output stage 21.

As shown in FIG. 2, the transistor switch TS includes two feedback, cross-coupled, alternately conducting, transistors, namely an input transistor T_1 and an output transistor T_2, constituting an electronic switch as well as an energy store, which in the embodiment illustrated is a timing capacitance means in the form of a single capacitor C, but in a variation of the invention can also be an inductance. The length of time required to discharge the timing capacitance means C determines the open time T_i of the valves 11. Before each discharge, the capacitor C must be charged at a definite rate.

In order to insure that the capacitor discharge time is based upon required information as to the amount of air drawn in during each suction stroke, the charging time is controlled by the signal generator 18, which acts as a switch that is operated in synchronism with the rotation of the engine crank shaft and connects, during a charging pulse LJ that occurs during a predetermined and constant angle of the rotation of the crank shaft, the capacitor C to a source of current that delivers a charging current J_A during each charging pulse. In FIG. 3 it is assumed that the signal generator 18, which in practice can be a bistable multivibrator operated by ignition pulses (not shown) to be triggered from one state to the other, is closed during 180° of rotation of the crank shaft and is open during the other 180° of the crank shaft rotation.

In FIG. 3 the individual suction strokes of the internal combustion engine are indicated by the shaded rectangles. It is also assumed that the capacitor C is charged during the suction strokes for the second cylinder Z_2 and the fourth cylinder Z_4. With the further assumption that the charging current J_A is held constant during the charging of the capacitor C, the voltage U_C across the capacitor C increases linearly with time, as shown in FIG. 3.

By cutting off the previously conductive transistor T_2 with a triggering pulse derived from the charging pulses LJ, the circuit of FIG. 2 begins to discharge the capacitor C immediately after it has been charged, the charging cycle ending at 0°, 360°, 720°, and so forth of crank shaft rotation. At the same time, the previously cut off input transistor T_1 is rendered conductive, since, because the output transistor T_2 is no longer conductive, a sufficient base current can flow through the collector resistor 35 and the coupling resistor 36 to the base emitter path of the input transistor. The charge stored in the capacitor C can flow through the diode 37, which is conductive in this direction, and the collector emitter path of the output transistor T_1, the discharge current J_E being held constant by a means E shown symbolically in FIG. 2. During the discharge cycle the voltage U_C across the capacitor C falls linearly. By the end of the period T_i the voltage on the right hand plate of the capacitor C has fallen sufficiently so that the output transistor T_2 again conducts, thereby shutting off the input transistor T_1. Since the diode 37 prevents a charging current from flowing to the capacitor C when the input transistor T_1 is non-conductive, the next charging cycle begins only when the next charging pulse LJ connects the charging source A to the capacitor C.

Of the various practicable embodiments that can be based upon the arrangement schematically shown in FIG. 2, FIG. 4 shows a particularly simple form of the invention that can be used in two different ways, in the first of which the capacitor C is charged with a charging current J_A that is proportional to the time average of the amount of air Q_L, whereas discharging occurs at a constant discharge current J_E.

To obtain a constant discharge current that is independent of operating conditions of the engine there is provided a second constant current source means comprising a continuously conductive transistor T_4 of which the emitter is connected by a fixed resistor R_2 with the positive rail 40, the base being connected to a fixed voltage divider composed of the resistors 41 and 42 so that the transistor operates as an emitter follower. The collector of the discharge transistor T_4 is connected to the right plate of the capacitor C and to the anode of the diode 38, which latter provides a conductive path for the base current of the transistor T_2.

The charging current source A in FIG. 2 is constituted, in FIG. 4, by a first constant current source means comprising a charging transistor T_3 of which the base is connected to the tap between two series-connected resistors 47 and 48. In the claims the first and second constant current means shown are broadly referred to as first means and as second means. These two resistors are connected in the collector circuit of a switching transistor T_5, which is conductive only when the signal generator 18 delivers a charging pulse LJ to the base of the transistor T_5, whereby the charging transistor T_3 is also rendered conductive. This transistor is non-conductive during the interval between two charging pulses. An adjustable resistor R_1, which in design is similar to the resistor R shown in FIG. 1, is provided in the emitter circuit of the charging transistor T_3, so that the charging current J_A can be varied in proportion to the amount of air Q_L drawn in during each suction stroke. The necessary proportionality between the charging current J_A and the amount of air Q_L can be obtained, for example, by suitable mechanical design of the resistor R_1, the resistor being manufactured as a thin or thick film resistor on a ceramic base.

In FIG. 5, the curve b shows the variation with time of the voltage U_C across the capacitor C. During the charging time T_L, which is proportional to the reciprocal of the engine r.p.m. n, the voltage across the capacitor reaches a peak value $\hat{u}$ that is expressed by the following relationship:

$$\hat{u} = J_A T_L / C = k(Q_L/n) = k' q_L, \tag{1}$$

where q_L is the volume of air sucked into an individual cylinder during an intake stroke. The peak value $\hat{u}$ thus corresponds to the individual suction stroke or to the amount of air q_L equals Q_L/n drawn into a cylinder.

During discharge the following relationship holds true:

$$\hat{u} = J_E T_i / C . \tag{2}$$

From the equations (1) and (2) there is obtained the following relationship between the period T_i of the opening pulses S and the amount of air q_L supplied to each cylinder:

$$T_i = (J_A/J_E)\ T_L = k''\ Q_L/n = k'' q_L. \tag{3}$$

From equation (3) it is apparent that any changes in the value of the capacitor C cannot effect the accuracy with which the correct amount of the fuel is supplied to a cylinder.

In a second variation of the circuit shown in FIG. 4, the capacitor C can be charged with a current J_A that is constant irrespective of the operating conditions of the engine, whereas the discharge current J_E is proportional to the reciprocal of the time average of the amount of air Q_L that is sucked in. To make the discharge current J_E proportional, the fixed resistor R_2 connected to the emitter of transistor T_4 (see FIG. 4) is replaced by the adjustable resistor R (see FIG. 1). FIG. 5e shows the variation of the voltage with time across the capacitor C The following relationships hold true.

During charging:

$$\hat{u} = J_A T_L / C = k\ (1/n) \tag{4}$$

During discharging:

$$\hat{u} = J_E T_i / C = k_2\ (T_i / C Q_L)\ , \tag{5}$$

where J_E is $\approx 1/Q_L$.

From the equations (4) and (5) is obtained the following expression for the pulse length T_i :

$$T_i = (J_A/J_E)\ T_L = k_3\ (Q_L/n) = k_4 q_L\ . \tag{6}$$

Inasmuch as the discharge current J_E is proportional to the reciprocal of the amount of air Q_L, this second variation of the circuit shown in FIG. 4 has the advantage that any changes (such as a sudden opening of the throttle valve **28**) in the amount of air sucked in occurring while the capacitor C is discharging immediately affects the discharge rate of the latter, so that the period T_i is changed, thereby altering the amount of fuel injected. Consequently, the amount of fuel injected is virtually instantaneously adapted to the amount of air sucked in.

The two variations of the embodiment shown in FIG. 4 alter the rate at which the capacitor C charges or discharges in dependence on the adjustment of a resistor. In the embodiment shown in FIG. **6**, the charging or discharging rate of the capacitor is varied by a voltage u_x; the resistor R, which is coupled to the static plate **30**, is used as a potentiometer.

In FIGS. **4** and **6**, the reference numerals are the same for all parts having the same function in both embodiments. Respective fixed resistors **44** and **45** connect the emitters of the transistors T_3 and T_4 to the positive rail **40.** Both transistors are connected as emitter-followers and can be used in either of two different ways, as in the embodiment shown in FIG. **4.** In the first variation, a constant discharge current J_E is obtained by connecting the base of the discharge transistor T_4 to the tap of a bias-adjustment means in the form of a potentiometer P_2, which latter is connected between the positive rail **40** and the negative rail **50.** This potentiometer supplies a constant bias voltage U_2 for the base of the discharge transistor and insures that the latter conducts a constant discharge current J_E. On the other hand, the charging transistor T_3 must conduct a charging current J_A that is proportional to the time average of the amount of air Q_L that is sucked in, the position of the static plate **30** being indicative of this amount. To this end, the bias voltage U_1 at the base of the charging transistor is varied in dependence on the position of the static plate, the bias adjustment potentiometer P_1 in FIG. **6** being equivalent to the adjustable resistor R in FIG. **1.** The potentiometer P_1 is connected between the positive rail **40** and the collector of the switching transistor T_5, the variable tap (**31** in FIG. **1**) of the potentiometer being connected directly to the base of the transistor T_3. The operation of this form of the embodiment shown in FIG. **6** corresponds to that of the first variation of the embodiment shown in FIG. **4**, and has the advantage that it is easier (than with the circuit shown in FIG. **4**) to make the change in the bias voltage U_1 linear with respect to changes in the amount of the air Q_L. There will be described several ways in which the desired change in voltage can be obtained. During the charging pulse LJ, the capacitor C is charged to a peak value $\hat{u}$ by a charging current J_A that is proportional to the amount of air Q_L; at the end of each pulse LJ the capacitor C is discharged with a constant current J_E, there being obtained the linearity between the open period T_i and the quantity q_L ($q_L = Q_L/n$) for each suction stroke. In the embodiment of FIG. **6**, the illustrated components, excluding switch T_2 and its associated biasing resistors, constitute timing means for determining the length of time switch T_2 remains in the non-conductive state. Charging-discharging means in this embodiment are comprised at the components shown in FIG. **6**, excluding capacitance means C and switch T_2 with its associated biasing resistors.

In the other variation of this embodiment, the capacitor C is charged by a constant charging current J_A, whereas it is discharged by a discharging current J_E that is suited to the amount of air sucked in. To this end, the resistor R, which is coupled to the static plate **30**, is substituted for the potentiometer P_2 in the base circuit of the discharge transistor T_4, the variable tap **31** being connected to the base of this transistor. The potentiometer P_1 is adjusted to obtain the desired value for the charging current J_A and is then left unchanged.

The manner of operation of this second variation of the embodiment shown in FIG. **6** makes it essential that the change in the bias voltage U_2 at the base of the discharge transistor T_4 is proportional to the reciprocal of the time average of the amount Q_L of the air as indicated by the position of the static plate **30**. As is the case with the embodiment shown in FIG. **4**, the second variation has the great advantage that any changes in the amount of air sucked in during a pulse LJ immediately changes the amount of fuel injected.

FIGS. **1, 7,** and **8** illustrate particularly advantageous shapes of the intake manifold **25** in the vicinity of the static plate **30**. The contour of the intake manifold in that part **55** where the static plate is free to move is such that the area A_B not closed by the static plate changes exponentially with the movement s (shown as the symbol S in FIG. 7) ($s = r\phi$) of the static plate in accordance with the equation:

$$A_B = ke^{as},$$

where k and a are constant. The area A_B is shown shaded in FIGS. **7**a and **8**a.

For an air meter of the illustrated kind, using a static plate, the area A_B is given with sufficient accuracy by the following equation:

$$A_B = b\,Q_L / \sqrt{F},$$

where A_B is the area not covered by the static plate, Q_L is the amount of air sucked in per unit of time, b is a constant, and F is the elastic force of the spring that, in the embodiments shown in FIGS. **7** and **8**, can be in the form of a spiral return spring **56**. Since for all practical purposes this elastic force is nearly constant throughout the range of movement of the static plate, the indicated time average of the amount of air is

$$Q_L = ke^{as}$$

The expotential shape of the intake manifold in the vicinity of the static plate has the great advantage that the relative error

$$(\Delta Q_L / Q_L)$$

remains constant over the entire range of movement of the static plate. This is an important advantage when it is remembered that the errors $\Delta\phi$ or Δs, caused by mechanical factors, cannot be avoided. However, it is exactly when the engine is idling — in other words, when small amounts of air are being sucked in — that high accuracy is necessary to avoid harmful exhaust.

In a particularly advantageous arrangement, the static plate is constructed as a pivotal flap of which the axis of pivot is preferably vertical. In this case, the static plate can be coupled in a very simple manner to the movable tap of the adjustable resistor.

In the embodiment shown in FIG. **7**, the static plate **30** is connected to a relatively long lever which is spaced a distance r from the pivot point **57**, the path s thus being equal to $r\phi$. In this form, the circular static plate **30** is positioned at least approximately centrally in the intake manifold **25** and in the area **55** of the walls of the intake manifold. These walls **55** are rotationally symmetrical about the central axis M.

In the embodiment shown in FIG. **8**, the intake manifold is rectangular in cross-section, the static plate **30** being approximately square. The pivot axis, as in the embodiment shown in FIG. **1**, extends horizontally along the lower wall of the intake manifold.

As in that form of the embodiment of FIG. **6** in which the bias voltage controls the rate at which the capacitor C is charged, the bias voltage U_1 at the base of the charging transistor T_3 must be proportional to the amount of air as measured by the air meter. With the previously described preferred construction, in which the walls of the intake manifold have an exponential shape, it is essential that the voltage U_1 must vary exponentially with the angle of rotation ϕ. Since it is difficult to mass-produce a potentiometer with an expotential taper with sufficient accuracy, a potentiometer **60** with a linear taper can be used, as shown in FIG. **9**, the potentiometer being easily manufactured with thick film techniques on a ceramic base. Between the end taps **61** and **62** the potentiometer incorporates a number of at least approximately uniformly spaced taps along the path over which the movable tap **31** slides. In the embodiment shown in FIG. **9**, there are three such intermediate taps **63, 64,** and **65.** Connected in parallel with the linear potentiometer **60** are four fixed resistors **66, 67, 68,** and **69.** The ratios between these resistors are so chosen that the voltage increases exponentially from the first tap **61** to the last tap **62.** The absolute values of the resistors are so chosen that the value of each resistor is small compared to that of the parallel connected segment of the potentiometer **60.** Consequently, the voltages at the taps **63, 64,** and **65** are determined almost solely by the values of the resistors **66, 67, 68,** and **69.** In FIG. **10**, the change in the voltage U_1 is plotted against the pivot angle ϕ. Since the actual change in the voltage U_1 (shown by the solid line) follows very closely the exponential curve (shown by the dashed line), it is apparent that only three intermediate taps are sufficient to obtain a nearly perfect exponential voltage curve.

It will be understood that each of the elements described above, or two or more together, may also find a useful application in other types of fuel injection system controlled by the amount of air drawn in during the suction stroke, differing from the types described above.

While the invention has been illustrated and described as embodied in circuits, it is not intended to be limited to the details shown, since various modifications and structural changes may be made without departing in any way from the spirit of the present invention.

Without further analysis, the foregoing will so fully reveal the gist of the present invention that others can, by applying current knowledge readily adapt it for various applications without omitting features that, from the standpoint of prior art, fairly constitute essential characteristics of the generic or specific aspects of this invention and, therefore, such adaptations should and are intended to be comprehended within the meaning and range of equivalence of the following claims.

What is claimed as new and desired to be protected by Letters Patent is set forth in the appended claims.

We claim:

1. In a fuel injection system for an internal combustion engine having a crankshaft and an air inflow passage, the fuel-injection system being of the type including at least one electrically operated fuel-injection valve, an arrangement for generating electrical valve-opening pulses, comprising in combination an electronic switch having a conductive and a non-conductive state, and so connected to said valve as to not effect valve opening when in a first state and so as to effect valve opening when in a second state; triggering means connected to said switch for causing the same to undergo a transition to said second state when the engine crankshaft assumes a predetermined position; timing means for determining the length of time said switch remains in said second state and comprising energy-storing timing capacitance means and charging-discharging means connected to said capacitance means and including first means operative for effecting a first change of stored energy of said timing capacitance means when said switch is in said first state and second means operative for effecting an opposite second change of stored energy of said timing capacitance means when said switch is in said second state, with at least said second means being a constant current source means, and with at least one of said first and second means being an adjustable constant current source means, and with said charging-discharging means so connecting said timing capacitance means to said triggering means and to said switch as to cause said switch to return to said first state upon completion of said second change of stored energy; and adjusting means for automatically adjusting said adjustable constant current source means in dependence upon the flow rate of air flowing through said inflow passage.

2. An arrangement as defined in claim 1, wherein said charging-discharging means comprises means for causing said first means to effect said first energy change during a predetermined fraction of a crankshaft rotation.

3. An arrangement as defined in claim 1, wherein said charging-discharging means comprises means for causing said first means to effect said first energy change during a fixed fraction of a crankshaft rotation independently of engine speed.

4. An arrangement as defined in claim 1, wherein said adjustable constant current source means comprises an adjustable resistor, and wherein said adjusting means comprises an airflow sensing member mounted in said passage for displacement by the inflowing air to an extent indicative of the air inflow rate and operatively associated with said adjustable resistor for varying the resistance value of the latter.

5. An arrangement as defined in claim 4, wherein said adjustable resistor is connected in the current path of said capacitance means and conducts current flowing through said capacitance means during the respective one of said energy changes.

6. An arrangement as defined in claim 4, wherein said adjustable constant current source means comprises an emitter-follower transistor, and wherein said adjustable resistor is connected in the emitter branch of said emitter-follower transistor.

7. An arrangement as defined in claim 1, wherein said adjustable constant current source means comprises a transistor having a base and having a collector-emitter path connected to said capacitance means for carrying current flowing through said capacitance means during the respective energy change, and bias-adjustment means for varying the voltage at the base of said transistor, and wherein said adjusting means comprises an airflow sensing member mounted in said passage for displacement by the inflowing air to an extent indicative of the air inflow rate and operatively associated with said bias-adjustment means for automatically varying the voltage at the base of said transistor in dependence upon said air inflow rate.

8. An arrangement as defined in claim 7, wherein said bias-adjustment means comprises a potentiometer having a movable tap connected to said base of said transistor.

9. An arrangement as defined in claim 1, wherein said adjustable constant current source means is said first means, and wherein said adjusting means comprises means for automatically adjusting the current of said first means to a value proportional to said flow rate, and wherein the operation of said second constant current source means is independent of said flow rate.

10. An arrangement as defined in claim 1, wherein said capacitor is charged by said first means during said first energy change and is discharged by said second means during said second energy change, and wherein said adjusting means comprises means for automatically adjusting the charging current passing through said capacitance means in dependence upon said flow rate, and wherein the operation of said second means is independent of said flow rate so that the discharge current of said capacitance means is independent of said flow rate.

11. An arrangement as defined in claim 1, wherein said adjustable constant current source means is said second means, and wherein said adjusting means comprises means for automatically adjusting the current of said second means to a value inversely proportional to said flow rate, and wherein the operation of said first means is independent of said flow rate.

12. An arrangement as defined in claim 1, wherein said capacitance means is charged by said first means during said first energy change and is discharged by said second means during said second energy change, and wherein said adjusting means comprises means for automatically adjusting the discharging current flowing through said capacitance means to a value inversely proportional to said flow rate, and wherein the operation of said first means is independent of said flow rate so that the discharge current of said capacitance means is independent of said flow rate.

13. An arrangement as defined in claim 5, wherein said first and second means are respectively operative for charging and discharging said capacitance means, and wherein said adjustable constant current source means is said first means.

14. An arrangement as defined in claim 5, wherein said first and second means are respectively operative for charging and discharging said capacitance means, and wherein said adjustable constant current source means is said means.

15. An arrangement as defined in claim 7, wherein said first and second means are respectively operative for charging and discharging said capacitance means, and wherein said adjustable constant current source means is said first means.

16. An arrangement as defined in claim 7, wherein said first and second means are respectively operative for charging and discharging said capacitance means, and wherein said adjustable constant current source means is said second means.

17. An arrangement as defined in claim 1, wherein both said first and said second means are adjustable constant current source means.

18. An arrangement as defined in claim 1, wherein said adjusting means comprises an airflow sensing member located in said passage and mounted for displacement by the inflowing air to an extent indicative of the air inflow rate, and wherein said sensing member is so mounted so as to reduce the free flow-cross-section of said inflow passage, and wherein said passage and said sensing member are so configurated that as the displacement of said sensing member is increased in equal increments the free flow-cross-section of said inflow passage increases substantially exponentially.

19. An arrangement as defined in claim 1, wherein said adjusting means comprises an airflow sensing member in said passage mounted for displacement by the inflowing air to an extent indicative of the air inflow rate, and wherein said adjustable constant current source means includes a potentiometer comprising a potentiometer resistor and a movable tap slidable along said potentiometer resistor, with equal increments of movement of said tap along said resistor corresponding to equal-value resistance portions of said potentiometer resistor, and a plurality of further resistors each connected in parallel with a respective portion of said potentiometer resistor and having such values as to impart to said potentiometer an exponential characteristic.

20. An arrangement as defined in claim 1, wherein said timing capacitance means and said charging-discharging means of said timing means together form a monostable multivibrator having an input transistor and an output transistor of the same conductivity type, with said input transistor and said output transistor being respectively non-conductive and conductive when said multivibrator is in the stable state thereof, a load resistor connecting the collector of said output transistor to one bias-voltage line, and a feedback resistor connecting the collector of said output transistor to the base of said input transistor, and with said timing capacitance means being connected between the collector of said input transistor and the base of said output transistor, and wherein said second means comprises a transistor having a collector connected to one terminal of said timing capacitance means, and having a base connected to the movable tap of an adjustable voltage divider and wherein said first means comprises a transistor having a collector connected to the other terminal of said capacitance means and having a base connected to the center tap of a further voltage divider, and voltage-divider control means for permitting said further voltage divider to bias said transistor of said first means to conductive state only during a predetermined fraction of a crankshaft rotation, with the transistors of said first and second means being of conductivity type opposite to that of said input and output transistors, and further including emitter resistors for said transistors of said first and second means connecting the respective emitters to said one bias-voltage line.

21. An arrangement as defined in claim 20, wherein said voltage-divider control means comprises a control transistor having a collector connected to one end terminal of said further voltage divider and having an emitter connected to another bias-voltage line, with the other end terminal of said further voltage divider being connected to said one bias-voltage line, and means for applying to the base of said control transistor a voltage sufficient to render the latter conductive only during a predetermined fraction of a crankshaft rotation.

22. An arrangement as defined in claim 1, wherein said timing capacitance means is a single capacitor.

23. In a fuel injection arrangement for an internal combustion engine having an electromagnetic fuel injection valve for each cylinder, comprising, in combination, electric storage means; electric circuit means connected to said electric storage means and having a first state during which electric energy is added to said electric storage means and a second state during which electric energy is removed from said electric storage means and a fuel injection valve is opened for the period of time required to remove electric energy from said electric storage means, said period of time being dependent on the amount of energy stored and on the rate at which said energy is removed; air meter means associated with the intake manifold of the engine for providing a quantity representative of the time average of the amount of air sucked through the engine intake manifold, and wherein said electric circuit means includes transducer means for making, in dependence on said quantity, an electric parameter of said electric storage means proportional to the amount of air drawn in during each suction stroke of the engine so that said period of time is proportional to said amount of air drawn in during each suction stroke, wherein said electric storage means is a capacitor, and wherein said electric circuit means includes an input transistor and an output transistor, both transistors being of the same conductivity type, the input and output transistors normally being respectively non-conductive and conductive, a load resistor connecting the collector of said output transistor to voltage of one polarity, a feedback resistor connecting said collector to the base of said input transistor, a normally conductive discharge transistor, a first voltage divider connected between voltage of the other polarity and said voltage of one polarity, the tap of said first voltage divider being connected to the base of said discharge transistor, one plate of said capacitor being connected to the collector of said discharge transistor so that the latter conducts the discharge current of said capacitor, a charging transistor, the other plate of said capacitor being connected to the collector of said charging transistor so that the latter can conduct the charging current of said capacitor, a second voltage divider connected to said voltage of one polarity, switch means for connecting said second voltage divider in synchronism with the rotation of the engine crank shaft to said voltage of the other polarity, the tap of said second voltage divider being connected to the base of said charging transistor, said charging transistor and said discharge transistor being of the same conductivity type and opposite to the input and output transistors, and respective resistors connecting the emitters of said charging transistor and said discharge transistor to said voltage of one polarity.

24. The arrangement as defined in claim 23, wherein said switch means includes a switching transistor the collector and emitter of said switching transistor being respectively connected to one end of said second voltage divider and said voltage of the other polarity, said switch means further including signal generator means for making said switching transistor conductive over a predetermined angle of rotation of the crankshaft of the engine.

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