

[54] **FUEL INJECTION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES**

[72] Inventors: **Isezi Kamazuka, Kariya; Katsuhiko Ohiwa, Handa, both of Japan**

[73] Assignee: **Nippondenso Kabushiki Kaisha, Aichi-ken, Japan**

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*Primary Examiner*—Laurence M. Goodridge  
*Attorney*—Cushman, Darby & Cushman

[57] **ABSTRACT**

A fuel injection control system used for internal combustion engines provided with electromagnetic fuel injectors, the said control system including electronic circuits to control the opening period of the injection valves so as to feed an appropriate amount of fuel to the engine according to peripheral conditions and characterized in that the said system includes means for stopping the supply of fuel to the cylinders during no-load driving and during braking with motor to thereby prevent the discharge of harmful exhaust gases.

**6 Claims, 2 Drawing Figures**

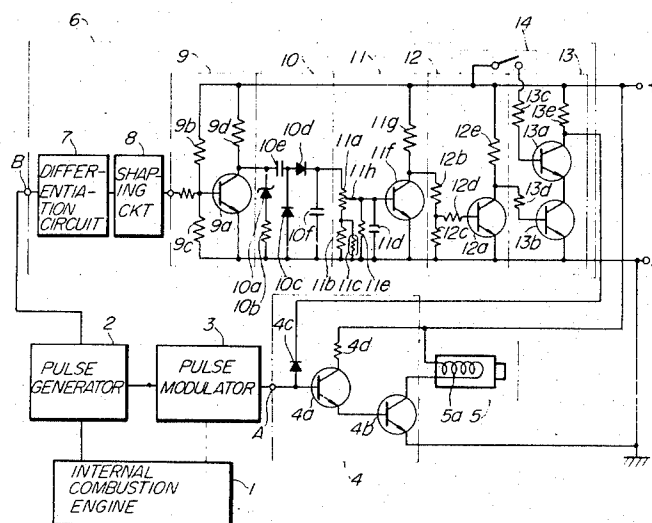


FIG. 1

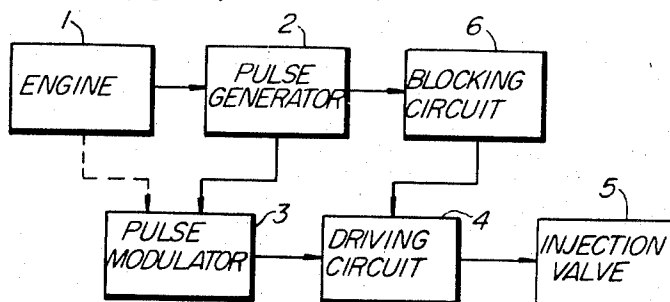
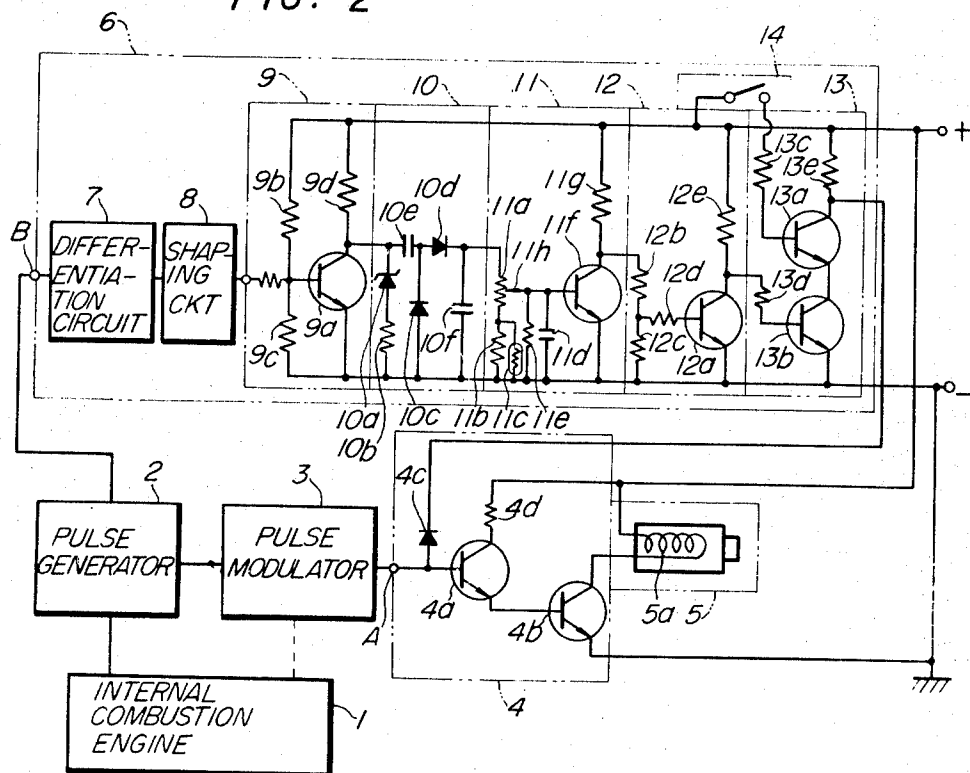


FIG. 2



INVENTORS

ISEKI KAMAZUKA  
KATSUHIKO OHIWA

BY *Cushman, Darby & Cushman*

ATTORNEYS

# FUEL INJECTION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES

## BACKGROUND OF THE INVENTION

### 1. Field of the Invention

This invention relates to a fuel injection control system for internal combustion engines which is provided with electromagnetically operable injection valves operated by electronic control means in relation to the operating parameters of the internal combustion engine.

### 2. Description of the Prior Art

The control system of the described type has recently been recommended for use with an internal combustion engine because of its advantages as described below. Such a control system ensures an optimal amount of fuel to be injected into the engine cylinders in synchronism with the opening period of the suction valve, which means a highly efficient consumption or complete combustion of the fuel as well as the minimization of the harmful uncombusted components such as carbon monoxide which may be contained in the exhaust gases. However, the amount of such harmful components contained in the exhaust gases is especially great when the internal combustion engine need not produce torque, or more specifically, during no-load driving or braking with motor which occurs, for example, when the vehicle having an internal combustion engine mounted therein is running down a decline under its own thrust.

Thus, the known control system of this type offers a problem concerning the need to minimize the harmful components contained in the exhaust gases discharged under the no-load driving conditions of the engine or during braking with motor.

## SUMMARY OF THE INVENTION

The present invention intends to solve the above-described problem peculiar to the prior art. Such an object can be achieved by a fuel injection control system for internal combustion engines which is provided with electro-magnetically operable injection valves operated by electronic control means in relation to the operating parameters of the internal combustion engine. A pulse corresponding to the number of revolutions of the internal combustion engine is provided and the waveform of the pulse is shaped through a monostable multivibrator circuit, then the digital output is converted into an analogous quantity corresponding to the number of revolutions of the engine. This analogous quantity is in turn compared with a reference voltage determined by a predetermined number of revolutions of the engine. On the other hand, a signal is provided by a switch adapted to be closed when the throttle valve of the engine is fully or substantially fully closed, so that the operation of the electromagnetic valves may be stopped when the logical product is obtained between the signal produced when the aforesaid analogous quantity exceeds the reference voltage value and the signal provided by the switch. Thus, the fuel injection can be positively stopped when the number of engine revolutions is at a substantially high level and the throttle valve is fully or substantially fully closed as in the case where the internal combustion engine does not need to produce a torque, for example, in the case where the vehicle having an internal combustion engine

mounted therein is running down a decline under its own thrust while braking with motor. In this way, the discharge of exhaust gases containing harmful components can be prevented and the fuel consumption can be effectively economized.

## BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a block diagram schematically showing the arrangement of the fuel injection control system according to the present invention; and

FIG. 2 shows the electric circuits of the control system shown in FIG. 1.

## DESCRIPTION OF THE PREFERRED EMBODIMENT

The invention will now be described in greater detail with respect to an embodiment thereof shown in the accompanying drawings.

Referring to the block diagram of FIG. 1, description will first be made of the construction and operation of the control system according to the present invention. The fuel injection control system includes an internal combustion engine 1, and a pulse generator 2 for detecting the number of revolutions of the internal combustion engine 1 and the opening period of the suction valve. The pulse generator 2 provides a pulse in synchronism with the opening period of the suction valve through the rotation of the crankshaft, for example. A pulse modulation circuit 3 is provided to convert the output pulse of the pulse generator 2 into a fuel injection pulse having a pulse width (or fuel injection time) corresponding to such parameters as the suction load pressure and temperature of the engine, ambient temperature and pressure, and it constitutes an electronic control device. There is also provided an injection valve driving circuit 4 which is started by the fuel injection pulse from the pulse modulation circuit 3 to energize the electromagnetic winding of an injection valve 5 and maintain it energized for a time corresponding to the pulse width of that fuel injection pulse. The injection valve 5 is opened for that time during which it is energized, thereby allowing the fuel to be injected therethrough into a corresponding cylinder or into the suction manifold communicating with that cylinder. Further provided is a blocking circuit which stops the operation of the injection valve driving circuit 4 to thereby stop the fuel injection of the injection valve 5 when the voltage provided by the output pulse of the pulse generator 2 and corresponding to the number of engine revolutions exceeds a reference voltages determined by a predetermined number of revolutions, which may be 1,500 r.p.m. for example, and at the same time the suction valve is fully or substantially fully closed. The injection valve 5 has an injection nozzle formed in the suction tube adjacent to the suction valve.

Referring to FIG. 2, there is shown the circuit arrangement including the injection valve driving circuit 4, injection valve 5 and blocking circuit 6. In FIG. 2, the injection valve driving circuit 4 comprises a couple of transistors 4a and 4b, a diode 4c and a load resistor 4d. The injection valve 5 has an electromagnetic winding 5a inserted in the collector circuit of the transistor 4b. The blocking circuit 6 comprises various circuit elements which will now be described. A differentia-

tion circuit 7 converts the output pulse of the pulse generator 2 into a trigger pulse. A waveform shaping circuit 8 consists of a monostable multivibrator circuit driven by the trigger pulse. A single-stage amplifier circuit 9 consists of a transistor 9a, bias resistors 9b and 9c, and a load resistor 9d, and amplifies the square-wave output pulse of the waveform shaping circuit 8. A D-A converter circuit 10 consists of a constant-voltage diode 10a, a voltage-compensating resistor 10b, diodes 10c and 10d, and capacitors 10e and 10f. The D-A converter circuit 10 converts the digital output of the amplifier circuit 9 into an analogous quantity corresponding to the number of engine revolutions. A comparator circuit 11, which consists of a voltage-dividing variable resistor 11a, a resistor 11b, a temperature-compensating thermistor 11c, a capacitor 11d, a resistor 11e, and a transistor 11f having a load resistor 11g, divides the output voltage of the D-A converter circuit 10 and thereafter compares the divided voltage with the reference voltage determined by a predetermined number of revolutions of the engine to thereby detect whether the engine speed has exceeded the predetermined value. The variable resistor 11a has a variable slide 11h connected with the base of the transistor 11f. The base-emitter turn-on voltage of the transistor 11f provides the above-mentioned reference voltage. There is another single-stage amplifier circuit 12 consisting of a transistor 12a, bias resistors 12b and 12c, a base resistor 12d and a load resistor 12e. A logical product circuit 13 is constituted by transistors 13a and 13b, base resistors 13c and 13d and a load resistor 13e. A switch 14 adapted to be closed when the throttle valve (not shown) of the engine is fully or substantially fully closed is inserted in the base circuit of the transistor 13a. The collector of the transistor 13a is connected with the base of the transistor 4a of the injection valve driving circuit 4 via the diode 4c. Although FIGS. 1 and 2 show only one injection valve 5 for clarity of illustration, such an injection valve is provided for each of the cylinders provided in the internal combustion engine. Thus, four such valves are used for a four-cylinder engine. In this case, the electromagnetic valve driving circuit 4 must be capable of distributing the fuel injection pulse from the pulse modulation circuit 3 to a corresponding injection valve.

In operation, if the internal combustion engine 1 is operating under normal driving conditions, the pulse generator 2 generates a pulse synchronous with the opening period of the suction valve. The pulse is applied to the pulse modulation circuit 3, where the pulse is converted into a fuel injection pulse having a pulse width corresponding to the parameters such as the suction load pressure and temperature of the engine, ambient temperature, and so on. When the fuel injection pulse is applied to the input terminal A of the injection valve driving circuit 4, the transistors 4a and 4b are turned on so as to pass a current to the electromagnetic winding 5a of the injection valve 5 inserted in the collector circuit of the transistor 4b, whereby the fuel is allowed to be injected through the injection valve 5 into a corresponding cylinder or into the manifold communicating with that cylinder. On the other hand, the output pulse of the pulse generator 2 is applied to the input terminal B of the blocking circuit 6 and converted into a trigger pulse by the differentiation circuit 7. The

trigger pulse thus provided drives the wave shaping monostable multivibrator circuit 8 which thus produces a square-wave pulse. The square-wave pulse is applied to the next amplifier circuit 9 for amplification, and further to the subsequent D-A converter circuit 10. Thereupon, a digital pulse voltage substantially equal to the source voltage that appears in the collector of the transistor 9a of the amplifier circuit 9 is restricted by the constant-voltage diode 10a to the breakdown voltage thereof, while the capacitor 10f is charged with that restricted pulse voltage through capacitors 10e and diode 10d. Every time the transistor 9a of the amplifier circuit 9 is turned on by the output pulse of the monostable multivibrator circuit 8, the charge in the capacitor 10e is completely discharged in a short time through a discharge circuit formed by the collector and emitter of the transistor 9a and the diode 10c, after which the capacitor 10e is ready for the subsequent charging which occurs when the transistor 9a is turned off. The discharge circuit of the capacitor 10f is constituted by the variable resistor 11a, resistors 11b and 11e and thermistor 11c of the comparator circuit 11. Since the resistance values of these resistors are selected to be relatively great, the capacitor 10f cannot complete its discharge in a short time through the aforesaid discharge circuit. Accordingly, as the engine increases its speed, the current charging the capacitor 10f becomes greater than the current discharge from the capacitor. As a result, the terminal voltage of the capacitor 10f is increased in proportion to the engine speed. When the number of revolutions of the engine thus exceeds a predetermined value, the terminal voltage of the capacitor 10f corresponding to the engine speed is divided by the variable resistor 11a, resistor 11b and thermistor 11c. If the voltage applied between the base and emitter of the transistor 11f exceeds the base-emitter turn-on voltage of the transistor 11f, this transistor becomes conductive. This causes the transistor 12a of the subsequent amplifier circuit 12 to be turned off, and a current flows through the base and emitter of the transistors 13b of the logical product circuit 13. The aforesaid predetermined number of revolutions is selected at a value such as 1,500 r.p.m. which is lower than the number of revolutions during the normal operation of the internal combustion engine 1 but higher than that during the idling of the engine, and therefore, if the engine 1 is in its normal operative condition as described above, the transistor 11f of the comparator circuit 11 is maintained in the "ON" state and the current flowing through the base and emitter of the transistor 13b in the logical produce circuit 13 is also maintained. Further, during the normal operation of the engine, the throttle valve of the engine is almost fully open and accordingly the switch 14 is also open, so that the other transistor 13a in the logical product circuit 13 is in the "OFF" state with its base circuit open. Thus, during the normal operation of the engine, no logical product is established in the logical product circuit 13, that is, the collector potential of the transistor 13a is equal to the positive potential of the power source, whereby the diode 4c in the injection valve driving circuit 4 is "OFF" in its forward direction. This enables the fuel injection pulse of the pulse modulation circuit 3 to be applied to the input terminal A of the injection valve driving circuit 4 without being blocked.

When the throttle valve is actuated to be fully or substantially fully closed in order to reduce the engine speed from the normal running level, the switch 14 is closed so that the transistor 13a of the logical product circuit 13 is turned on with its base circuit completed, and by that time the other transistor 13b of the logical product circuit 13 has already been turned on. Thus, the logical product circuit 13 establishes its logical product for the first time. This logical product of the logical product circuit 13 is established when the engine speed is higher than the predetermined level with the throttle valve fully or substantially fully closed, as in the case where the vehicle with the internal combustion engine 1 is running down a decline under its own thrust while braking with motor. Upon establishment of the logical product in the logical product circuit 13, the collector potential of the transistor 13a approximates to ground potential with a result that the diode 4c of the injection valve driving circuit 4 is turned on in its forward direction. Consequently, the fuel injection pulse provided by the pulse modulation circuit 3 is passed to the ground through the diode 4c and the collector and emitter of the transistors 13a and 13b in the logical product circuit 13, so that the transistors 4a and 4b in the injection valve driving circuit 4 are turned off without any signal appearing thereat. This causes the electromagnetic winding of the injection valve 5 to become de-energized to thereby stop the fuel injection therethrough.

The above-described operation relates to the case where the speed of the internal combustion engine 1 is reduced from its normal operative level. When the internal combustion engine 1 is idling, the throttle valve is substantially fully closed so that a voltage is applied to the base of the transistor 13a of the logical product circuit 13 to turn on this transistor, while the other transistor 13b of the logical product circuit 13 is not conducting because the predetermined number of revolutions is selected at a higher level than the engine speed during idling. As a result, there is established no logical product whereby the fuel injection pulse produced by the pulse modulation circuit 3 is applied to the injection valve driving circuit 4 without being blocked, thereby enabling idling to be properly effected.

If the predetermined number of revolutions must be changed in accordance with the rated output of the internal combustion engine 1, such a requirement could be met by displacing the variable slide 11h of the variable resistor 11a so as to vary the ratio of the voltages divided by the resistors 11a and 11b because the base-emitter turn-on voltage of the transistor 11f providing the reference voltage remains constant.

A variation in the source voltage will cause a variation, though very small, in the base-emitter turn-on voltage of the transistor 11f in the comparator circuit 11 as well as in the breakdown voltage of the constant-voltage diode 10a of the D-A converter circuit 10 which has its own operating resistance. In this case, if the degree of the variation is the same between the transistor 11f and the diode 10a, the predetermined number of revolutions would not vary, but if the variation is greater in the turn-on voltage of the transistor 11f than in the breakdown voltage of the constant-voltage diode 10a and this state continues, the predetermined number of revolutions will vary with the varia-

tion in the source voltage. However, the voltage-compensating resistor 10b connected in series with the constant-voltage diode 10a provides a voltage drop which can act to bring the variation in the breakdown voltage of the constant-voltage diode 10a resulting from the source voltage variation in accord with the variation in the turn-on voltage of the transistor 11f resulting from the same reason. Thus, the restricted number of revolutions of the engine would never be varied with the variations of the source voltage.

Further, in the above-described embodiment of the present invention, a voltage dividing circuit constituted by variable resistor 11a, resistor 11b, etc., is provided so that the reference voltage determined by the predetermined number of revolutions may be set up in accordance with the base-emitter turn-on voltage of the transistor 11f and that the terminal voltage of the capacitor 10f may be made to correspond to that small turn-on voltage. However, it is also possible to set up the reference voltage in accordance with the breakdown voltage of the constant-voltage diode and replace the transistor 11f by this constant-voltage diode. Also, the comparator circuit 12 may be constituted by a differential amplifier, a bridge circuit and other elements.

What is claimed is:

1. A fuel injection control system for an internal combustion engine having a throttle valve and being provided with electromagnetically operable injection valves operated by electronic control means in relation to the operating parameters of said engine,

characterized by the provision of a pulse generator for generating output pulses corresponding in number to the number of revolutions of the engine, and

a blocking circuit comprising:

a waveform shaping circuit including a monostable multivibrator circuit connected to said pulse generator for developing constant length digital output signals of frequency corresponding to the frequency of said generator output pulses,

digital-analog converter circuit means connected to said multivibrator circuit for converting the said constant length digital output signals of said waveform shaping circuit into an analog output voltage varying in magnitude only in correspondence to the frequency of said digital signals,

means for developing a reference voltage corresponding in magnitude only to a predetermined number of revolutions of the engine,

comparator circuit means including said voltage developing means and connected to said converter means for comparing the magnitudes of said reference voltage and analog output voltage for producing an output only when the latter exceeds the former,

a switch adapted to be closed when the throttle valve of the engine is fully or substantially fully closed, and

logical product circuit means connected to said comparator means and said switch and adapted for connection to said injection valves for producing an output signal only when said switch is closed while said comparator means produces its said output to thereby stop the operation of said injection valves.

2. A fuel injection control system as defined in claim 1, wherein said D-A converter circuit comprises a constant-voltage diode, a voltage compensating resistor, further diodes and connected thereto capacitors, said constant-voltage diode being connected in series with said voltage compensating resistor.

3. A fuel injection control system as defined in claim 1, wherein said comparator circuit comprises a voltage dividing variable resistor, a temperature compensating thermistor connected thereto and a transistor, the movable contact of said variable resistor being connected to the base of said transistor.

4. In a fuel injection control system for internal combustion engines having electromagnetically operable injection valves operated by engine speed pulses modified in relation to operating parameters of said engine, the improvement in a blocking circuit for preventing such operation of said injection valves under certain conditions, comprising:

means for developing a reference signal related to a predetermined minimum number of engine revolutions above idling speed and below which minimum said blocking circuit is to be prevented from operating,

means for developing an analog speed signal from said engine speed pulses including means for generating trigger pulses from said engine speed pulses, monostable multivibrator means for effec-

tively shaping said trigger pulses into digital square wave pulses of constant duration and converting means for changing said digital pulses into said analog speed signal,

means for comparing said speed and reference signals to provide an output signal only when said speed signal exceeds said reference signal,

means for developing a third signal representing when said engine throttle valve is substantially fully closed, and

means responsive to said output signal and said throttle valve signal for developing the logical product thereof to cause inhibiting of fuel injection by said injection valves when said output and throttle valve signals are both present.

5. A fuel injection control system as in claim 4 wherein said analog speed signal developing means further includes means connected to the input of said trigger pulse generating means for differentiating said engine speed pulses.

6. A fuel injection control system as in claim 4 wherein said converting means includes a constant voltage diode and connected thereto a voltage compensating resistor for causing the voltage drop across said constant voltage diode to vary in correspondence with variation in said reference signal resulting from source variation.

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