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FUEL INJECTION SYSTEMS FOR INTERNAL COMBUSTION ENGINES

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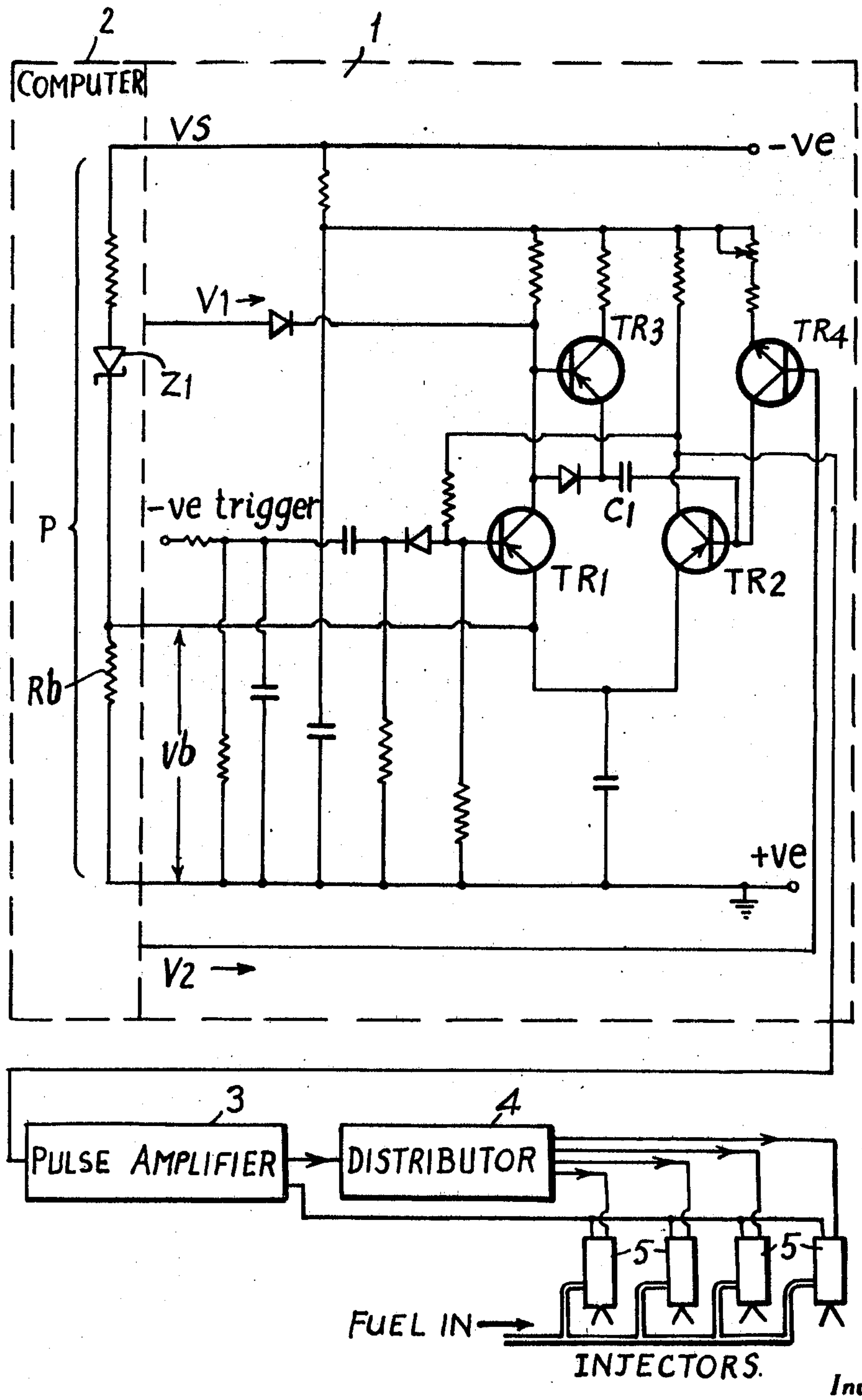

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FUEL INJECTION SYSTEMS FOR INTERNAL COMBUSTION ENGINES

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ABSTRACT OF THE DISCLOSURE

This invention relates to a fuel injection system for internal combustion engines comprising at least one electromagnetically operated fuel injector and a control pulse generator producing pulses for energising said at least one injector, so that the injector or a injector is opened for a period depending on the duration of each of the pulses to pass fuel to the engine, wherein means are provided for compensating for the effect of supply voltage variations on the time that an injector is open in response to a pulse from the control pulse generator, whereby the fuel delivery from the or each injector is substantially independent of variations in said supply voltage.

The present invention relates to fuel injection systems for internal combustion engines and more particularly to improvements in the fuel injection systems such as are described in U.S. Pats. Nos. 3,240,191 and 3,272,187.

Such systems comprise at least one electromagnetically operated fuel injection valve or injector and a control circuit producing pulses for energising said at least one injection valve so that the valve or a valve is open for a period depending on the duration of each of the pulses to pass fuel to the engine. The control circuit is fed with at least one variable voltage which varies as a function of one or more parameters of engine operation and which controls the duration of the pulses produced by the control circuit which are fed to energise the injection valve or valves. As specifically described, the control circuit comprises a monostable multivibrator for producing the electrical pulses and the duration of the pulses is varied by varying two control voltages applied to the timing capacitor circuit of the multivibrator. The two control voltages may be derived from a computer circuit fed with a plurality of signals which respectively vary with variations in different parameters of engine operation.

The fuel injection valves are solenoid operated devices and variations in the voltage of the vehicle battery have been shown to cause a variation in the opening time of the valves, and hence produce a variation in fuel delivery through a valve for any chosen pulse duration or width. Therefore the quantity of fuel fed to the engine is no longer solely determined by variations in engine operating parameters, as is desired.

Thus it has been found that for a fixed injector design, the solenoid current builds up to a greater level during the first millisecond as the battery supply voltage increases, with the result that the injector opens more rapidly at increased supply voltages and delivers more fuel for a given pulse duration or width. This reduction in opening time for any given increase in supply voltage is however the same for all pulse durations or widths.

According to the present invention, means are provided for compensating for the effect of supply voltage variations on the time that an injector is open in response to a pulse from the control pulse generator, whereby the fuel delivery from the or each injector is substantially independent of variations in said supply voltage.

Where the control pulse generator comprises a monostable multivibrator, means are provided for varying a bias applied to the monostable multivibrator with changes in battery supply voltage, in order to keep the fuel delivery more nearly constant, as determined by the control parameters, with variations in the battery supply voltage.

Preferably the bias applied to the monostable multivibrator is derived from a network connected across the voltage supply and according to a feature of the present invention, this network includes a non-linear element such as a saturated diode or a Zener diode.

The invention will now be further described by way of example with reference to the accompanying drawing which is a simplified diagram of one embodiment of fuel injection system according to the present invention.

The system basically comprises a control pulse generator **1**, a computer **2**, a pulse amplifier **3**, a distributor **4** and fuel injectors **5**, and operates generally in the manner described in Pat. No. 3,272,187.

As described in that application, the system is intended for a four cylinder internal combustion engine and a separate fuel injector is provided for each cylinder. The injectors are preferably mounted in the inlet manifold of the engine.

The duration of the pulses fed to energise the injectors, via the amplifier **3** and distributor **4**, is controlled by the control pulse generator **1**, which is in turn controlled by two voltages V1 and V2 derived from the computer **2**. The control pulse generator is triggered by pulses at the firing frequency of the engine and the computer **2** is fed with information supplied by a number of transducers, each responsive to one or more conditions of engine operation. Since the injectors are supplied with fuel at constant pressure, a periodic activation of an injector for a time dependent upon engine operating conditions, as determined by voltages V1 and V2, will meter the fuel supplied to the engine through each injector.

The control pulse generator **1** is basically similar to that shown in FIG. 2 of the aforementioned copending application, and is in the form of a monostable multivibrator circuit comprising transistors TR1 and TR2 and including the timing capacitor C1, which during the timing period is discharged through the constant current transistor TR4. In the steady state or rest condition of the circuit, transistor TR2 is held in the normally ON condition, its base current being supplied by the collector current of the NPN transistor TR4. At this time, transistor TR1 is held OFF by a negative bias voltage V_b supplied from the voltage divider network P connected across the battery supply voltage V_s. In practice, this network may be located in the computer circuit. When a negative-going trigger pulse is applied to the base of transistor TR1, it is turned ON and transistor TR2 is turned OFF. This state of the multivibrator circuit will be maintained until capacitor C1 has discharged through transistor TR4 to a voltage which is sufficient to turn transistor TR2 ON again, whereupon the circuit reverts to its original state and the pulse is terminated. Transistor TR3 provides a low impedance charge path for capacitor C1 when transistor TR2 is turned ON.

The duration of the pulses produced by the multivibrator is determined by the voltage change across capacitor C1 and the discharge current through transistor TR4. The control of the voltage change across capacitor C1 is effected by a control voltage V1 derived from the computer circuit and dependent, for example, upon inlet manifold pressure, engine speed and acceleration. The discharge current through transistor TR4 is varied by control voltage V2 also derived from the computer circuit and varying, for example, in dependence with engine water temperature, air temperature, a starting enrichment signal and an idling enrichment signal.

The operation of the circuit so far described is generally similar to that described in the aforementioned application. However, in that application the bias voltage V*b* applied to the emitter of transistor TR1 is derived from a purely resistive voltage divider connected across the battery supply voltage, and hence the fuel delivery through an injector is substantially dependent on variations in the voltage of the battery supply.

In accordance with the present invention, the voltage divider P connected across the battery supply voltage V*s* includes a non-linear element, such as Zener diode Z1. Since the voltage across the Zener diode remains practically constant as its current increases, the voltage across the remaining resistive parts of the voltage divider increases in proportion faster than the supply voltage, including the bias voltage V*b* which is developed across resistor R*b*. In this way the bias voltage applied to the emitters of transistors TR1 and TR2 is increased at a greater rate than the supply voltage. The voltage change across capacitor C1 which in part determines the pulse width is thus increased at a lesser rate than the supply voltage, so that the width of the pulse energising the fuel injection valves is reduced to compensate for the shorter opening time of the valves at the increased supply voltage. The bias voltage decreases proportionally in a similar manner with decreases in battery supply voltage. Since Zener diodes can be obtained with a wide range of working voltages, a close approximation to the right amount of compensation can be obtained to suit the characteristic of any particular type of fuel injector. In certain cases, for example where it is desired to set up the circuit particularly to provide a lower than normal degree of compensation one or more forward conducting Zener diodes or saturated normal diodes may be used connected in series in the voltage divider network.

By means of the present invention the fuel delivery from the or each fuel injector is substantially independent of variations in the vehicle battery voltage and varies only in accordance with the control voltages applied to the control pulse generator, as determined by parameters of engine operation.

In the embodiment described it will be understood that at a fixed supply voltage V*s* the relationship between the change in charge on the capacitor and the output pulse width is linear. The change in charge on the capacitor is itself determined by the difference between control voltage V1 and bias voltage *Vb*.

I claim:

1. A fuel injection system for internal combustion engines comprising at least one electromagnetically operated fuel injector and a control pulse generator producing pulses for energising said at least one injector, so that the injector or a injector is opened for a period depending on the duration of each of the pulses to pass fuel to the engine, wherein means are provided for compensating for the effect of supply voltage variations on the time that an injector is open in response to a pulse from the control pulse generator, said compensating means comprising means for varying a bias voltage applied to the control pulse generator by a greater percentage in like polarity than a percentage variation of the total supply voltage, whereby the quantity of fuel injected by the or each injector is substantially independent or variations in said supply voltage.

2. A system is claimed in claim **1**, wherein the control pulse generator comprises a monostable multivibrator and means are provided for varying a bias applied to the monostable multivibrator with changes in the supply voltage.

3. A system as claimed in claim **2**, wherein the bias applied to the monostable multivibrator is derived from a network connected across the voltage supply.

4. A system as claimed in claim **3**, wherein said network includes a non-linear element such as a saturated diode or a Zener diode.

5. A system as claimed in claim **3**, including a computer circuit fed with a plurality of signals which respectively vary with variations in different parameters of engine operation and which provides at least one variable voltage fed to control the duration of the pulses produced by the control pulse generator.

6. A system as claimed in claim **5**, wherein said network connected across the supply voltage forms a part of the computer circuit.

7. A system as claimed in claim **2**, wherein the monostable multivibrator includes a timing capacitor and is so arranged that the voltage change across the timing capacitor, which in part determines the pulse width produced by the multivibrator, is increased at a lesser rate than an increase in the supply voltage, so that the width of the pulses energising the fuel injector or injectors is reduced to compensate for the shorter opening time of an injector which occurs at an increased supply voltage.

8. In a fuel injection system for internal combustion engines comprising at least one electromagnetically operated fuel injector and a control pulse generator producing pulses for energising said at least one injector, so that the injector or a injector is opened for a period depending on the duration of each of the pulses to pass fuel to the engine, the improvement which comprises providing means for compensating for the effect of supply voltage variations on the time that an injector is open in response to a pulse from the control pulse generator, said compensating means comprising means for varying a bias voltage applied to the control pulse generator by a greater percentage in like polarity than a percentage variation of the total suply voltage, whereby the quantity of fuel delivered by the or each injector is substantially independent of variations in said supply voltage.

9. In a system as claimed in claim **8**, the control pulse generator comprises a monostable multivibrator, means are provided for varying a bias applied to the monostable multivibrator with changes in the supply voltage and the bias applied to the monostable multivibrator is derived from a network connected across the voltage supply and including a non-linear element.

10. In a system as claimed in claim **9**, a computer circuit fed with a plurality of signals which respectively vary with variations in different parameters of engine operation and which provides at least one variable voltage fed to control the duration of the pulses produced by the control pulse generator.

11. In a system as claimed in claim **9**, the monostable multivibrator includes a timing capacitor and is so arranged that the voltage change across the timing capacitor, which in part determines the pulse width produced by the multivibrator, is increased at a lesser rate than an increase in the supply voltage, so that the width of the pulses energising the fuel injector or injectors is reduced to compensate for the shorter opening time of an injector which occurs at an increased supply voltage.

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