

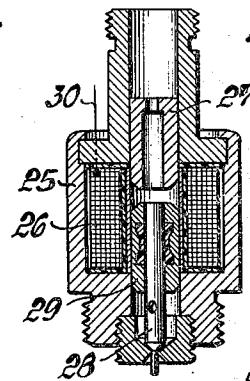
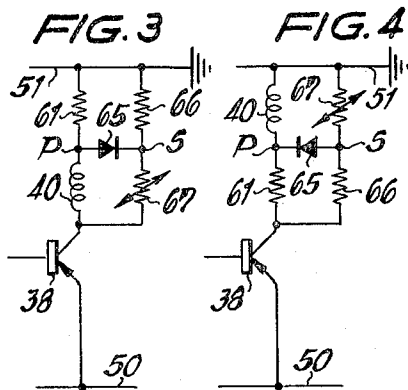
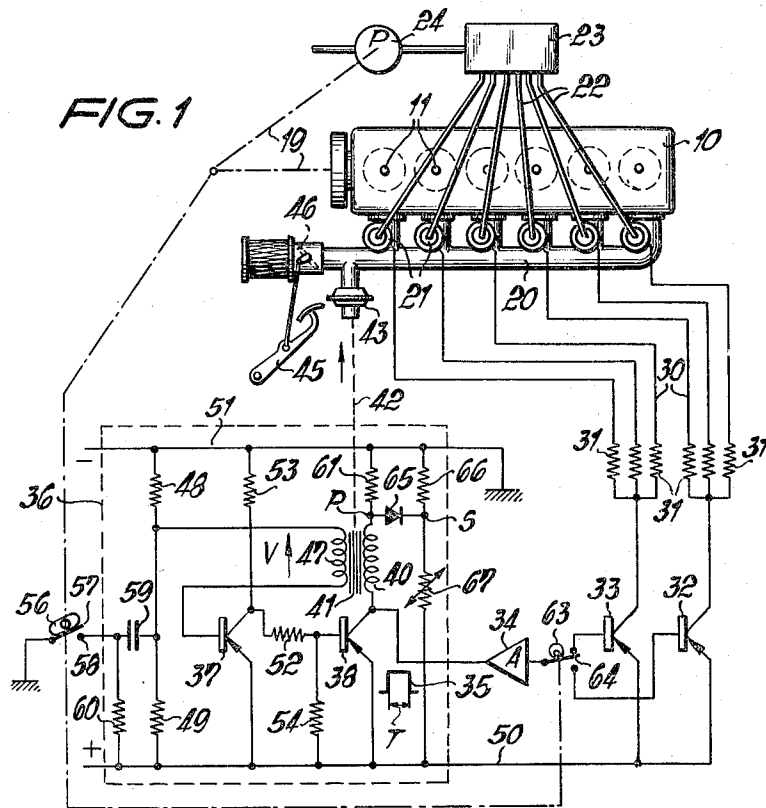
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ELECTRICALLY CONTROLLED FUEL INJECTION SYSTEM

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**ELECTRICALLY CONTROLLED FUEL
INJECTION SYSTEM**

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The present invention relates to a fuel injection system for use with internal combustion engines, particularly automobile engines wherein the fuel is injected into the suction pipe or intake, having a monostable trigger or flip-flop circuit, comprising an input transistor and an output transistor for producing pulse-shaped supply currents for the electromagnetically actuated injector. The duration of the injection produced by the injector is determined by a time member associated with the flip-flop, this member incorporating a transformer which has its primary winding connected with the collector circuit of the output transistor, the secondary winding of the transformer being connected to the base circuit of the input transistor.

In conventional fuel injection systems of this type, the transformer connected to the time member is provided with an armature which is spaced, by an air gap, from the iron core of the transformer. The armature is connected to a capsule containing a diaphragm, which capsule is connected to the intake of the internal combustion engine such that the higher the vacuum, the further away will the armature be moved from the iron core of the transformer. This movement of the armature decreases the inductance of the primary winding of the transformer. This, in turn, varies the duration of the injection and hence the quantity of fuel which is injected. While such an arrangement allows the injected amounts to be readily adjusted to the particular operating requirements of the internal combustion engine, the fact remains that the control valve, namely, the vacuum pressure in the suction pipe or intake, is dependent on the rotational speed of the internal combustion engine as well as on the position of the throttle flap and thus upon the load. Besides these major factors relating to the operation of the internal combustion engine, the fuel requirement also depends on the particular operating temperature. In order to obtain satisfactory performance even when the engine is cold, a substantially larger amount of fuel has to be injected than at the operating temperature reached by the engine after a warm-up time of some 5 to 10 minutes. These additional quantities should be approximately proportional to the temperature difference between the actual temperature and the lower limit of the normal operating temperature range, i.e., about 60° C.

It is, therefore, the basic object of the present invention to provide a way in which to complement conventional fuel injection systems which comprise a transformer serving as the time member such that, at an operating temperature of, for example, 60° C. or higher, the injection time which is set by the time member as a function of the vacuum pressure remains constant, but, below this temperature, is increased by a fixed amount, for example by 2% per degree of sub-temperature.

With the above objects in view, the present invention resides in an injection system of the type described above in which, according to the invention, the primary winding is connected in series with an input resistor and wherein one of the two terminals of a rectifier is connected to the juncture of the primary winding and the input resistor, the other terminal of this rectifier being connected to the junction of two serially-connected resistors forming a

voltage divider. At least one of these two last-mentioned resistors is variable in response to an operating condition of the engine, particularly upon its operating temperature.

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, in which:

FIGURE 1 is a partly schematic circuit diagram of the fuel injection system according to the present invention;

FIGURE 2 is a sectional view of an injection valve forming part of the injection system of FIGURE 1; and

FIGURES 3 and 4 are circuit diagrams of two modified embodiments of certain details.

Referring now to the drawings and to FIGURE 1 thereof in particular, the same shows a fuel injection system for a six cylinder internal combustion engine 10 whose spark plugs 11 are connected to a high-voltage ignition device (not shown). Arranged in the immediate vicinity of each of the intake valves (not shown) of the engine, there is an electromagnetically actuatable injection valve 21.

Each valve is positioned on a respective one of the branches of the intake manifold 20, each branch leading to its respective individual cylinder. Each valve is supplied with fuel via one of the fuel lines 22, all of which are connected to a distributor 23. The fuel is kept under approximately constant pressure in the distributor and in the lines 22 by means of a pump 24 which couples with the crankshaft 19 of the internal combustion engine, as shown schematically by phantom lines.

As shown in FIGURE 2, each of the injection valves includes a housing 25 constructed of magnetizable material and containing a magnetizing or exciter winding 26 which surrounds the stationary iron core 27 and the movable armature 29, the latter carrying the nozzle needle 28. One of the ends of winding 26 is grounded, i.e., electrically connected with the housing 25, by means which are not illustrated, while the other end of each of the windings is connected, via lines 30, to one of six resistors 31. The resistors 31 are connected, in two groups of three each, with the collectors of two power transistors 32 and 33, i.e., three resistors are connected to the collector of transistor 32 and the other three resistors are connected to the collector of the other transistor 33. The transistors 32 and 33 form part of an electronic regulating and control device which will be described in more detail below. The connection between the injection valves and the power transistors is such that the valves are in their open position as long as the transistors are conductive. The regulating and control device comprises, in addition to the two power transistors 32 and 33, a transistorized amplifier 34, shown schematically only. Rectangular control pulses 35 are applied to this amplifier 34 from a monostable flip-flop 36 whose unstable condition determines the duration of the control pulses and thus also the duration of injection, i.e., the unstable condition is utilized such that the amount of fuel injected by the valves 21 is proportional to this duration.

The flip-flop 36 comprises an input transistor 37 and an output transistor 38, as well as a time member which is determinative for the respective duration T of the unstable switching condition. The time member is made up of a transformer whose primary winding 40 is connected to the collector circuit of the output transistor 38. In order that the inductance of winding 40 is adjusted automatically as a function of the negative pressure in the intake manifold 20—this pressure varies with the engine speed

and the position of the throttle flap and assumes different values which yield the amount of injection and which are adjusted to the negative pressure—the transformer is provided with an adjustable armature 41. This armature is fastened to a connecting rod 42 which is connected with the diaphragm membrane (not shown) of a vacuum box or capsule 43. The latter is connected with its suction side to the intake manifold 20 of the engine at a point directly behind the throttle flap 46 of the engine, which flap is a butterfly valve whose position is suitably regulated, for example, by means of a foot lever 45 constituting the familiar gas pedal. As the vacuum increases, the box lifts the armature 41 in the direction indicated by an arrow, such that an air gap in the iron core (not shown) is increased, thereby decreasing the inductance of the primary winding 40. Thus, the lower the pressure, (i.e., the “higher” the vacuum) in the suction intake manifold pipe 20, the lower the inductance of winding 40.

The secondary winding 47 which is wound on the same iron core as the primary winding 40, is connected with one of its ends to the base of the input transistor 37 and, with its other end, to the connection point or juncture of two resistors 48 and 49, which resistors are series-connected to form a voltage divider lying across the two current supply lines, namely the positive line 50 and the negative line 51 connected to the terminals of the D.C. power supply for the flip-flops, represented symbolically by the + and — signs. These two lines are connected with a 12-volt battery (not illustrated). The transistor 37 has its emitter connected directly to the positive line 50, while its collector is connected to the base of transistor 38 via a coupling resistor 52 and with the negative line 51 via a load resistor 53.

A resistor 54 is connected between the positive line 50 and the base of the output transistor 38. The emitter of this transistor 38 is directly connected to the positive line 50. The control pulses 35 are derived from the collector of the transistor 38.

In order to be able to produce the control pulses in synchronism with the revolutions of the crankshaft, there is provided a two-load cam 56 which is coupled with the crankshaft, as shown in phantom lines. With each crankshaft revolution, the cam 56 presses the grounded switching arm 57 against the stationary contact 58, thereby to ground a capacitor 59. This capacitor 59 has one of its terminals connected to contact 58, and, via a resistor 60, to the positive line 50 the other terminal of capacitor 59 is connected to the connection point or juncture of the two resistors 48, 49 and the secondary winding 47. During the period lasting between the instant of closing and the subsequent instant at which the switch 57, 58, is opened, the capacitor 59 is charged to a voltage proportional to the ratio of the resistances of the two resistors 48 and 49. During this period, the input transistor 37 is conductive and maintains the output transistor 38 in its blocked condition. As soon as the switching arm 57 lifts off contact 58, the charge stored in capacitor 59 becomes effective to raise the connection point of the resistors 48 and 49 to a potential which is positive with respect to the emitter of the input transistor 37. At the instant of opening, the input transistor 37 is thus blocked and the output transistor 38, whose base is connected via resistor 52 and the now currentless resistor 53, to a large negative potential, becomes conductive and begins to conduct a magnetizing current, via the primary winding 40, which, when the inductance is large, rapidly increases to its quiescent current value which is determined by the magnitude of the resistance of the winding and that of an input resistor 61 connected in series with the winding 40. During this increase, the voltage V across the secondary winding 47, indicated by an arrow in the drawing, decays exponentially. This voltage makes the base of the input transistor 37, likewise, positive, and decreases at a rate proportional to the rate at which the collector current in the primary winding increases. As soon as the voltage V drops below

the value determined by the divisional relationship of the resistors 48 and 49, the base of the input transistor 37 once again becomes negative and the input transistor switches back to its conductive condition, at the same time blocking the output transistor 38. In this manner, there are produced the control pulses 35 which are derived from the collector of the output transistor 38. The duration T of these pulses depends upon the particular inductance of the primary winding 40, the same being set by the vacuum diaphragm 43 via the rod 42. These control pulses 35 are fed alternately to one of the two power transistors 32 and 33, via the amplifier 34 and via a switching arm 64 which is controlled by a cam 63 which, as shown by the phantom lines representing a mechanical connection, rotates at the same speed as the cam 56, but has only one lobe. Thus, the pulses effect the fuel injection of the duration T through the valves of the particular valve group whose transistor (32 or 33) is connected to the output of amplifier 34 at any one time.

The magnitude of the inductance of primary winding 40 is chosen, in conjunction with the input resistor 61, such that when the internal combustion engine operates at its normal temperature, i.e., at a cooling water temperature of more than 60° C., the quantity of fuel is just right, i.e., the fuel-air mixture is properly balanced so that there is no excess of air or of fuel. However, in order to achieve satisfactory performance even at lower cooling water temperatures, more fuel has to be injected; the colder the engine, i.e., the farther the particular engine temperature lies below the normal operating temperature of 60° C., the more fuel is required. This additional quantity should amount to about 2% of the fuel quantity required at normal operating temperature, per degree of sub-temperature. These correction values are applied to the control device, according to the invention, by connecting one of the two terminals of a rectifier 65 to the juncture P of the primary winding 40 and its input resistor 61, the other terminal of which rectifier is connected to the juncture of two resistors 66 and 67 forming a voltage divider. Resistor 66 is fashioned to be a temperature-independent resistor and is connected with the negative line 51, while the second resistor 67 is in heat-conductive connection with the cooling water of the internal combustion engine 10 and is constructed as a “hot” conductor or so-called NTC (negative temperature coefficient) resistor. In the illustrated embodiment, the low-resistance direction of rectifier 65 is such that it can carry current only if the juncture P is at a higher potential than the juncture S of the two resistors 66 and 67. The resistance values of these two resistors 66 and 67 are such that the rectifier 65 is permanently blocked at a cooling water temperature above 60° C., and thus point S is always a higher potential than point P. If, however, the temperature of the NTC-resistor 67 decreases and the latter therefore assumes higher resistance values, the potential of point S shifts in the negative direction. The potential of the point P increases with the collector current flowing through the primary winding 40 and thus ultimately reaches the potential of connection point S. The lower the cooling water temperature and consequently the lower the potential at point S, the earlier will the potential at P reach to potential at S. If, however, the rectifier 65 becomes conductive before the unstable switching condition, which determines the duration T of the control pulses, has come to an end, the time constant which determines for the increase of the collector current is abruptly increased. This increase in the time constant prolongs the pulse duration T by an amount ΔT ; the farther the operating temperature lies below the working temperature of 60° C., the larger will be ΔT and the earlier, thus, the rectifier 65 becomes conductive.

In the modified embodiments which are shown in FIGURES 3 and 4, the same structural elements, or the elements having the same function, are provided with the same reference numerals as in FIGURE 1.

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While, according to the embodiment of FIGURE 1, the NTC-resistor 67 is connected with the positive line 50, this resistor is connected, in the embodiment of FIGURE 3, between the collector of the output transistor 38 and the connection point S at which the non-variable resistor 66 and the rectifier 65 are connected as in FIGURE 1. This circuit has the advantage that current can flow via the NTC-resistor 67 only if, and as long as, the transistor 38 is in its unstable switching condition. For this reason, it is subjected to a self-heating which is the larger, the higher the rotational speed of the internal combustion engine. In this way, the transistor 38 compensates for the delay which may arise on account of the large heat capacity of the cooling system.

In the embodiment according to FIGURE 4, the non-variable resistor 66 is provided between the point S and the collector of the output transistor 38, while the NTC-resistor 67, which is reversed with resistor 66 with respect to its position in FIGURE 3, is connected between the negative line 51 and the point S. Furthermore, the input resistor 61, reversed with regard to position with the primary winding 40, is connected directly with the collector of the output transistor 38; furthermore, the rectifier 65 is connected with reversed polarity between the two points P and S. However, the rectifier 65 has the same effect as set forth in connection with the embodiments according to FIGURES 1 and 3.

In case a "cold" conductor is used for the temperature-dependent resistor, this conductor must be provided at that place at which the resistor 66 is provided in FIGURES 1, 3 and 4, whereas the non-variable resistor which forms a voltage divider together with the first-mentioned resistor, is then exchanged with the NTC-resistor 67 of FIGURES 1, 3 and 4.

The arrangement according to FIGURE 4 is advantageous because the transformer and the NTC-resistor normally have to be positioned so as to spatially be separated from the remainder of the circuit. The one-sided connection of these components with ground then results in a saving of connecting leads thereby simplifying the original installation as well as any subsequent servicing of the control device.

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 circuits differing from the types described above.

While the invention has been illustrated and described as embodied in fuel injection control 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 secured by Letters Patent is:

1. In a fuel injection system for an internal combustion engine, incorporating electromagnetically actuated injector means, a monostable flip-flop having an input transistor and an output transistor for producing pulse-shaped supply current for the injector means, which flip-flop further has a time member that includes a transformer whose primary winding is connected to the collector circuit of the output transistor and whose secondary winding is connected to the base circuit of the input transistor, the improvement which comprises, in combination: an input resistor connected in series with said primary winding of said transformer; a rectifier having one terminal connected to the

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juncture of said input resistor and said primary winding; and two serially-connected resistors forming a voltage divider, at least one of said two last-mentioned resistors being a variable one whose resistance varies as a function of an operating condition of said engine, the other terminal of said rectifier being connected to the juncture of said two serially-connected resistors.

2. A fuel injection control arrangement for an internal combustion engine having electromagnetically actuated injector means, said control arrangement comprising, in combination: a monostable flip-flop having an input transistor and an output transistor for producing pulse-shaped supply current for the injector means, said flip-flop incorporating a time member having a transformer whose primary winding is connected to the collector circuit of said output transistor and whose secondary winding is connected to the base circuit of said input transistor; an input resistor connected in series with said primary winding of said transformer; a rectifier having one terminal connected to the juncture of said input resistor and said primary winding; and two serially-connected resistors forming a voltage divider, at least one of said two last-mentioned resistors being a variable one whose resistance varies as a function of an operating condition of said engine, the other terminal of said rectifier being connected to the juncture of said two serially-connected resistors.

3. A fuel injection control arrangement for an internal combustion engine having electromagnetically actuated injector means, said control arrangement comprising, in combination: a monostable flip-flop having an input transistor and an output transistor for producing pulse-shaped supply current for the injector means, said flip-flop incorporating a time member having a transformer whose primary winding is connected to the collector circuit of said output transistor and whose secondary winding is connected to the base circuit of said input transistor; an input resistor connected in series with said primary winding of said transformer; a rectifier having one terminal connected to the juncture of said input resistor and said primary winding; and two serially-connected resistors forming a voltage divider, at least one of said two last-mentioned resistors being a variable one whose resistance varies as a function of the temperature of said engine, the other terminal of said rectifier being connected to the juncture of said two serially-connected resistors.

4. A fuel injection control arrangement for an internal combustion engine having electromagnetically actuated injector means, said control arrangement comprising, in combination: a monostable flip-flop having an input transistor and an output transistor for producing pulse-shaped supply current for the injector means, said flip-flop incorporating a time member having a transformer whose primary winding is connected to the collector circuit of said output transistor and whose secondary winding is connected to the base circuit of said input transistor; an input resistor connected in series with said primary winding of said transformer; a rectifier having one terminal connected to the juncture of said input resistor and said primary winding; and two serially-connected resistors forming a voltage divider, at least one of said two last-mentioned resistors being a variable one whose resistance varies as a function of the temperature of said engine, the other terminal of said rectifier being connected to the juncture of said two serially-connected resistors, the voltage divider constituted by said series-connected resistors being connected across a D.C. power supply to which said flip-flop is connected.

5. A fuel injection control arrangement for an internal combustion engine having electromagnetically actuated injector means, said control arrangement comprising, in combination: a monostable flip-flop having an input transistor and an output transistor for producing pulse-shaped supply current for the injector means, said flip-flop incorporating a time member having a transformer whose

primary winding is connected to the collector circuit of said output transistor and whose secondary winding is connected to the base circuit of said input transistor; an input resistor connected in series with said primary winding of said transformer; a rectifier having one terminal connected to the juncture of said input resistor and said primary winding; and two serially-connected resistors forming a voltage divider, at least one of said two last-mentioned resistors being a variable one whose resistance varies as a function of the temperature of said engine, the other terminal of said rectifier being connected to the juncture of said two serially-connected resistors, the voltage divider constituted by said series-connected resistors being connected in parallel with the series-circuit formed by said primary winding of said transformer and said input resistor, each of said series-circuits being connected across the collector of said output transistor and one terminal of a D.C. power supply to which said flip-flop is connected.

6. A fuel injection control arrangement for an internal combustion engine having electromagnetically actuated injector means, said control arrangement comprising, in combination: a monostable flip-flop having an input transistor and an output transistor for producing pulse-shaped supply current for the injector means, said flip-flop incorporating a time member having a transformer whose primary winding is connected to the collector circuit of said output transistor and whose secondary winding is connected to the base circuit of said input transistor; an input resistor connected in series with said primary winding of said transformer; a rectifier having one terminal connected to the juncture of said input resistor and said primary winding; and two serially-connected resistors forming a voltage divider, at least one of said two last-mentioned resistors being a variable one whose resistance varies as a function of the temperature of said engine, the other terminal of said rectifier being connected to the juncture of said two serially-connected resistors, the voltage divider constituted by said series-connected resistors being connected in parallel with the series-circuit formed by said primary winding of said transformer and said input resistor, each of said series-circuits being connected across the collector of said output transistor and one terminal of a D.C. power supply to which said flip-flop is connected, said primary winding of said transformer

being electrically closer to said collector of said output transistor than is said input resistor and the temperature responsive resistor being electrically closer to said collector of said output transistor than is the other of the two resistors of said voltage divider.

7. A fuel injection control arrangement for an internal combustion engine having electromagnetically actuated injector means, said control arrangement comprising, in combination: a monostable flip-flop having an input transistor and an output transistor for producing pulse-shaped supply current for the injector means, said flip-flop incorporating a time member having a transformer whose primary winding is connected to the collector circuit of said output transistor and whose secondary winding is connected to the base circuit of said input transistor; an input resistor connected in series with said primary winding of said transformer; a rectifier having one terminal connected to the juncture of said input resistor and said primary winding; and two serially-connected resistors forming a voltage divider, at least one of said two last-mentioned resistors being a variable one whose resistance varies as a function of the temperature of said engine, the other terminal of said rectifier being connected to the juncture of said two serially-connected resistors, the voltage divider constituted by said series-connected resistors being connected in parallel with the series-circuit formed by said primary winding of said transformer and said input resistor, each of said series-circuits being connected across the collector of said output transistor and one terminal of a D.C. power supply to which said flip-flop is connected, said one terminal of the D.C. power supply being grounded, said primary winding of said transformer being electrically closer to said grounded terminal of the D.C. power supply than is said input resistor and the temperature responsive resistor being closer to said grounded terminal of the D.C. power supply than is the other of the two resistors of said voltage divider.

8. The combination defined in claim 7 wherein said temperature responsive resistor is a negative temperature coefficient resistor.

No references cited.

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