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

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[52] **U.S. Cl.** .... **123/32 EA,** 123/32 R, 123/139 E
[51] **Int. Cl.** **F02b 3/00,** F02m 39/00
[58] **Field of Search** .... 123/32 EA

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[57] **ABSTRACT**

A system for electrically controlling the fuel injection in an internal combustion engine having means for delivering output voltages representative of various parameters indicative of the operating conditions of the engine, a pulse modulator connected to the above means for generating a pulse signal having a pulse width corresponding to the sum of the input voltages applied from these means, and means for sequentially distributing the pulse signal delivered from the pulse modulator to solenoid operated fuel injection valves associated with individual cylinders of the engine in a predetermined order for causing the fuel injection valves to inject fuel in an amount corresponding to the pulse width of the pulse signal. The system is provided with means for delivering a voltage representative of a variation relative in time to the negative pressure in the air intake manifold during the acceleration of the engine. The width of the pulse signal is modified by this voltage and the amount of fuel injected into each individual cylinder during the acceleration of the engine is controlled by this modified pulse signal so as to improve the acceleration characteristics of the engine.

8 Claims, 16 Drawing Figures

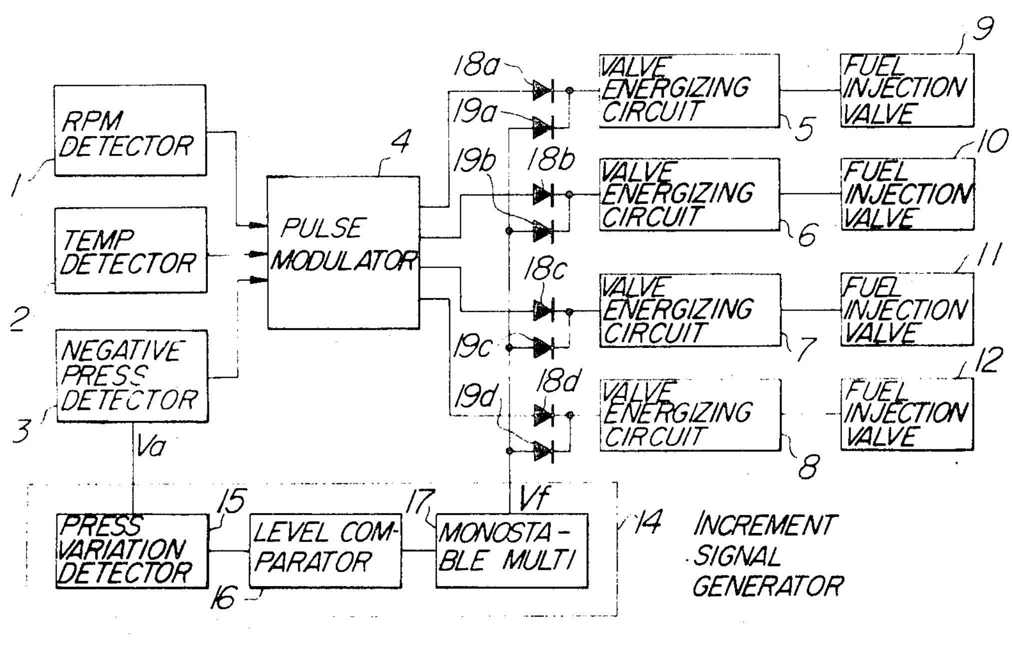


FIG. 1

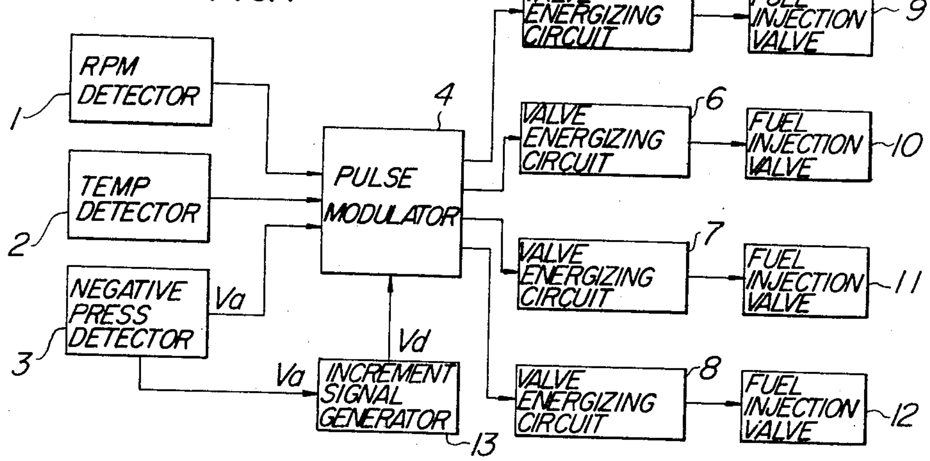


FIG. 2

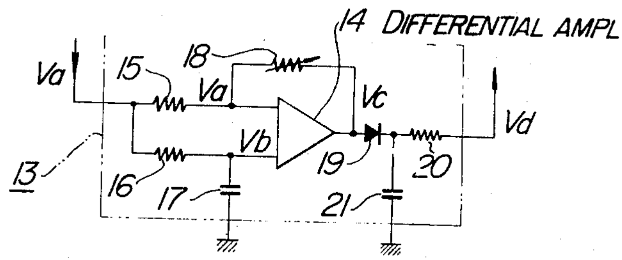
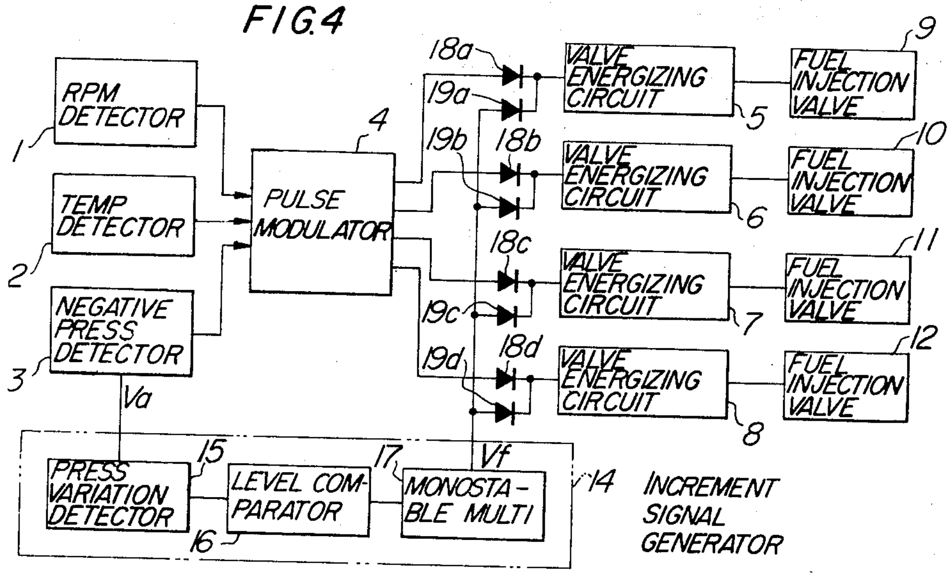


FIG. 4



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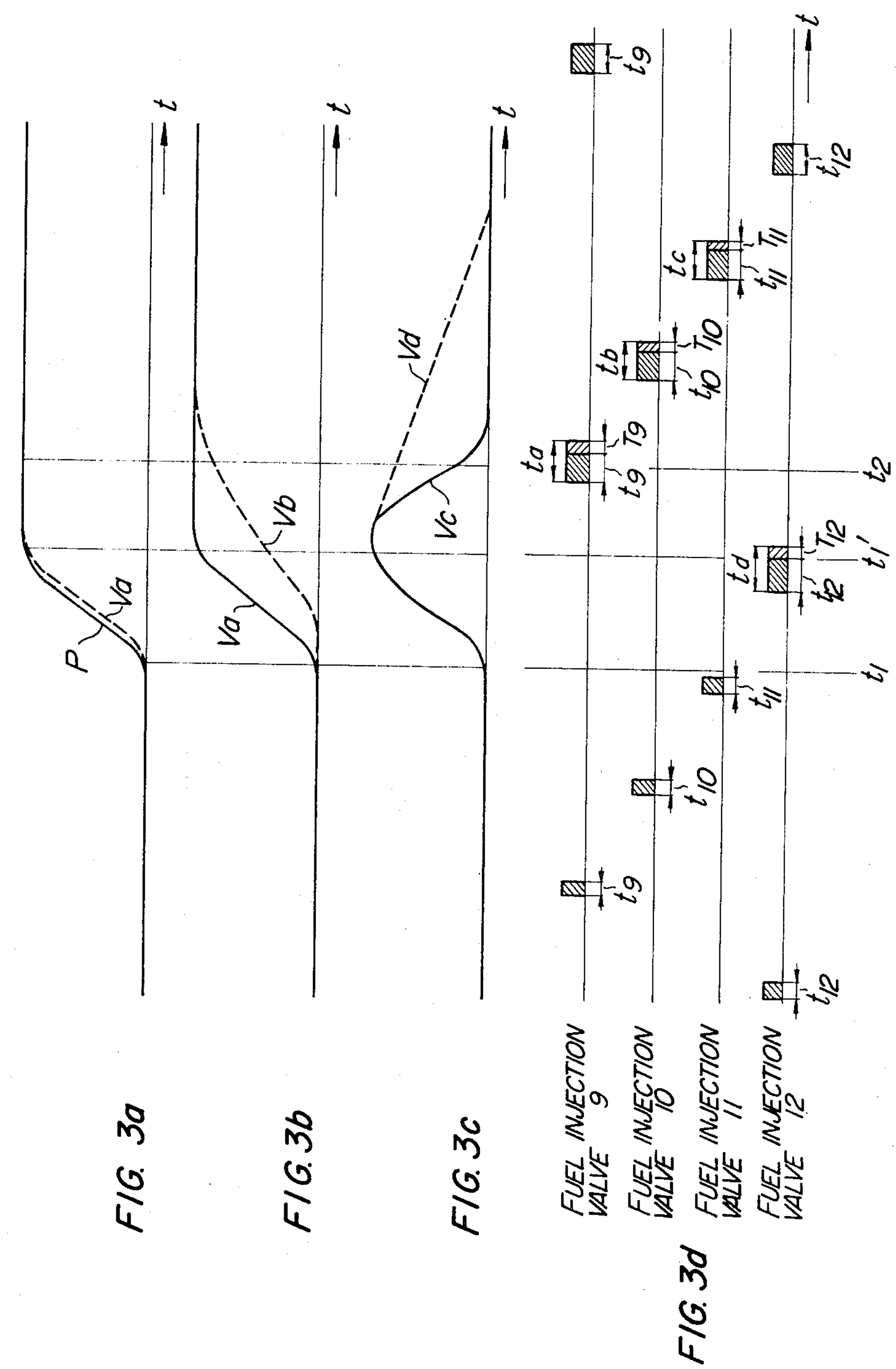

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FIG. 5

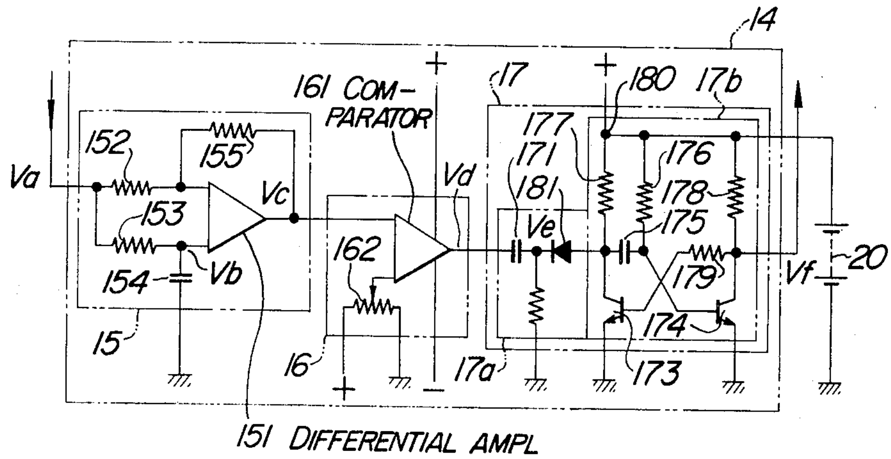
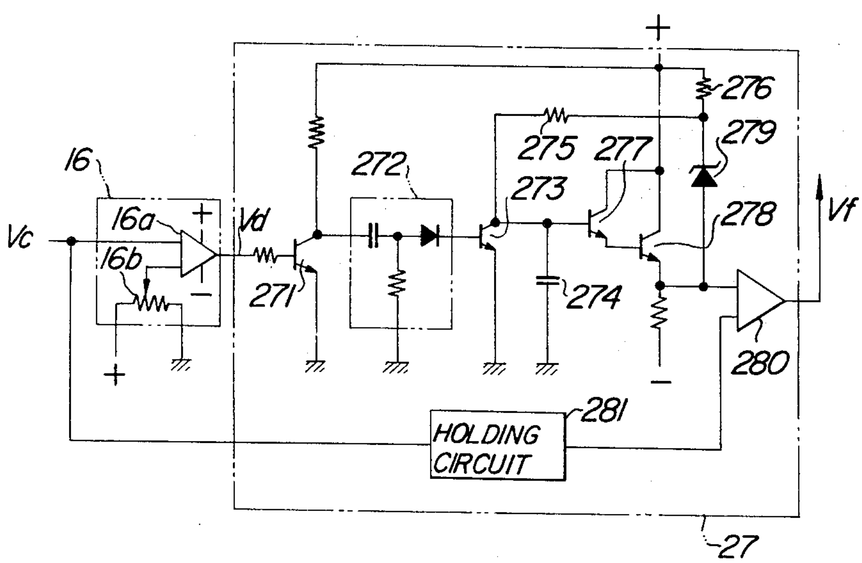


FIG. 7



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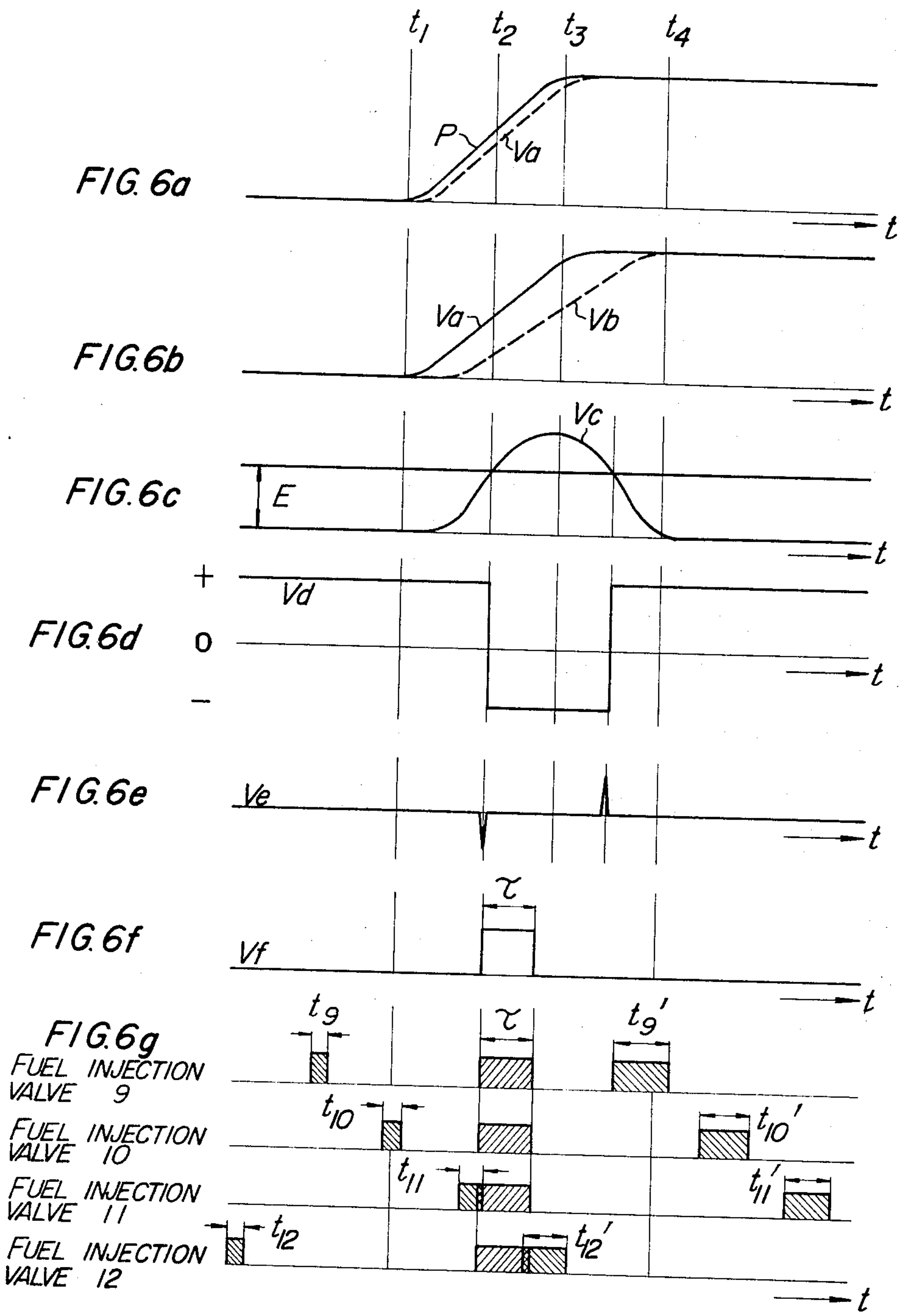

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ELECTRICAL FUEL INJECTION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to a system for electrically controlling the fuel injection in an internal combustion engine having means for delivering output voltages representative of various parameters indicative of the operating conditions of the engine, means connected to the above means for generating a pulse signal having a pulse width corresponding to the sum of the input voltages applied from these means, means for sequentially distributing the pulse signal delivered from the pulse generating means to electromagnetic or solenoid operated fuel injection valves associated with individual cylinders of the engine in a predetermined order for causing the fuel injection valves to inject fuel in an amount corresponding to the pulse width of the pulse signal, and the means functioning to increase the amount of injected fuel during the acceleration of the engine.

2. Description of the Prior Art

In conventional fuel injection control systems of this kind, the negative pressure in the air intake manifold of the engine is generally employed as one of the parameters indicative of the operating conditions of the engine. In such a system, a pressure responsive means such as a diaphragm detects a variation in the negative pressure in the air intake manifold and converts same into a mechanical displacement. A detector for the negative pressure in the air intake manifold detects this mechanical displacement and converts same into a voltage. The output voltage of the negative pressure detector is then applied to a pulse modulator so that the pulse width of the pulse signal delivered from the pulse modulator for energizing the solenoid operated fuel injection valves is varied depending on the magnitude of the output voltage delivered from the negative pressure detector. This causes a variation in the length of time during which each individual solenoid operated fuel injection valve is kept in its open position thereby controlling the amount of injected fuel.

In the conventional fuel injection control system, depression of the accelerator pedal for the purpose of acceleration results in an abrupt increase in the pressure within the air intake manifold and the pressure responsive means responds to this increase in the pressure with the result that the output voltage of the negative pressure detector is correspondingly increased. In response to the application of this voltage to the pulse modulator, the pulse width of the pulse signal is increased so that the solenoid operated fuel injection valves are kept in the open position for a greater length of time for injecting an increased amount of fuel and this increases the r.p.m. of the engine thereby accelerating the engine. However, with the conventional arrangement in which the pulse width of the pulse signal is increased merely in response to the increment in the negative pressure in the air intake manifold in the manner described above for increasing the amount of injected fuel during the acceleration of the engine, it has been impossible to obtain the desired satisfactory acceleration characteristics really responsive to the depression of the accelerator pedal.

SUMMARY OF THE INVENTION

It is therefore a primary object of the present invention to solve the above problem by providing means for injecting an additional amount of fuel during the acceleration of the engine besides the injection of an increased amount of fuel corresponding to the increment in the negative pressure in the air intake manifold.

In accordance with the present invention, there is provided, in an electrical fuel injection control system for an internal combustion engine having means for detecting a plurality of parameters indicative of the operating conditions of the engine and delivering output voltages representative of the parameters, a pulse modulator connected to said means for generating a pulse signal having a pulse width corresponding to the sum of the input voltages in response to the application of these input voltages, and means for sequentially distributing the pulse signal delivered from said pulse modulator to solenoid operated fuel injection valves associated with individual cylinders of the engine in a predetermined order for causing said solenoid operated fuel injection valves to inject fuel in an amount corresponding to the pulse width of said pulse signal, means for detecting a variation relative to time of the negative pressure in the air intake manifold during the acceleration of the engine and applying a voltage representative of such variation to said pulse modulator so as to add the latter voltage to the voltages representative of the parameters indicative of the operating conditions of the engine thereby to produce a modified pulse signal having a pulse width corresponding to the sum of these voltages in said pulse modulator for distribution to said solenoid operated fuel injection valves.

Thus, during the acceleration of the engine, the pulse signal representative of the parameters indicative of the operating conditions of the engine is modified by the signal representative of a variation relative to time of the negative pressure in the air intake manifold of the engine, and an increased amount of fuel is injected into the engine cylinders. It is therefore possible to obtain the desired acceleration characteristics really responsive to the depression of the accelerator pedal.

The above and other objects, features and advantages of the present invention will be apparent from the following detailed description taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

FIG. 1 is a block diagram showing the structure of an embodiment of the present invention.

FIG. 2 is an electrical connection diagram of the increment signal generator in the embodiment shown in FIG. 1.

FIGS. 3*a*, 3*b*, 3*c* and 3*d* show voltage waveforms appearing at various parts of the system shown in FIGS. 1 and 2.

FIG. 4 is a block diagram showing the structure of another embodiment of the present invention.

FIG. 5 is an electrical connection diagram of the increment signal generator in the embodiment shown in FIG. 4.

FIGS. 6*a*, 6*b*, 6*c*, 6*d*, 6*e*, 6*f* and 6*g* show voltage waveforms appearing at various parts of the system shown in FIGS. 4 and 5.

FIG. 7 is an electrical connection diagram of another form of the pulse generator shown in FIG. 4.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The present invention will be described with regard to its application to an internal combustion engine having four cylinders by way of example, but it is in no way limited to such an engine.

Referring now to FIG. 1, an embodiment of the present invention includes an engine r.p.m. detector 1 which generates a d.c. voltage representative of the r.p.m. of the engine, a temperature detector 2 which detects the temperature of the engine on the basis of the temperature of cooling water, lubricating oil, etc. and generates a d.c. voltage representative of the temperature of the engine, and a negative pressure detector 3 which generates a d.c. voltage representative of the negative pressure in the air intake manifold of the engine. Although three means described above are provided in the present embodiment for detecting the three parameters, that is, the engine r.p.m., engine temperature and negative pressure in the air intake manifold, out of various parameters indicative of the operating conditions of the engine which are at least required for controlling the fuel injection in the engine, the system may include additional detectors as required which detect the throttle valve opening and any other parameters indicative of the operating conditions of the engine and generate d.c. voltages representative of the detected values. The output voltages of the three detectors 1, 2 and 3 are applied to a pulse modulator 4 together with an output voltage of an increment signal generator described later. In response to the application of these input voltages, the pulse modulator 4 generates a pulse signal having a pulse width corresponding to the sum of these input voltages, hence the amount of injected fuel, and this pulse signal is distributed sequentially to a plurality of fuel injection valve energizing circuits 5, 6, 7 and 8 associated with the respective cylinders in accordance with a predetermined order of fuel injection in these cylinders. The pulse signal having a pulse width corresponding to the d.c. voltage level can be obtained by the use of a differential amplifier similar to that described in copending U. S. Pat. application Ser. No. 846699 filed by the same inventor. The pulse signal distributed from the pulse modulator 4 is subjected to current amplification by amplifiers in the respective fuel injection valve energizing circuits 5, 6, 7 and 8 to be applied to the energizing coils or solenoids (not shown) of electromagnetic or solenoid operated fuel injection valves 9, 10, 11 and 12 associated with the first, second, third and fourth cylinders of the engine respectively. In response to the application of the pulse signal or current to the solenoids, the solenoid operated fuel injection valves 9, 10, 11 and 12 are urged to the open position for a limited length of time equal to the pulse width so as to inject fuel supplied under pressure from the fuel pump (not shown) toward the intake valves of the individual cylinder. Thus, the amount of injected fuel corresponds to the pulse width of the pulse signal.

An increment signal generator is connected between the negative pressure detector 3 and the pulse modulator 4. The structure of the increment signal generator 13 will be described in detail with reference to FIG. 2. Referring to FIG. 2, an output voltage Va of the negative pressure detector 3 is applied through an input resistor 15 to one of the input terminals of a differential amplifier 14, while this same output voltage Va of the negative pressure detector 3 is delayed by a delay circuit composed of a resistor 16 and a capacitor 17 to provide a voltage Vb and this voltage Vb is applied to the other terminal of the differential amplifier 14. The delay time is determined by the time constant of the delay circuit composed of the resistor 16 and the capacitor 17. A variable feedback resistor 18 is connected between one of the input terminals and the output terminal of the differential amplifier 14 as shown. The differential amplifier 14 delivers a voltage Vc which represents the difference between the two input voltages Va and Vb. A diode 19, a resistor 20 and a capacitor 21 constitute a delay circuit. This delay circuit acts to delay the output voltage Vc of the differential amplifier 14 by a delay time which is determined by the time constant of the combination consisting of the resistor 20 and the capacitor 21 thereby to provide a voltage Vd. This voltage Vd is applied to the pulse modulator 4.

The voltage waveforms appearing at various parts of the system shown in FIGS. 1 and 2 have a phasic relationship as shown in FIGS. 3*a*, 3*b*, 3*c* and 3*d* in which such voltages are plotted on the same time axis. In the horizontal axis representing time t_1 depression of the accelerator pedal is started at time t_1 and is completed at time t_2. FIG. 3*a* shows the relation between a curve P representing the variation relative to time of the negative pressure in the air intake manifold in response to the depression of the accelerator pedal and the voltage Va applied to one of the input terminals of the differential amplifier 14. FIG. 3*b* shows the relation between this voltage Va and the voltage Vb applied to the other input terminal of the differential amplifier 14. FIG. 3*c* shows the relation between the output voltage Vc of the differential amplifier 14 and the voltage Vd applied to the pulse modulator 4, this voltage Vd being obtained by delaying the voltage Vc. FIG. 3*d* shows the pulse signal delivered from the pulse modulator 4, and the pulses applied to the solenoid operated fuel injection valves 9, 10, 11 and 12 are serially shown therein.

The operation of the system of the present invention having the above structure will be described with reference to FIGS. 3*a*, 3*b*, 3*c* and 3*d*. Suppose that the negative pressure in the air intake manifold has a value of, for example, −500 mmHg before the depression of the accelerator pedal. When now the accelerator pedal is depressed at time t_1 in FIG. 3*a*, the negative pressure increases quickly with time as shown by the curve P in FIG. 3*a* until finally it attains a level substantially equal to the atmospheric pressure at time t_1' before time t_2 is reached. The output voltage Va of the negative pressure detector 3 responsive to the negative pressure in the air intake manifold starts to increase with a slight delay in relation to the curve P as shown, and this voltage Va is applied to one of the input terminals of the differential amplifier 14. The voltage Vb shown in FIG. 3*b* is obtained by delaying the voltage Va by the delay time which is determined by the time constant of the combination consisting of the resistor 16 and the capacitor 17, and this voltage Vb is applied to the other input terminal of the differential amplifier 14. In response to the application of these two voltages Va and Vb, the differential amplifier 14 delivers the voltage Vc shown in FIG. 3*c* representing the difference between these two voltages Va and Vb. In the present embodiment, this voltage Vc has a peak value in the vicinity of time t_1', but the time at which the peak value appears can be freely controlled by suitably varying the gradient of the rising slope of the voltage Vb, that is, by suitably selecting the time constant of the combination consisting of the resistor **16** and the capacitor **17**. Further, the magnitude of the peak can be freely selected by suitably varying the resistance value of the variable feedback resistor **18**. The voltage Vd obtained by delaying this voltage Vc by the delay circuit composed of the diode **19**, the resistor **20** and the capacitor **21** has a waveform as shown in FIG. 3c in which it will be seen that the voltage waveform has a gradually falling slope extending from the peak of the voltage Vc. The degree of this extension is determined by the time constant of the combination consisting of the resistor **20** and the capacitor **21**, and this time constant is determined in dependence on the increment of the amount of injected fuel required during the acceleration. The voltage Vd is applied to the pulse modulator **4**. In the starting time of the engine, the pulse modulator **4** generates a pulse signal having a pulse width corresponding to the sum of the output voltages of the three detectors **1**, **2** and **3** and the voltage Vd, while in the steady operating state of the engine after it has been started, the pulse modulator **4** generates a pulse signal having a pulse width corresponding to the sum of the output voltages of the r.p.m. detector **1** and negative pressure detector **3** and the voltage Vd. The function of the temperature detector **2** is to ensure satisfactory starting of the engine when the engine is started from a cold condition, and arrangements are made so that the output voltage of the temperature detector **2** may be zero or may not be applied to the pulse modulator **4** in the steady operating state of the engine.

Description given hereunder will be directed to the operation of the system when the engine is operating in the steady state. In the steady operating state of the engine, the pulse generator **4** generates a pulse signal as shown in FIG. 3*d*. In FIG. 3*d*, t_9 represents the pulse width of a pulse applied to the solenoid operated fuel injection valve **9** for the first cylinder at time earlier than time t_1 at which the accelerator pedal is depressed, and this pulse width corresponds to the sum of the output voltages of the r.p.m. detector **1** and negative pressure detector **3**. Pulses applied after time t_1 at which the accelerator pedal was depressed have respective pulse widths t_9' and t_9'' which are larger than the pulse width t_9 as seen in FIG. 3*d*. Similarly, the pulse width increases from t_{10} to t_{10}' in the case of the solenoid operated fuel injection valve **10** for the second cylinder, from t_{11} to t_{11}' in the case of the solenoid operated fuel injection valve **11** for the third cylinder, and from t_{12} to t_{12}' and t_{12}'' in the case of the solenoid operated fuel injection valve **12** for the fourth cylinder. However, in accordance with this invention, after time t_1 or after the accelerator pedal has been depressed, the pulse width of the pulses appearing within a limited period of time is increased even further by the application of the output voltage Vd of the increment signal generator **13** to the pulse modulator **4**. The increment is represented by T_{12} in the case of the solenoid operated fuel injection valve **12** for the fourth cylinder, T_9 in the case of the solenoid operated fuel injection valve **9** for the first cylinder, T_{10} in the case of the solenoid operated fuel injection valve **10** for the second cylinder, and T_{11} in the case of the solenoid operated fuel injection valve **11** for the third cylinder. After this limited period of time, no increase in the pulse width due to the outpt voltage Vd of the increment signal generator **13** is made, and the pulse width is dependent upon the sum of the output voltages of the r.p.m. detector **1** and negative pressure detector **3**. The increment is gradually reduced in the order of T_{12}, T_9, T_{10} and T_{11} along the falling slope of the waveform of the output voltage Vd of the increment signal generator **13** and is dependent on the gradually lowering voltage level of the voltage Vd. After time T_1 or after the accelerator pedal has been depressed, the pulses of pulse widths $t_d = (t_{12}' + T_{12})$, t_{12}'', ... are successively applied to the solenoid operated fuel injection valve **12** for the fourth cylinder, the pulses of pulse widths $t_a = (t_9' + T_9)$, t_9'', ... are successively applied to the solenoid operated fuel injection valve **9** for the first cylinder, the pulses of pulse widths $t_b = (t_{10}' + T_{10})$, ... are successively applied to the solenoid operated fuel injection valve **10** for the second cylinder, and the pulses of pulse widths $t_c = (t_{11}' + T_{11})$, ... are successively applied to the solenoid operated fuel injection valve **11** for the third cylinder so that these fuel injection valves are urged to the open position for a limited length of time equal to the pulse width and fuel in an amount corresponding to the length of time of the open position of the valve is injected into each individual cylinder. The time constant of the combination consisting of the resistor **16** and the capacitor **17**, the resistance value of the variable feedback resistor **18**, and the time constant of the combination consisting of the resistor **20** and the capacitor **21** in the increment signal generator **13** may be suitably selected to set the value of the increments T_{12}, T_9, T_{10} and T_{11} as required and to determine the extent until which the increments due to the voltage Vd are to be applied to the pulses after time t_1 at which the accelerator pedal was depressed.

The means for deriving the voltage representative of the variation relative to time of the negative pressure in the air intake manifold during the acceleration of the engine is not limited to the increment signal generator **13** of the structure described above, and may be a combination of a differentiator composed of a capacitor and a resistor and an amplifier or a combination of a mechanical element such as a diaphragm and an electrical element such as a differential transformer.

FIG. 4 is a block diagram showing the structure of another embodiment of the present invention. In the embodiment shown in FIG. 1, a pulse signal representative of a variation relative to time of the negative pressure in the air intake manifold is applied from an increment signal generator to a pulse modulator. The embodiment shown in FIG. 4 differs from the embodiment shown in FIG. 1 in that such a pulse signal is directly and simultaneously applied to fuel injection valve energizing circuits associated with individual cylinders. More precisely, a pulse signal having a pulse width corresponding to the sum of voltages representative of a plurality of parameters indicative of the operating conditions of the engine is distributed from a pulse modulator to the fuel injection valve energizing circuits, and independently of this pulse signal, another pulse signal representative of a variation relative to the time of the negative pressure in the air intake manifold is applied to the fuel injection valve energizing circuits simultaneously in addition to the former plus signal during the acceleration of the engine. By this arrangement, fuel in an amount corresponding to the degree of depression of the accelerator pedal is supplied to all of the cylinders during the accelerative of the engine regardless of the depression timing of the accelerator pedal, thereby remarkably improving the acceleration characteristics.

Referring to FIG. 4 in which like reference numerals are used to denote like parts appearing in FIG. 1, an engine r.p.m. detector **1**, an engine temperature detector **2** and a negative pressure detector **3** are connected to a pulse modulator **4**, and a pulse signal is distributed from the pulse modulator **4** to fuel injection valve energizing circuits **5, 6, 7** and **8** through diodes **18***a*, **18***b*, **18***c* and **18***d* each forming a part of an OR gate. After having been subjected to current amplification in the energizing circuits **5, 6, 7** and **8**, the pulse signal is applied to the exciting coils or solenoids (not shown) of electromagnetic or solenoid operated fuel injection valves **9, 10, 11** and **12** associated with the first, second, third and fourth cylinders of the engine respectively. In response to the application of the pulse signal to the solenoid, each fuel injection valve is urged to the open position for a limited length of time equal to the pulse width for injecting the fuel supplied under pressure from the fuel pump (not shown) toward the intake valve of the associated, cylinder. The amount of injected fuel is proportional to the pulse width of the pulse signal. An increment signal generator **14** is connected to the negative pressure detector **3** and includes a negative pressure variation detector **15**, a level comparator **16**, a monostable timing circuit or pulse generator **17** and a power supply **20** (FIG. 5).

The structure of the increment signal generator **14** will be described in detail with reference to FIG. 5. The negative pressure variation detector **15** includes a differential amplifier **151**. The output voltage Va of the negative pressure detector **3** is applied through an input resistor **152** to one of the input terminals of the differential amplifier **151**, while this same output voltage Va of the negative pressure detector **3** is delayed by a certain delay time by a delay circuit composed of a resistor **153** and a capacitor **154** to obtain a voltage Vb which is applied to the other input terminal of the differential amplifier **151**. The delay time is determined by the time constant of the combination consisting of the resistor **153** and the capacitor **154**. A variable feedback resistor **155** is connected between the output terminal and one of the input terminals of the differential amplifier **151** as shown. The differential amplifier **151** delivers a voltage Vc which represents the difference between these two input voltages Va and Vb. The level comparator **16** includes a comparator **161** which compares the output voltage Vc of the differential amplifier **151** with a reference voltage E applied from a variable resistor **162** and generates an output pulse Vd of negative polarity over a period of time in which the voltage Vc is higher than the reference voltage E. The pulse generator **17** is composed of a differentiator **17***a* and a monostable multivibrator **17***b*. The differentiator **17***a* includes a capacitor **171**, a resistor **172** and a diode **181** and acts to differentiate the output pulse Vd delivered from the level comparator **16**. The monostable multivibrator **17***b* includes a pair of transistors **173** and **174**, a capacitor **175** and a resistor **176** constituting a timing element, and resistors **177, 178** and **179**. In response to the application of a negative trigger pulse from the differentiator **17***a*, the monostable multivibrator **17***b* delivers an output pulse Vf of positive polarity having a constant pulse duration τ. This constant pulse duration τ can be varied by varying the time constant of the timing element consisting of the capacitor **175** and the resistor **176** or by varying the voltage applied to a terminal **180**. The output pulse Vf delivered from the monostable multivibrator **17***b* is applied through diodes **19***a*, **19***b*, **19***c* and **19***d* each forming a part of the OR gate to the respective fuel injection valve energizing circuits **5, 6, 7** and **8**, and after having been subjected to current amplification therein, the pulse Vf is applied to the solenoid operated fuel injection valves **9, 10, 11** and **12** simultaneously.

The voltage waveforms appearing at various parts of the system shown in FIGS. **4** and **5** have a phasic relationship as shown in FIGS. **6***a*, **6***b*, **6***c*, **6***d*, **6***e*, **6***f* and **6***g* in which such voltages are plotted on the same time axis. In the horizontal axis representing time t_1 depression of the accelerator pedal is started at time t_1 and is completed at time t_4. FIG. **6***a* shows the relation between a curve P representing the variation relative to time of the negative pressure in the air intake manifold in response to the depression of the accelerator pedal and the voltage Va applied to one of the input terminals of the differential amplifier **151**. FIG. **6***b* shows the relation between this voltage Va and the voltage Vb applied to the other input terminal of the differential amplifier **151**. FIG. **6***c* shows the relation between the reference voltage E and the output voltage Vc of the differential amplifier **151** applied to the input terminal of the comparator **161**. FIG. **6***d* shows the output pulse Vd delivered from the comparator **161**. FIG. **6***e* shows the differentiated pulses obtained by differentiating the pulse Vd by the differentiator **17***a*. FIG. **6***f* shows the output pulse Vf delivered from the pulse generator **17**. FIG. **6***g* shows the pulse signal applied to the solenoid operated fuel injection valves **9, 10, 11** and **12**.

The operation of the system of the present invention having the above structure will be described with reference to FIGS. **6***a* to **6***g*. Suppose that the negative pressure completed. the air intake manifold has a value of, for example, −500 mmHg before the depression of the accelerator pedal. When now the accelerator pedal is depressed at time t_1 in FIG. **6***a*, the negative pressure quickly increases with time as shown by the curve P until finally it attains a level substantially equal to atmospheric pressure at time t_3 before time t_4 at which the depression of the accelerator pedal is competed. The output voltage Va of the negative pressure detector **3** responsive to the negative pressure in the air intake manifold starts to increase in slightly delayed relation from the curve P as shown, and this voltage Va is applied to one of the input terminals of the differential amplifier **151**. The voltage Vb shown in FIG. **6***b* is obtained by delaying the voltage Va by the delay time which is determined by the combination consisting of the resistor **153** and the capacitor **154**, and this voltage Vb is applied to the other input terminal of the differential amplifier **151**. In response to the application of these two voltages Va and Vb, the differential amplifier **151** delivers the voltage Vc shown in FIG. **6***c* representing the difference between these two voltages Va and Vb. In the present embodiment, this voltage Vc has a peak value in the vicinity of time t_3, but the time at which this peak value appears can be freely controlled by varying the gradient of the rising slope of the voltage Vb, that is, by suitably selecting the time constant of the combination consisting of the resistor **153** and the capacitor **154**. Further, the magnitude of the peak can be freely selected by suitably varying the resistance value of the variable feedback resistor **155.** In response to the application of the output voltage Vc of the differential amplifier **151** and the reference voltage E supplied from the variable resistor **162** to the input terminals of the comparator **161**, the pulse Vd of negative polarity starts to appear from the comparator **161** at time t_2 and lasts for a period of time during which the voltage Vc is higher than the reference voltage E as seen in FIGS. *6c* and *6d*. This pulse Vd is differentiated by the differentiator **17***a* to provide the pulses of negative and positive polarity shown in FIG. *6e*, and this negative pulse is used to trigger the monostable multivibrator **17**b. As a result, the output pulse Vf of constant pulse duration τ shown in FIG. *6f* is delivered from the monostable multivibrator **17***b*. This output pulse Vf is applied through the diodes **19***a*, **19***b*, **19***c* and **19***d* to the fuel injection valve energizing circuits **5, 6, 7** and **8,** and after having been subjected to current amplification therein, it is simultaneously applied to the solenoid operated fuel injection valves **9, 10, 11** and **12.** In FIG. *6g*, this pulse is shown by a rightwardly upwardly extending hatching. By this arrangement, the solenoid of each of the solenoid operated fuel injection valves **9, 10, 11** and **12** is energized independently of the pulse signal distributed from the pulse modulator **4** for the regular injection of fuel and also independently of the normal fuel injection timing. Thus, each of the solenoid operated fuel injection valve **9, 10, 11** and **12** is urged to the open position for a limited length of time equal to the duration or pulse width τ of the pulse Vf to inject fuel in an amount corresponding to the pulse width τ. The amount of injected fuel can be freely regulated. To do this, the time constant of the timing element composed of the capacitor **175** and the resistor **176** or the voltage applied to the terminal **180** of the monostable multivibrator **17***b* may be varied depending on, for example, the r.p.m. of the engine or the negative pressure in the air intake manifold to vary the pulse width τ of the output pulse Vf thereby regulating the amount of injected fuel. The fuel injected by the solenoid operated fuel injection valves **9, 10, 11** and **12** is drawn into the cylinders as soon as the intake valves are opened thereby accelerating the engine quickly. Since, in this case, the intake valves are opened sequentially, the fuel injected toward the cylinders of which their intake valves are still in the closed position can be sufficiently vaporized while remaining within the intake manifold although the staying period of time is very short.

The regular fuel injection is carried out independently of the injection of the increased amount of fuel due to the output pulse Vf delivered from the monostable multivibrator **17***b* during the acceleration of the engine. That is, due to the increase in the output voltage of the negative pressure detector **3** in response to the acceleration of the engine, pulses as shown in FIG. *6g* are delivered from the pulse modulator **4** to be applied to the solenoid operated fuel injection valves **9, 10, 11** and **12.** As seen in FIG. *6g*, the pulse applied to the solenoid operated fuel injection valve **9** for the first cylinder at a time earlier than time t_1 at which the accelerator pedal is depressed has a pulse width t_9, and the next pulse applied after time t_1 at which the accelerator pedal was depressed has a pulse width t_9' which is larger than t_9. Similarly, the pulse width increases from t_{10} to t_{10}' in the case of the solenoid operated fuel injection valve **10** for the second cylinder, from t_{11} to t_{11}' in the case of the solenoid operated fuel injection valve **11** for the third cylinder, and from t_{12} to t_{12}' in the case of the solenoid operated fuel injected valve **12** for the fourth cylinder.

FIG. 7 shows another form of the pulse generator shown in FIG. **5.** The pulse generator **27** shown in FIG. 7 is connected to a level comparator **16** same as that shown in FIG. 5 and includes a transistor **271** for polarity inversion, a differentiator **272** which differentiates a pulse applied from the transistor **271** and supplies a differentiated pulse of positive polarity to the next stage, a transistor **273**, a capacitor **274**, resistors **275** and **276**, a pair of Darlington connected emitter follower transistors **277** and **278**, a Zener diode **279**, a comparator **280**, and a holding circuit **281** for holding the peak value of the output voltage Vc of the negative pressure variation detector **25** and applying this voltage to one of the input terminals of the comparator **280.**

In operation, the level comparator **16** applies an output pulse Vd of negative polarity as shown in FIG. *6d* to the pulse generator **27.** In the pulse generator **27,** the transistor **271** converts the negative pulse Vd into a positive pulse and applies this positive pulse to the differentiator **272.** The differentiator **272** differentiates this positive pulse and applies a differentiated pulse of positive polarity to the base of the transistor **273** so that the transistor **273** conducts to short-circuit the capacitor **274.** As a result, the transistors **277** and **278** are cut off and a negative potential appears at the emitter of the transistor **278.** The positive differentiated pulse applied to the base of the transistor **273** disappears in a very short period of time and the transistor **273** is cut off again. The capacitor **274** starts to be charged through the resistors **275** and **276** to a constant voltage level determined by the Zener diode **279.** As the voltage is charged across the capacitor **274,** the transistors **277** and **278** are biased into the saturation region and the emitter voltage of the transistor **278** is increased with an inclination corresponding to the time constant of the combination consisting of the capacitor **274** and the resistors **275** and **276.** This emitter voltage of the transistor **278** is applied to one of the input terminals of the comparator **280.** On the other hand, the holding circuit **281** holds the peak value of the output voltage Vc delivered from the negative pressure variation detector **15** and the voltage held therein is applied to the other input terminal of the comparator **280.** The comparator **280** compares the emitter voltage of the transistor **278** with the output voltage delivered from the holding circuit **281** and delivers an output pulse only when the former is smaller than the latter. Since the emitter voltage of the transistor **278** increases along a fixed gradient, the pulse width of the output pulse delivered from the comparator **280** is dependent upon the voltage value of the output from the holding circuit **281,** hence the peak value of the variation relative to time of the negative pressure in the air intake manifold. The output pulse delivered from the comparator **280** is applied through the diodes **19***a*, **19***b*, **19***c* and **19***d* to the fuel injection valve energizing circuits **5, 6, 7** and **8,** and after having been subjected to current amplification therein, the pulse is applied to the solenoid operated fuel injection valves **9, 10, 11** and **12** simultaneously in the manner described with reference to FIGS. **4** and **5.** Although three means are provided in the embodiment shown in FIG. 4 for detecting the three parameters, that is, the engine r.p.m., engine temperature and negative pressure in the air intake manifold, among various parameters indicative of the operating conditions of the engine which are at least required for controlling the fuel injection in the engine, the system may include additional detectors as required which detect the throttle valve opening and any other parameters indicative of the operating conditions of the engine and generate signals representative of the detected values for application to the pulse modulator 4.

I claim:

1. A system for electrically controlling the fuel injection in an internal combustion engine having means for detecting a plurality of parameters indicative of the operating conditions of the engine and delivering output voltages representative of the parameters, said detecting means including at least a sensor for detecting a negative pressure in the air intake manifold of the engine and producing an output voltage representation of said negative pressure, a pulse modulator connected to said means for generating a pulse signal having a pulse width corresponding to the sum of the output voltages of said means in response to the application of these output voltages, and means for sequentially, distributing the pulse signal delivered from said pulse modulator to solenoid operated fuel injection valves associated with individual cylinders of the engine in a predetermined order for causing said solenoid operated fuel injection valves to inject fuel in an amount corresponding to the pulse width of said pulse signal; said system comprising

first means for producing a voltage delayed by a predetermined delay time from the output voltage of said negative pressure sensor,

second means for producing an output voltage upon diffrentially comparing said output voltage of said negative pressure sensor with said delayed voltage, and

third means for applying the output voltage of said second means as an additional input signal to said pulse modulator to further increase the pulse width signal from said modulator.

2. A fuel injection control system as claimed in claim 1, in which the parameters indicative of the operating conditions of the engine include the r.p.m. of the engine, the temperature of the engine and the negative pressure in the air intake manifold.

3. A system for electrically controlling the fuel injection in an internal combustion engine having means for detecting a plurality of parameters indicative of the operating conditions of the engine and delivering output voltages representative of the parameters, a pulse modulator connected to said means for generating a pulse signal having a pulse width corresponding to the sum of the input voltages in response to the application of these input voltages, and means for sequentially, distributing the pulse signal delivered from said pulse modulator to solenoid operated fuel injection valves associated with individual cylinders of the engine in a predetermined order for causing said solenoid operated fuel injection valves to inject fuel in an mount corresponding to the pulse width of said pulse signal; said system comprising

first means for detecting a variation relative to time of the negative pressure in the air intake manifold during the acceleration of the engine,

second means for detecting the rate of variation of the negative pressure detected by said first means with respect to time and producing a voltage signal representative of said rate of variation of the negative pressure, and

third means for applying said voltage signal as an additional input to said pulse modulator, and

in which said means for delivering the voltage representative of the variation relative to time of the negative pressure in the air intake manifold includes a differential amplifier which delivers a voltage representing the difference between a first voltage representative of the negative pressure in the air intake manifold and a second voltage delayed by a predetermined delay time from said first voltage.

4. A system for electrically controlling the fuel injection in an internal combustion engine having means for detecting a plurality of parameters indicative of the operating conditions of the engine and delivering output voltages representative of the parameters, said detecting means including at least a sensor for detecting a negative pressure in the air intake manifold of the engine and producing an output voltage representative of said negative pressure, a pulse modulator connected to said means for generating a pulse signal having a pulse width corresponding to the sum of the output voltages of said means in response to the application of these output voltages, and means for sequentially distributing the pulse signal delivered from said pulse modulator to solenoid operated fuel injection valves associated with individual cylinders of the engine in a predetermined order for causing said solenoid operated fuel injection valves to inject fuel in an amount corresponding to the pulse width of said pulse signal; said system comprising

first means for producing a voltage delayed by a predetermined delay time from the output voltage of said negative pressure sensor,

second means for producing an output voltage upon differentially comparing said output voltage of said negative pressure sensor with said delayed voltage,

third means for comparing the output voltage of said second means with a predetermined reference voltage and producing a given voltage signal when said output voltage of said second means is higher than said reference voltage,

fourth means for differentiating said given voltage signal of said third means to produce a pulse, and

fifth means for producing a pulse signal having a predetermined duration of time responsive to said pulse produced by said fourth means upon differentiation of said given voltage signal, said pulse signal being applied to the solenoid operated fuel injection valves.

5. A fuel injection control system as claimed in claim 4, in which the parameters indicative of the operating conditions of the engine include the r.p.m. of the engine, the temperature of the engine and the negative pressure in the air intake manifold.

6. A system for electrically controlling fuel injection in an internal combustion engine having means for detecting a plurality of parameters indicative of the operating conditions of the engine and delivering output voltages representative of the parameters, a pulse modulator connected to said means for generating a pulse signal having a pulse width corresponding to the sum of the input voltages in response to the application of these input voltages, and means for sequentially distributing the pulse signal delivered from said pulse modulator solenoid operated fuel injection valves associated

with individual cylinders of the engine in a predetermined order for causing said solenoid operated fuel injection valves to inject fuel in an amount corresponding to the pulse width of said pulse signal; said system comprising

a first means for detecting the negative pressure in the air intake manifold during the acceleration of the engine,

second means for detecting the rate of variation of the negative pressure detected by said first means with respect to time, thereby producing a signal representative of said rate of variation of the negative pressure, and

third means including a pulse generator for generating a pulse signal of a predetermined duration when said signal delivered from said second means exceeds a predetermined value so as to apply said pulse signal to said solenoid operated fuel injection valves simultaneously, and

fourth means in which said first means for delivering the voltage representative of the variation relative to time of the negative pressure in the air intake manifold includes a differential amplifier which delivers a voltage representing the difference between a first voltage representative of the negative pressure in the air intake manifold and a second voltage delayed by a predetermined delay time from said first voltage.

7. A fuel injection control system as claimed in claim **4**, in which said fifth means includes a monostable multivibrator to produce said signal having said predetermined duration of time.

8. A system for electrically controlling the fuel injection in an internal combustion engine having means for detecting a plurality of parameters indicative of the operating conditions of the engine and delivering output voltages representative of the parameters, a pulse modulator connected to said means for generating a pulse signal having a pulse width corresponding to the sum of the input voltages in response to the application of these input voltages, and means for sequentially distributing the pulse signal delivered from said pulse modulator to solenoid operated fuel injection valves associated with individual cylinders of the engine in a predetermined order for causing said solenoid operated fuel injection valves to inject fuel in an amount corresponding to the pulse width of said pulse signal; said system comprising

a first means for detecting the negative pressure in the air intake manifold during the acceleration of the engine,

second means for detecting the rate of variation of the negative pressure detected by said first means with respect to time, thereby producing a signal representative of said rate of variation of the negative pressure, and

third means including a pulse generator for generating a pulse signal of a predetermined duration when said signal of a predetermined duration when said signal delivered from said second means exceeds a predetermined value so as to apply said pulse signal to said solenoid operated fuel injection valves simultaneously, and

in which said second means includes means for generating a pulse when the variation relative to time of the negative pressure in the air intake manifold exceeds a predetermined value, means responsive to said pulse to provide a voltage which increases with a predetermined time constant, and means for comparing the value of this voltage with the peak value of the voltage applied from said first means thereby generating a pulse during a period of time in which the former voltage value is smaller than the latter voltage value.

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