ELECTRICALLY CONTROLLED FUEL INJECTION ARRANGEMENTS

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ABSTRACT

A monostable multivibrator generates pulses having lengths dependent on the pressure in the intake manifold of the engine, which pulses trigger an npn silicon power transistor into conduction to provide current to respective ones of the control windings of the fuel injection spray valves, which windings are connected through the emitter of the power transistor.

14 Claims, 5 Drawing Figures
ELECTRICALLY CONTROLLED FUEL INJECTION ARRANGEMENTS

BACKGROUND OF THE INVENTION

The invention relates to electrically controlled fuel injection arrangements for internal combustion engines. In the prior art, these arrangements frequently comprised at least one electromagnetic fuel injection spray valve having a control winding connected at one end to ground. Fuel under constant pressure is supplied to the valve, which latter is opened by a square-wave pulse generated in synchronism with the rotation of the crank shaft. The length the pulse, which determines the amount of fuel discharged by a valve, is dependent on at least one engine operating parameter, and is obtained from a transistor power output stage connected to a DC source that has a negative ground.

In known fuel injection arrangements, the branches of the intake manifold are connected to the individual fuel admission valves of the four or six-cylinder engine. In each of these branches, an electromagnetic valve is so arranged that the fuel discharged by the valves strikes the valve disks of the intake valve. The fuel injection spray valves are divided into two groups that are alternately operated by a respective transistor power output stage. The operation of each group is determined by a respective engine firing circuit so arranged as to reach the valve of each group at each revolution of the engine crankshaft.

In known fuel injection arrangements, the power output transistor is a pnp Germanium type, which is triggered into conduction for the duration of the pulse by an npn silicon driver transistor connected to its base. Since the maximum operating temperatures and cut-off voltages are higher for silicon output transistors than for Germanium power output transistors, it is desirable to use a silicon transistor in place of the Germanium. With modern semiconductor technology, npn silicon power output transistors are substantially more cheaply and reliably manufactured than the corresponding pnp types. The use of npn silicon power output transistors has however the disadvantage that with circuits used until the present time, one of the ends of the control winding of the fuel injection valve must be connected to the positive pole or to a positive line, so that two current supply leads are required for each fuel injection valve.

SUMMARY OF THE INVENTION

An object of the invention is to provide a circuit arrangement to insert a npn power output transistor without having to change the polarity of the connections to the control windings of the fuel injection spray valves. The invention essentially comprises at least one electromagnetic fuel injection valve means having control winding means with first and second terminals, DC source means having a negative pole connected to the first terminal and a positive pole, electric pulse generating means, such as a monostable multivibrator, for generating pulses in synchronism with rotation of the engine crank shaft, the pulses having lengths dependent on at least one engine operating parameter, and an electric power output stage connected to receive these pulses and to deliver pulses to the valve winding means, to operate the valve means, the output stage including a normally non-conductive npn power transistor connected to the pulse generating means to be turned on during the time that the latter generates a pulse, the power transistor defining a base-emitter path, ad having a collector connected to the positive pole of the DC source and an emitter connected to the second terminal of the winding means, whereby when the power transistor is turned on, current flows through the valve winding means and the valve means is operated to supply an amount of fuel in dependence on the pulse length.

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 DRAWING

FIG. 1 is a circuit diagram of one embodiment of the invention;

FIG. 2 is a circuit diagram showing a power output stage merely as a box in broken line; and

FIGS. 3, 4 and 5 show three different embodiments of the power output stage.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

With reference to FIG. 1, the fuel injection arrangement is intended for a four-cylinder, four-cycle internal combustion engine. The essential components of the arrangement are four-electromagnetically operated fuel injection valves 11, each connected by a fuel line 13 to a distributor valve; are fuel pump 15 operated by an electric motor; a pressure regulator 16; and a control arrangement that will be described. The control arrangement, by means of a signal generator 18 connected to the engine crank shaft 17, delivers for each revolution of the engine crank shaft a square-wave pulse 19 to a fuel injection valve 11. The pulse length Tp, shown in FIG. 1, determines the opening time of the injection valve and therefore the amount of fuel discharged from the valve chamber during each open period of the valve. The fuel pressure in the valve chamber is practically constant at 2 atmospheres.

The pulse 19 for opening valves 11 is obtained from a monostable multivibrator 20, in the stable state of which the input transistor 21 conducts and the output transistor 23 does not conduct. A resistor 22 connects the collector of transistor 21 to the base of transistor 23. This transistor is also connected to a timing component that determines the length of each pulse Tp. This timing component is shown, merely by way of example, as a transformer of which the primary winding 24 is connected in series with a resistor 25 between the collector and the positive line 26, which latter is common to the electronic control arrangement. The secondary winding 27 is inductively coupled to the primary by an adjustable, magnetically permeable member 28. When the absolute air pressure in the intake manifold 30 falls — caused, for example, by closing the throttle valve 32 — the member 28 can be raised in the direction of the arrow from the transformer to restore, not shown, by the pressure means 31 that reacts to the pressure in the manifold. When the pressure in the manifold 30 increases, a spring, not shown, moves the member 28 in the opposite direction and increases the inductance of the transformer.

In a manner common to multivibrators of this kind, the transformer secondary 27 is connected at one end to the junction P of two resistors 33 and 34, which form a voltage divider between the negative line 35 and the positive line 36. The negative line 35 is connected to ground. The other end of the secondary 27 is connected through a diode 36 to the base of the input transistor 21. Both transistors 21 and 23 are npn types, and their emitters are connected to the negative line 35.

The signal generator 18, which controls the operation of the multivibrator 20, is mounted in the housing of an ignition distributor that forms part of a high voltage ignition circuit, not shown, of the internal combustion engine. The signal generator comprises a single lobe cam 37 that is mounted on the distributor shaft 38 and operates two contact levers 40 and 41. The contact levers are connected by respective resistors 42 and 43 to the positive line 26, and they are also connected to the electrode of respective differentiating capacitors 44 and 47. The cam 37 alternately presses the contact levers 40 and 41 against the respective stationary spring contacts 46 and 47 that are connected to the negative, or ground, line 35. Each lever is alternately held closed during one-half of a revolution of the distributor shaft 38.
Each time that a lever 40 or 41 is held closed, the multivibrator 20 is triggered to its unstable state, the period of which determines the pulse length T. The length of time that the multivibrator 20 remains triggered to its unstable state, depends upon the position of the member 28, which position determines the mutual inductance between the windings 24 and 27. In order to be able to cut off the transistor 21 after a desired time, the capacitors 44 and 45 are connected by respective diodes 48 and 49 to the base of this transistor 66 and also by respective charging resistors 50 and 51 to the negative line 35. As long as a respective contact lever 40 or 41 is opened, its differentiating capacitor 44 or 45 can charge. When the contact lever is closed, however, the capacitor discharges and cuts off the transistor 21. As soon as the input transistor 21 is non-conductive, the output transistor 23 becomes conductive. The exponentially rising collector current flowing through the primary 24 induces in the secondary 27 a feedback voltage that keeps transistor 21 cut off beyond the closing time of the respective control lever 40 or 41. The transistor 21 remains non-conductive until the feedback voltage falls below the potential at the tap peak of the voltage divider formed by the resistors 33 and 34. This tap voltage is set at a value at which the transistor 21 can again conduct. A pulse 19 is produced for as long as the transistor 23 remains conductive.

The necessary current for operating the valve 11 is provided by a power output stage 60, which is connected by an amplifier, shown schematically in broken line, to a resistor 25 connected in the collector circuit of the transistor 23. In accordance with the invention, the input of the power output stage has a npn type silicon amplifier transistor 64 acting as a driver. The emitter of the driver is connected directly to the positive line 26. The output stage also has a npn type silicon power transistor 66, which is operated as an emitter follower. Its collector is connected directly to the positive line 26, and its emitter is connected to the resistors 68 connected to the individual control windings 67 of the fuel injection valves 11. A bypass resistor 69 connects the base of the power transistor 66 directly to its emitter. This base is connected to the collector of the driver 64. This circuit arrangement ensures that when the driver 64 is cut off, the power transistor 66 is also completely cut off. The power transistor is reliably held non-conductive even when the control windings 67 form in the emitter circuit of the power transistor a substantial inductive load that makes the emitter of this transistor more negative than the negative line 35 at the end of a pulse 19.

In the embodiments shown in FIGS. 3 to 5, the power output transistor 66 is again connected in a common collector circuit configuration, but the output stage, shown in broken line as a box 70 in FIG. 2, is altered and elaborated.

When the current through a control winding 67 is suddenly broken at the end of a pulse period T, there can be induced in the winding appreciable voltage peaks that are opposed to the normal voltage across the winding. The danger is that these voltage peaks on the emitter will keep the power transistor 66 conductive longer than the desired period of time. The consequence is that the cut off of the power transistor is appreciably delayed and that the power losses in this transistor are increased.

These drawbacks are avoided in the embodiments shown in FIGS. 3 to 5. In the output stage shown in FIG. 3, the 3 to type silicon driver transistor 64 has its emitter connected to the positive line 26. In contrast to the embodiment shown in FIG. 1, a resistor 72 is connected between the collector of the transistor 64 and the base of transistor 66. Moreover, there is provided a bypass diode 73 of which its cathode is connected to the collector of transistor 64 and its anode to the negative line 35. Whereas in the circuit shown in FIG. 1, the voltage peaks occurring when the valve control winding 67 is being deenergized, can act on the power transistor 66 when it is cut off or being cut off, this is not possible in the circuit shown in FIGS. 3, 4 and 5. These induced voltage peaks appear virtually only across the resistor 72, provided that the base bypass resistor 69 is sufficiently small.

In order not to adversely affect the control of the power transistor 66 by the driver transistor 64, it is essential that the resistor 72 have not too large a resistance value. Moreover, a great amount of control power can be lost because the bypass resistor 69 has a low resistance value.

To avoid these disadvantages, the embodiment shown in FIG. 4 uses in place of the base bypass resistor the emitter-collector path of a pnp type transistor 75, on which the emitter is directly connected to the emitter of the power transistor 66. The base of the transistor 75 is connected to a resistor 76 to the negative line 35. Connected across the emitter base path of transistor 75, is a diode 76 the anode of which is connected to the emitter of the power transistor 66. A voltage peak appearing on a control winding of a fuel injection valve 11, shown schematically in FIGS. 3 to 5, triggers the transistor 75 into its conductive state. The transistor 75 consequently provides a low ohmage shunt of the emitter base path of the power transistor 66.

As long as power transistor 66 is held conductive by a pulse 19, the transistor 75 is automatically cut off. The diode 77 prevents the appearance of an excessively high base emitter cut-off voltage on the bypass transistor 75. A rather high resistance value can now be chosen for the resistor 76, and the diode 77 do not shunt an appreciable amount of current past a control winding 67 of a valve 11, when the latter is to be opened. If an appreciable amount of current did flow in this parallel path, the valve would open more slowly.

In the embodiment shown in FIG. 1, a respective resistor 68 is connected in series with each of the valve control windings 67, and the collector of the power transistor is connected directly to the positive line 26. As shown in FIGS. 3 to 5, a single resistor can be used if a resistor 78 is connected between the collector of the power transistor 66 and the positive line 26.

The more general significance of the bypass diode 73 is made clear in the embodiment shown in FIG. 5. As against the previous embodiments, a pnp type silicon amplifier transistor 80 is connected before the power transistor 66. The transistor 80 is connected common emitter, and its collector is connected through a resistor 72 to the base of the power transistor and through a load transistor 81 to the positive line. The bypass diode 73 protects the emitter-collector path of the amplifier transistor 80 from the effects of the voltage peaks that can also appear across the control winding 67 when the ignition switch, for example, is turned off while the transistor 66 is conducting.

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 electrically controlled fuel injection arrangements, 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 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

1. In an electrically controlled fuel injection arrangement for an internal combustion engine having a crank shaft, in combination, at least one electromagnetic fuel injection valve means having control winding means with first and second terminals; DC source means having a negative pole connected to
said first terminal and a positive pole; electric pulse generating means for generating pulses in synchronism with rotation of said crankshaft, said pulses having lengths dependent on at least one engine operating parameter; an electric power output stage including an n-p-n amplifier transistor, of which the emitter is connected to said negative pole and the collector is connected to the base of said power transistor; load means connected between said positive pole and the collector of said amplifier transistor; and diode means having an anode connected to said negative pole and a cathode connected to the collector of said amplifier transistor; and resistance means connected between the collector of said amplifier transistor and the base of said power transistor.

2. In an electrically controlled fuel injection arrangement for an internal combustion engine having a crankshaft, in combination, at least one electromagnetic fuel injection valve means having control winding means with first and second terminals; DC source means having a negative pole connected to said first terminal and a positive pole; electric pulse generating means for generating pulses in synchronism with rotation of said crankshaft, said pulses having lengths dependent on at least one engine operating parameter; an electric power output stage including an n-p-n amplifier transistor, of which the emitter is connected to said negative pole and the collector is connected to the base of said power transistor; load means connected between said positive pole and the collector of said amplifier transistor; and diode means having an anode connected to said negative pole and a cathode connected to the collector of said amplifier transistor; and resistance means connected between the collector of said amplifier transistor and the base of said power transistor.

3. In an electrically controlled fuel injection arrangement for an internal combustion engine having a crankshaft, in combination, at least one electromagnetic fuel injection valve means having control winding means with first and second terminals; DC source means having a negative pole connected to said first terminal and a positive pole; electric pulse generating means for generating pulses in synchronism with rotation of said crankshaft, said pulses having lengths dependent on at least one engine operating parameter; an electric power output stage including said pulse generating means; said output stage including a normally non-conductive n-p-n power transistor connected to said pulse generating means to be turned on during the time that the latter generates a pulse, said power transistor defining a base-emitter path, and having a collector connected to the positive pole of said DC source and an emitter connected to said second terminal of said winding means, whereby when said power transistor is turned on current flows through said valve winding means and said valve means is operated to supply an amount of fuel in dependence on the pulse length; protective bypass means connected to shunt said base-emitter path at least during the period when said power transistor begins to turn off, whereby voltage peaks induced in said valve winding means cannot keep said power transistor conductive when the current therethrough is broken due to turning off of said power transistors, said power output stage including a n-p-n amplifier transistor having an emitter connected to said positive pole and a collector connected to the base of said power transistor; diode means having an anode connected to said negative pole and a cathode connected to the collector of said amplifier transistor, and resistance means connected between said collector of said amplifier transistor and said positive pole.

4. In an electrically controlled fuel injection arrangement for an internal combustion engine having a crankshaft, in combination, at least one electromagnetic fuel injection valve means having control winding means with first and second terminals; DC source means having a negative pole connected to said first terminal and a positive pole; electric pulse generating means for generating pulses in synchronism with rotation of said crankshaft, said pulses having lengths dependent on at least one engine operating parameter; an electric power output stage including a normally non-conductive n-p-n power transistor connected to said pulse generating means to be turned on during the time that the latter generates a pulse, said power transistor defining a base-emitter path, and having a collector connected to the positive pole of said DC source and an emitter connected to said second terminal of said winding means, whereby when said power transistor is turned on current flows through said valve winding means and said valve means is operated to supply an amount of fuel in dependence on the pulse length; protective bypass means connected to shunt said base-emitter path at least during the period when said power transistor begins to turn off, whereby voltage peaks induced in said valve winding means cannot keep said power transistor conductive when the current therethrough is broken due to turning off of said power transistors, said power output stage including a n-p-n amplifier transistor, of which the emitter is connected to said negative pole and the collector is connected to the base of said power transistor; load means connected between said positive pole and the collector of said amplifier transistor; and diode means having an anode connected to said negative pole and a cathode connected to the collector of said amplifier transistor; and resistance means connected between the collector of said amplifier transistor and the base of said power transistor.

5. In an electrically controlled fuel injection arrangement for an internal combustion engine having a crankshaft, in combination, at least one electromagnetic fuel injection valve means having control winding means with first and second terminals; DC source means having a negative pole connected to said first terminal and a positive pole; electric pulse generating means for generating pulses in synchronism with rotation of said crankshaft, said pulses having lengths dependent on at least one engine operating parameter; an electric power output stage including said pulse generating means; said output stage including a normally non-conductive n-p-n power transistor connected to said pulse generating means to be turned on during the time that the latter generates a pulse, said power transistor defining a base-emitter path, and having a collector connected to the positive pole of said DC source and an emitter connected to said second terminal of said winding means, whereby when said power transistor is turned on current flows through said valve winding means and said valve means is operated to supply an amount of fuel in dependence on the pulse length; protective bypass means connected to shunt said base-emitter path at least during the period when said power transistor begins to turn off, whereby voltage peaks induced in said valve winding means cannot keep said power transistor conductive when the current therethrough is broken due to turning off of said power transistors, said power output stage including a n-p-n amplifier transistor having an emitter connected to said positive pole and a collector connected to the base of said power transistor; diode means having an anode connected to said negative pole and a cathode connected to the collector of said amplifier transistor, and resistance means connected between the collector of said amplifier transistor and said positive pole.
valve means, said output stage including a normally non-conductive npn power transistor connected to said pulse generating means to be turned on during the time that the latter generates a pulse, said power transistor defining a base-emitter path, and having a collector connected to the positive pole of said DC source and an emitter connected to said second terminal of said winding means, whereby when said power transistor is turned on current flows through said valve winding means and said valve means is operated to supply an amount of fuel in dependence on the pulse length; protective bypass means connected to shunt said base-emitter path at least during the period when said power transistor begins to turn off, whereby voltage peaks induced in said valve winding means cannot keep said power transistor conductive when the current therethrough is broken due to turning off of said power transistor; a normally non-conductive bypass transistor having an emitter-collector path connected across said base-emitter path of said power transistor and constituting said bypass means, and resistance means connecting the base of said bypass transistor to said negative pole, whereby said bypass transistor is rendered conductive by said voltage peaks induced in said valve winding means.

6. A combination as defined in claim 5, wherein said power transistor is a silicon type.

7. A combination as defined in claim 5, wherein said negative pole is ground potential.

8. A combination as defined in claim 5, wherein said power output stage includes a pnp amplifier transistor having an emitter connected to said positive pole and a collector connected to the base of said power transistor.

9. A combination as defined in claim 5, wherein said power output stage includes an npn amplifier transistor, of which the emitter is connected to said negative pole and the collector is connected to the base of said power transistor, and including load means connected between said positive pole and the collector of said amplifier transistor.

10. A combination as defined in claim 8, including diode means having an anode connected to said negative pole and a cathode connected to the collector of said amplifier transistor.

11. A combination as defined in claim 9, including diode means having an anode connected to said negative pole and a cathode connected to the collector of said amplifier transistor.

12. A combination as defined in claim 5, wherein said bypass transistor is of pnp type and the emitter thereof is connected to the emitter of said power transistor.

13. A combination as defined in claim 5, including diode means connected across the base-emitter path of said bypass transistor to prevent an excessive base-emitter voltage on said bypass transistor when the latter is not conductive.

14. A combination as defined in claim 5, wherein the anode of said diode means is connected to the emitter of said power transistor.

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