

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

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 97,880, Dec. 14, 1970, abandoned.

[52] U.S. Cl. 123/32 EA; 123/119 R; 123/140 MC

[51] Int. Cl. F02b 3/00

[58] Field of Search 123/32 EA, 119, 139 AW, 123/140 MC

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Primary Examiner—Charles J. Myhre
Assistant Examiner—Ronald B. Cox
Attorney, Agent, or Firm—Cushman, Darby & Cushman

[57] **ABSTRACT**

A system for electrically controlling the fuel injection in a multi-cylinder internal combustion engine comprising a first fuel injection starting signal generator for generating a first starting signal defining the fuel injection starting timing for a specific cylinder, a second fuel injection starting signal generator for generating second starting signals defining the fuel injection starting timing for the individual cylinders, a fuel injection duration signal generator for generating a fuel injection duration signal for the specific cylinder in response to the application of at least the first starting signal, a fuel injection ending signal generator coupled with the second starting signal generator and said duration signal generator for initiating fuel injection ending timing for the individual cylinders, the ending signals appearing after the occurrence of the starting signals and while the duration signals are activated, a fuel injection ending signal distributor for distributing said ending signals to the individual cylinders taking each ending signal corresponding to the specific cylinder as a reference, and a fuel injection starting signal distributor for distributing the second starting signals to each of the individual cylinders taking said first starting signal as a reference.

22 Claims, 76 Drawing Figures

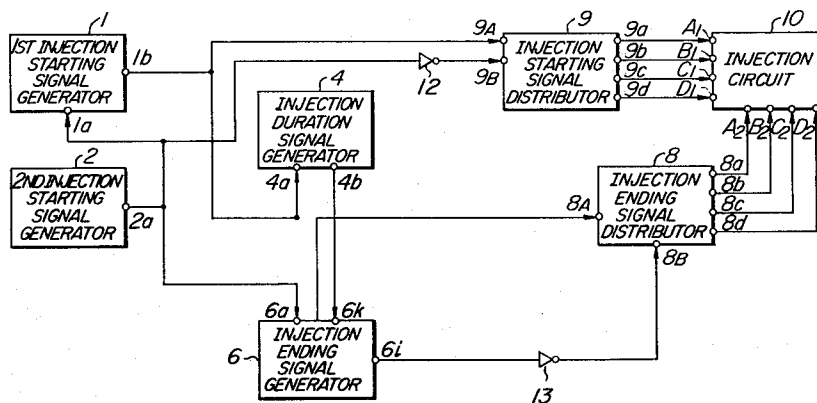


FIG. 1

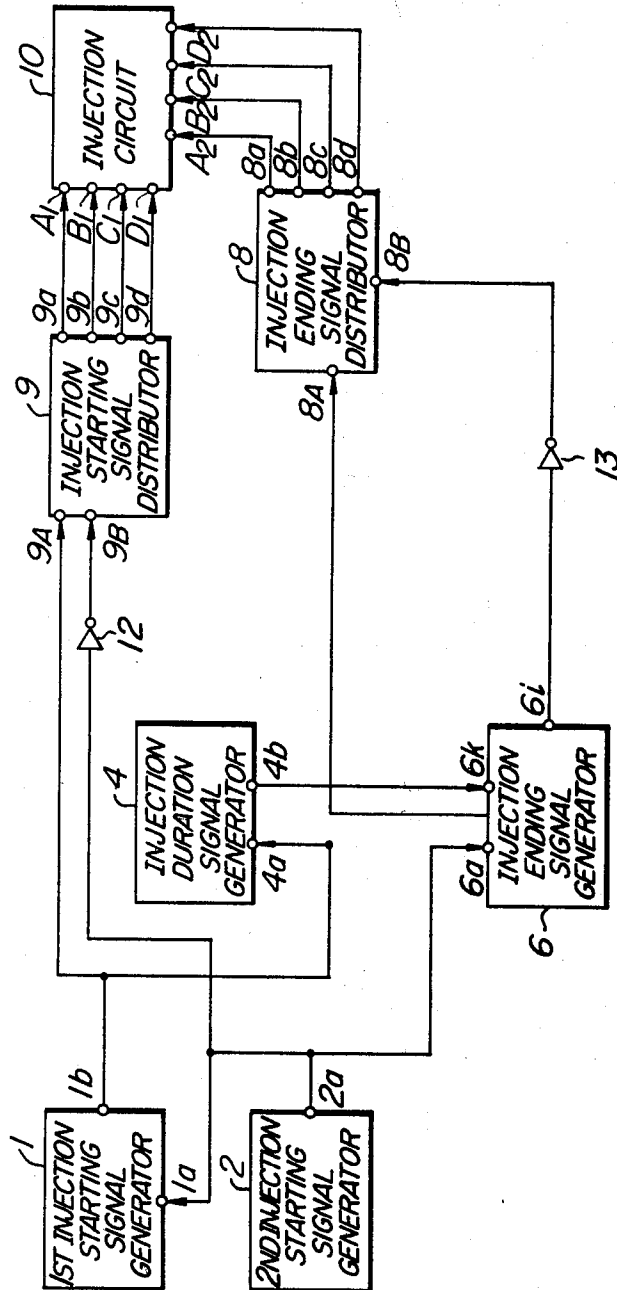


FIG. 2

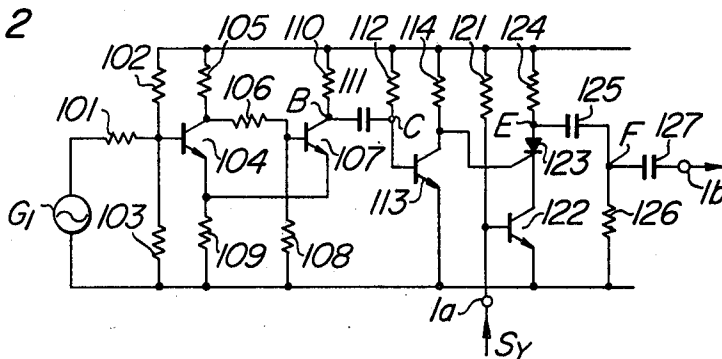


FIG. 3a
OUTPUT OF G_1

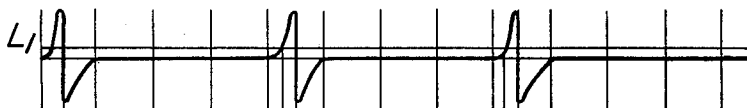


FIG. 3b
WAVEFORM AT B



FIG. 3c
WAVEFORM AT C

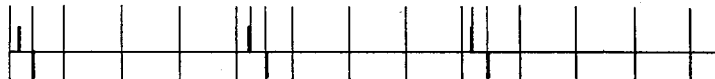


FIG. 3d
INPUT TO I_a



FIG. 3e
WAVEFORM AT E

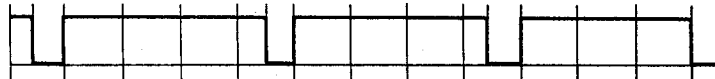


FIG. 3f
OUTPUT AT I_b

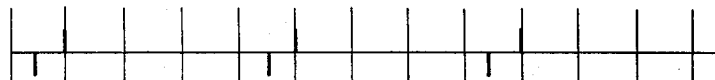


FIG. 4

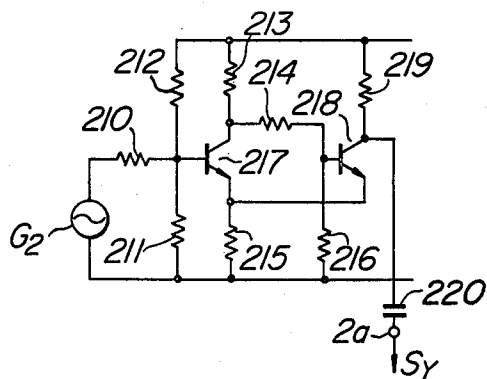


FIG. 5a

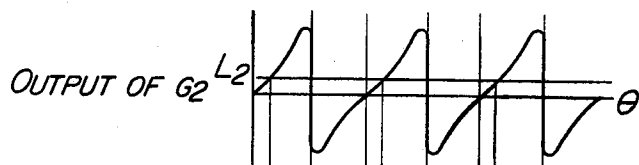


FIG. 5b

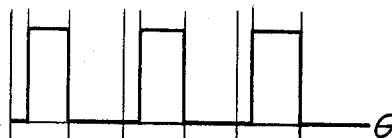


FIG. 5c

OUTPUT S_Y AT 2a

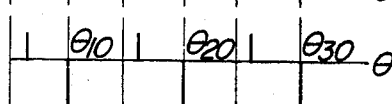


FIG. 6

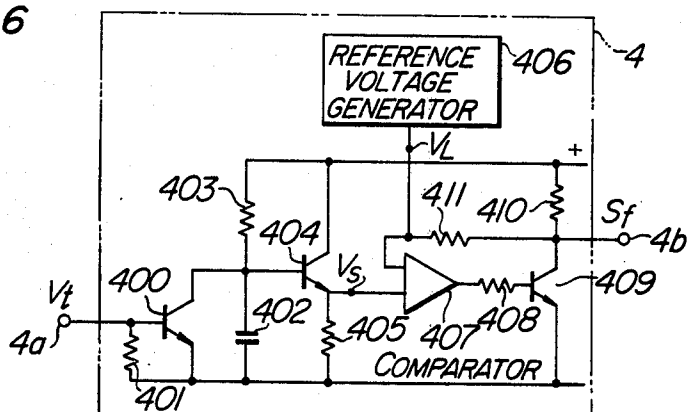


FIG. 7a

INPUT TO 4a

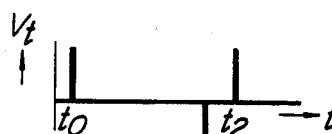


FIG. 7b

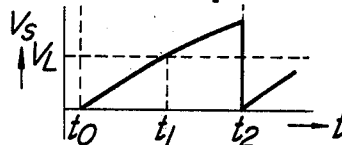


FIG. 7c

OUTPUT AT 4b

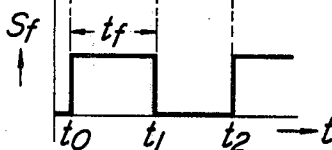


FIG. 8

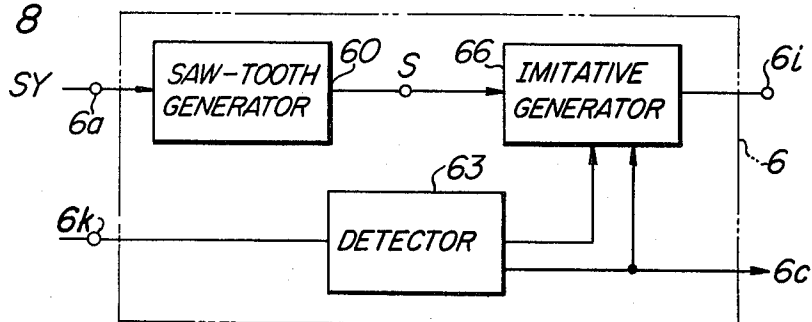


FIG. 9

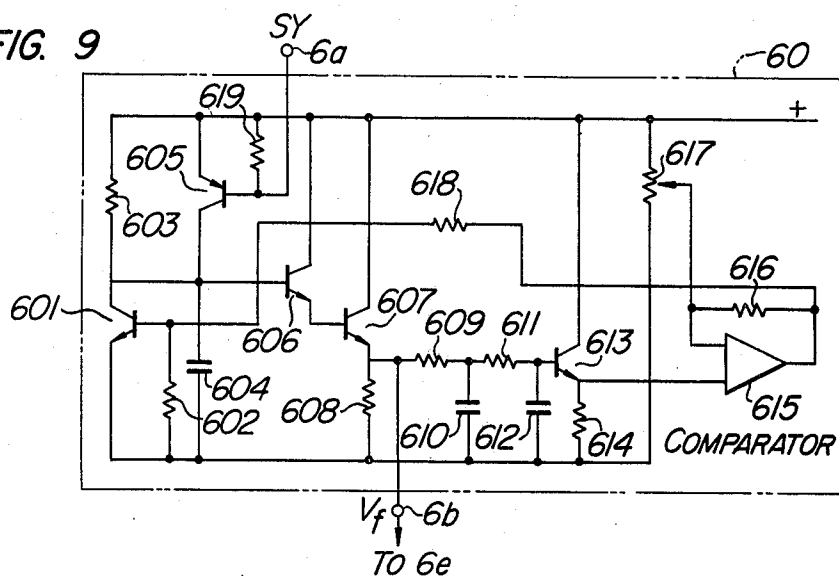


FIG. 10

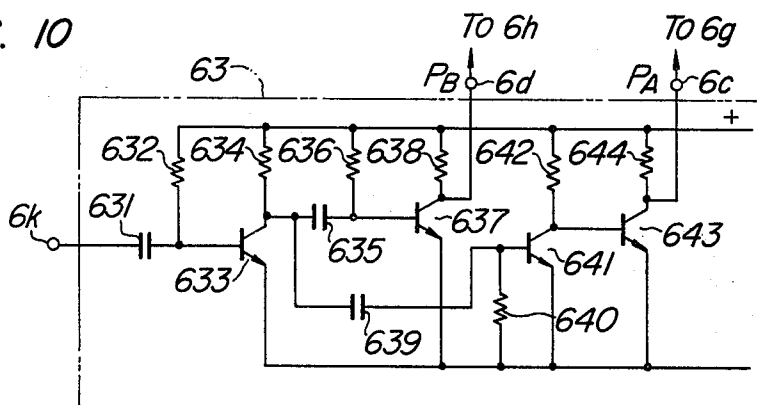


FIG. 11

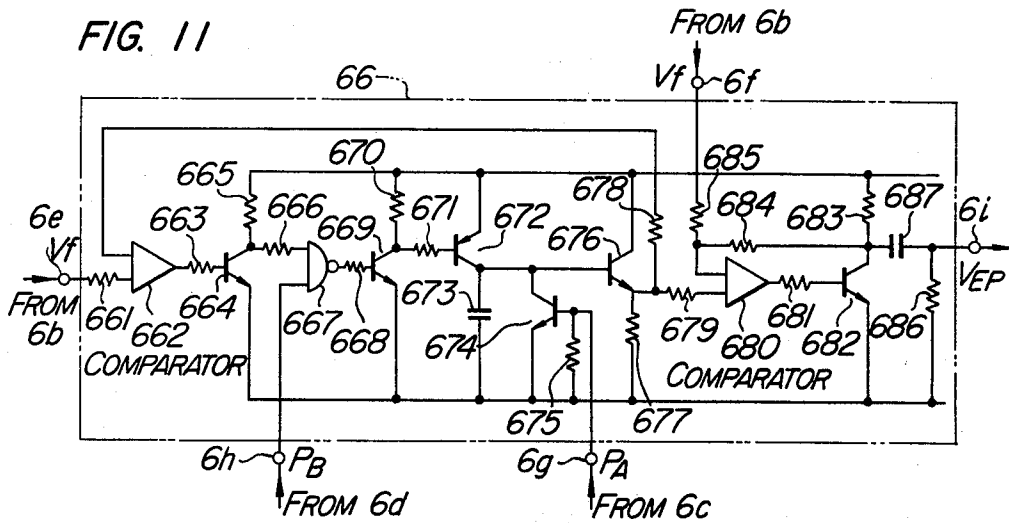


FIG. 12a
INJECTION
DURATION
SIGNAL

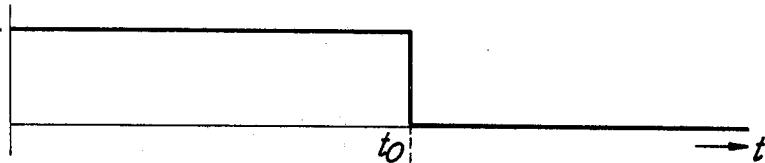


FIG. 12b
SAW-TOOTH
VOLTAGE

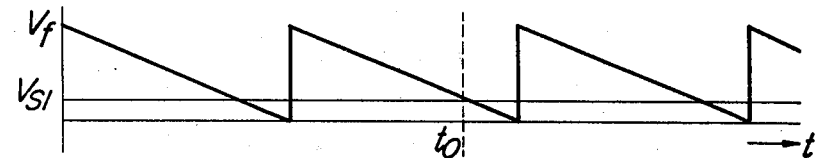


FIG. 12c
END INDICATIVE
PULSE

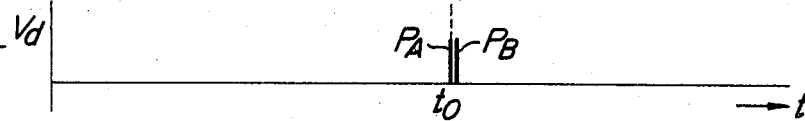


FIG. 12d

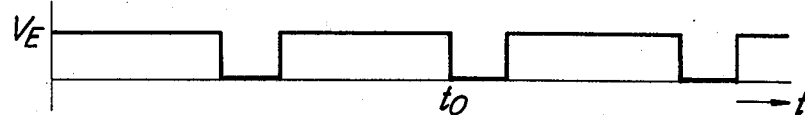


FIG. 12e
INJECTION
ENDING
PULSE

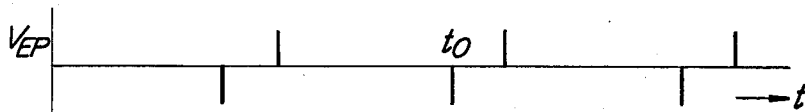


FIG. 13

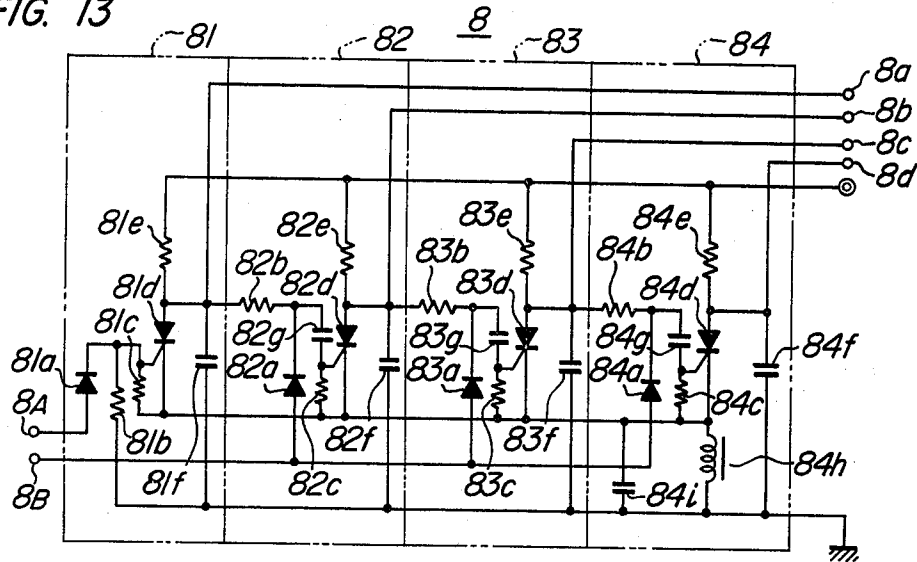


FIG. 14a

INPUT TO 8A

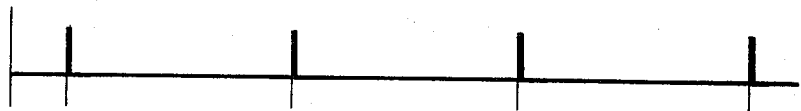


FIG. 14b

INPUT TO 8B

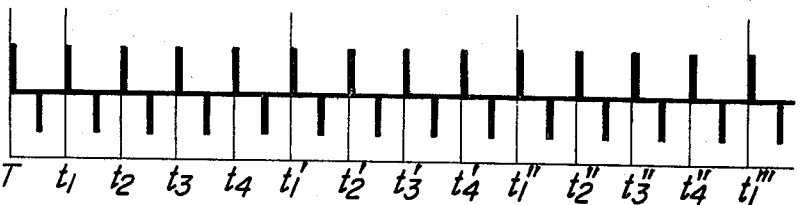


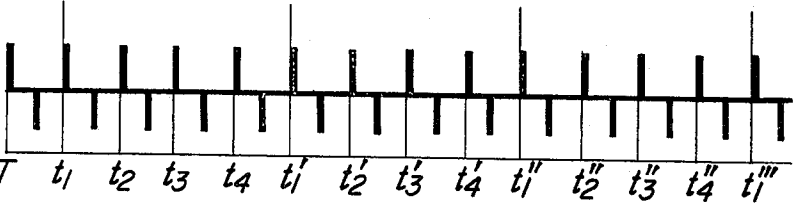
FIG. 17a

INPUT TO 9A



FIG. 17b

INPUT TO 9B



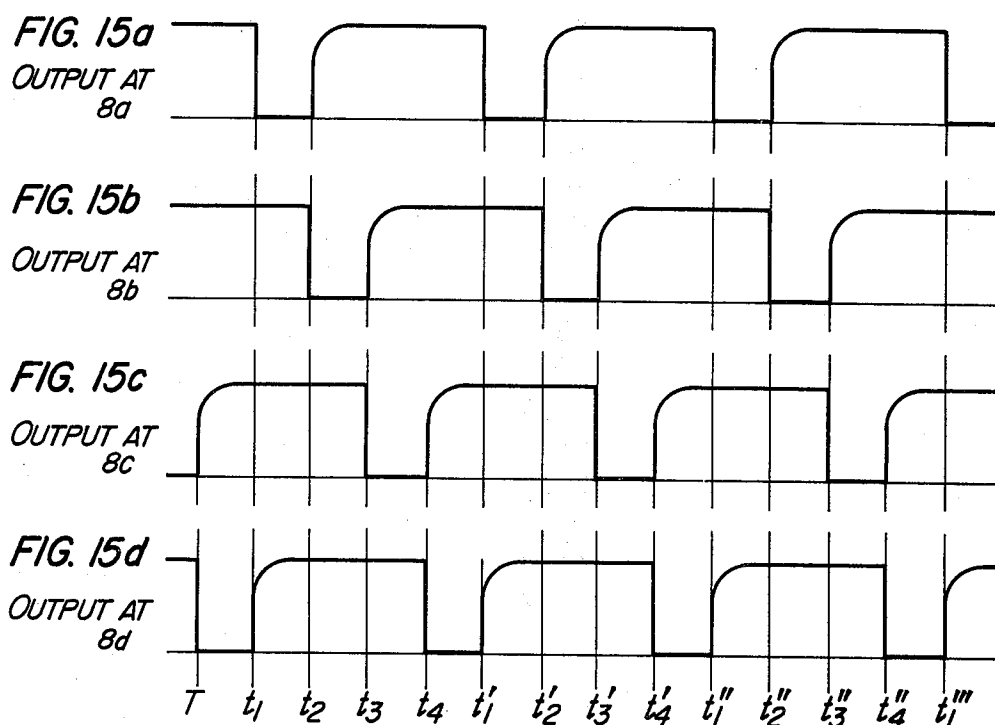
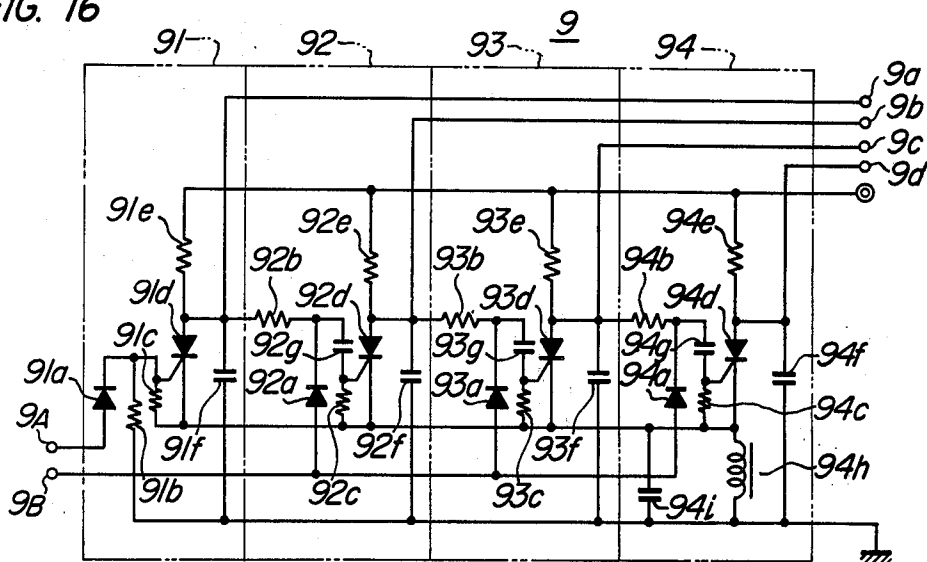


FIG. 16



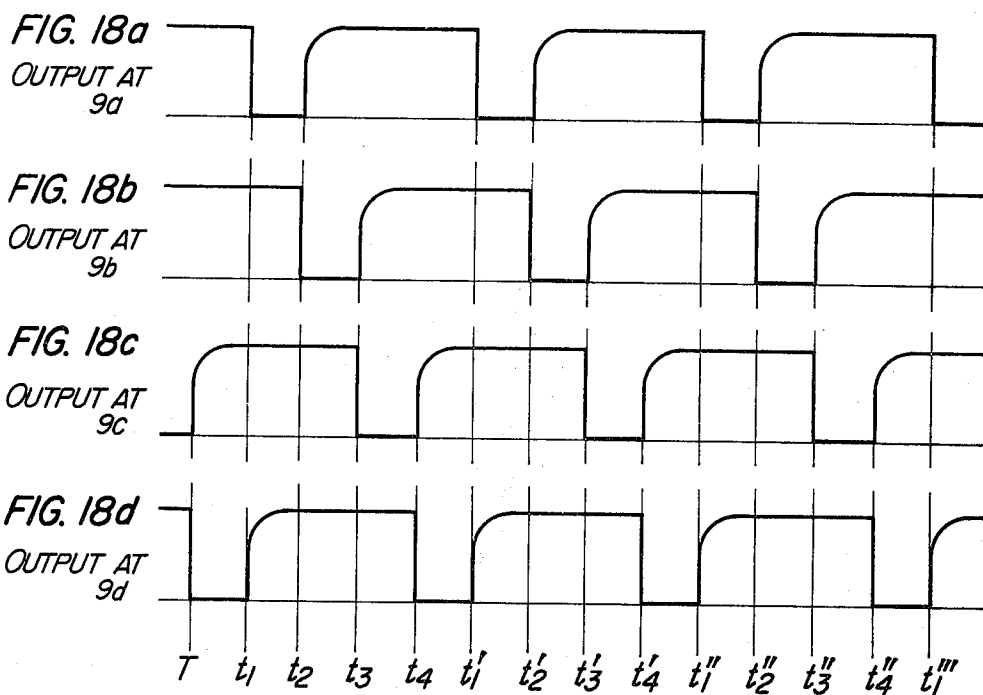
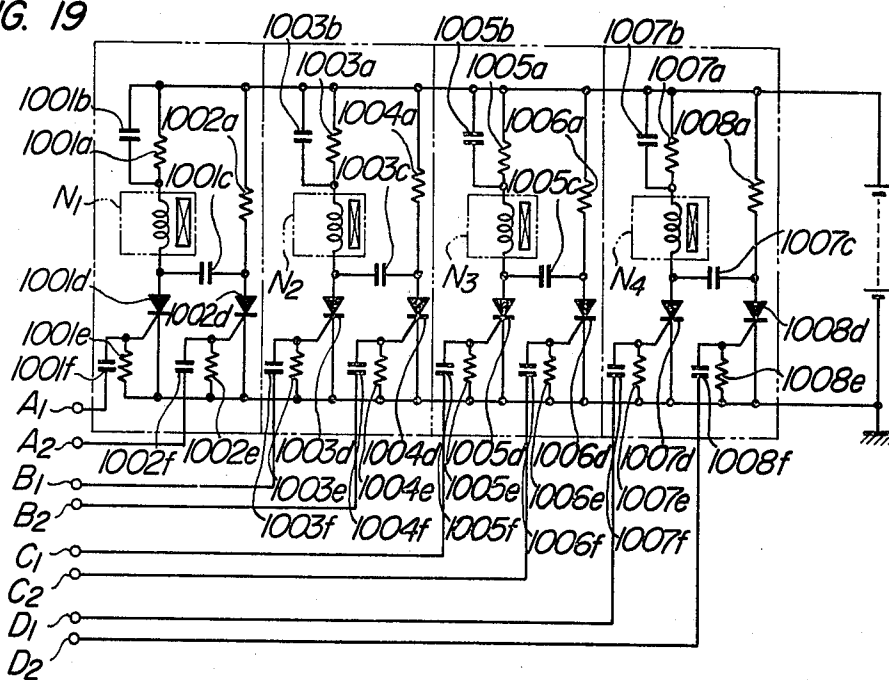
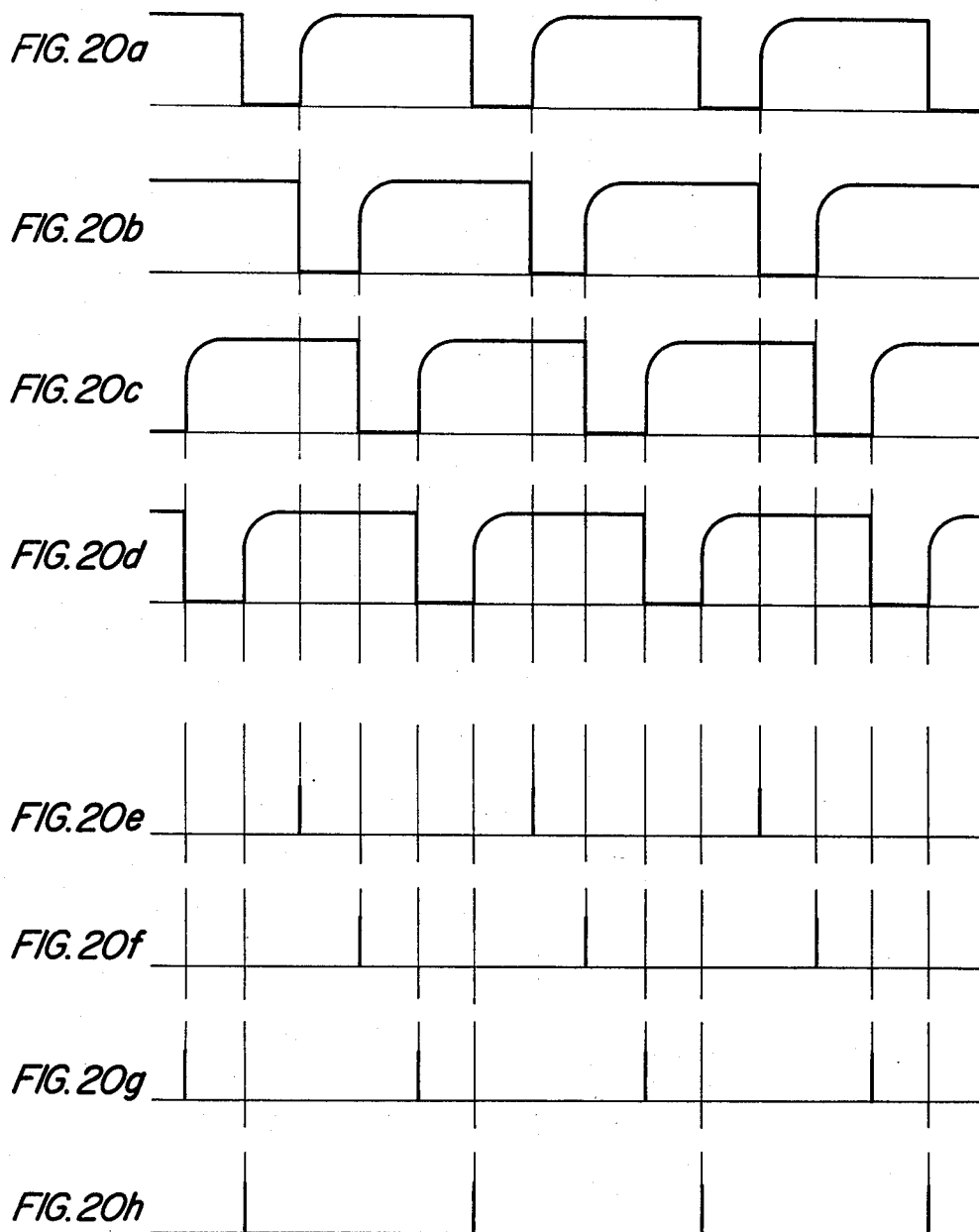
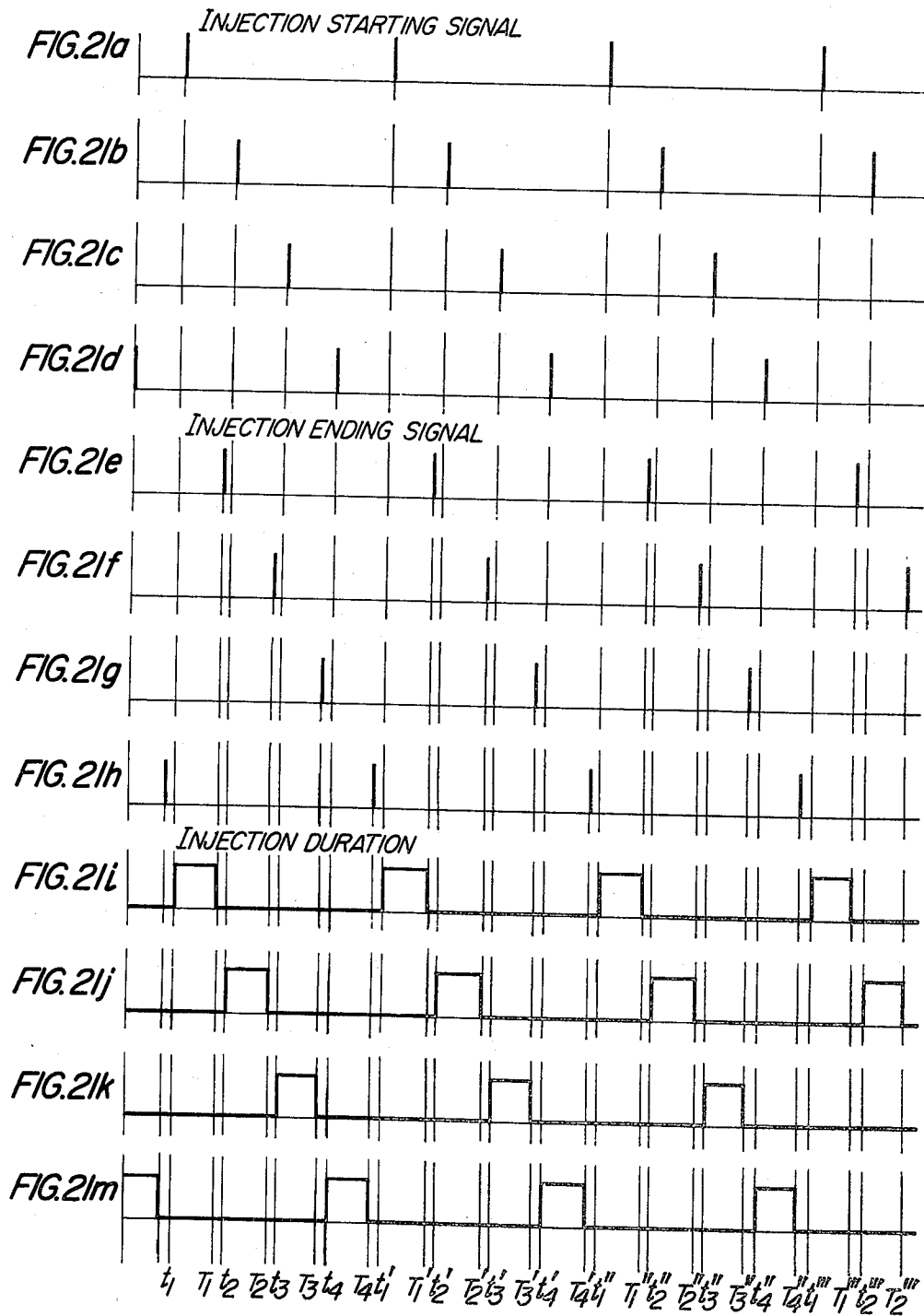


FIG. 19







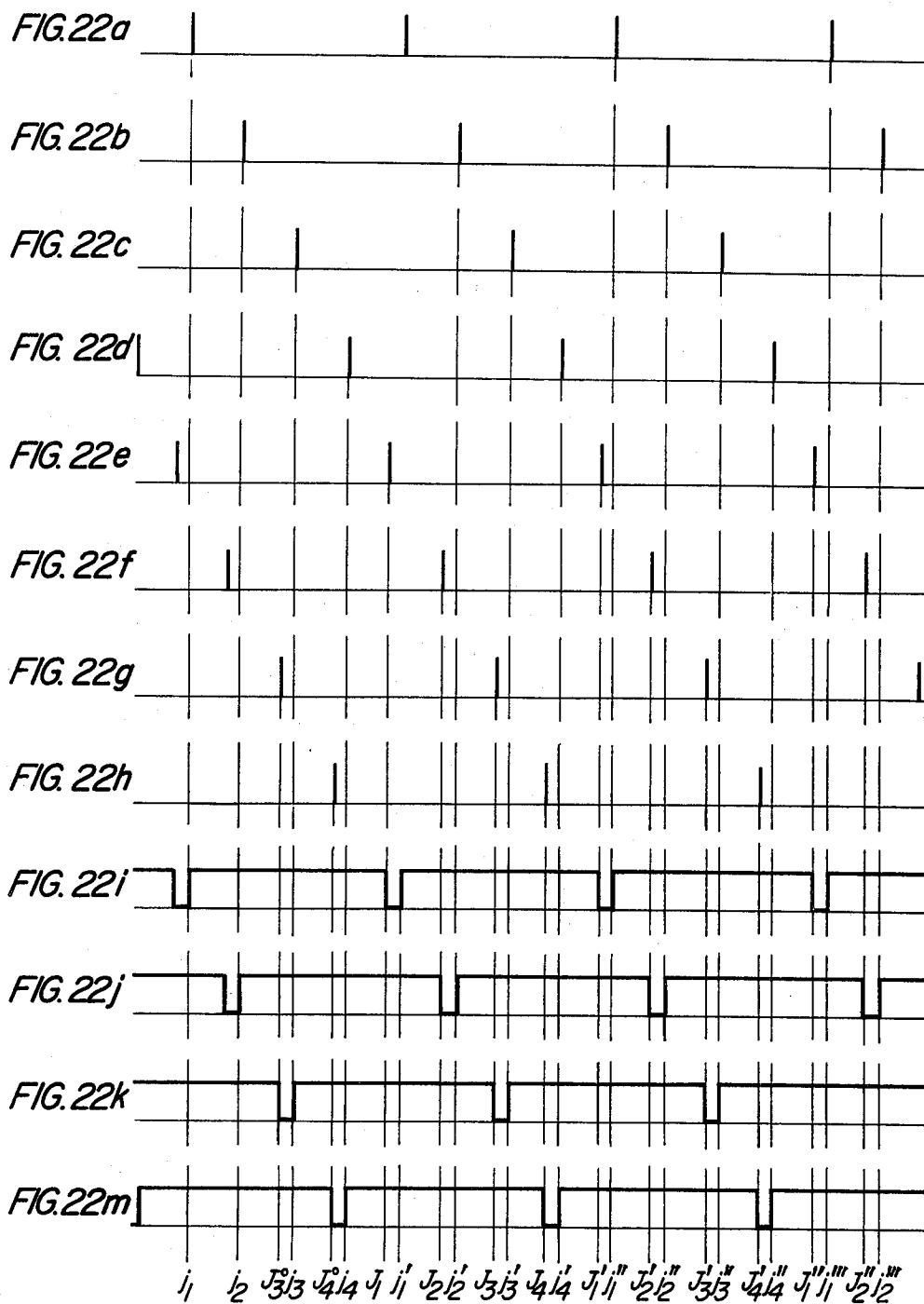


FIG. 23

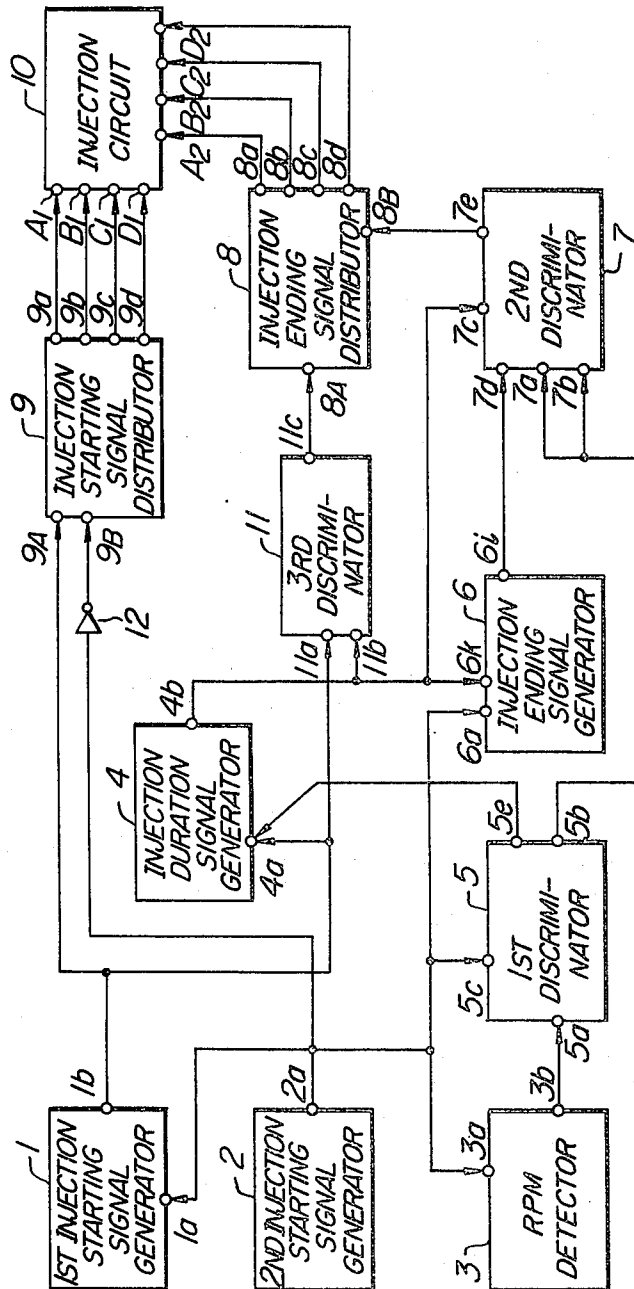


FIG. 24

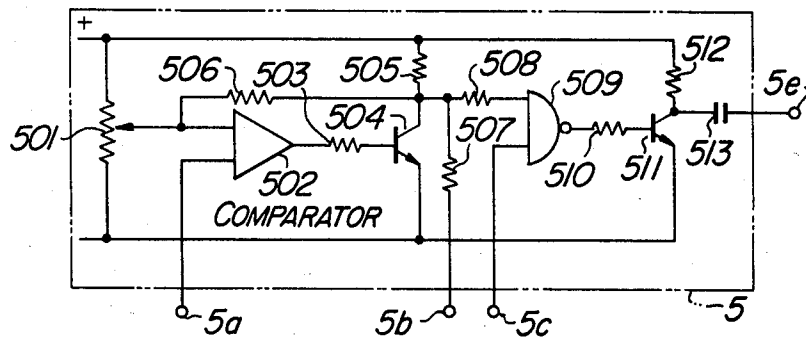


FIG. 25

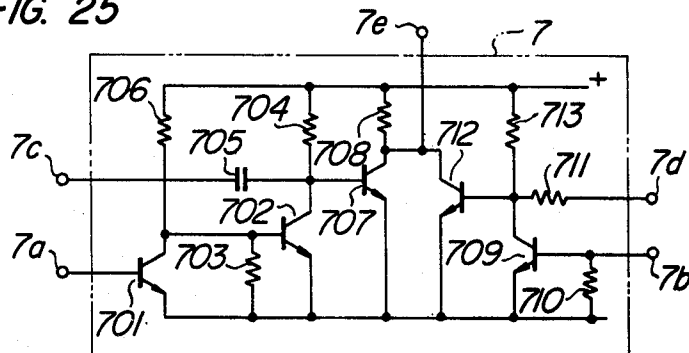
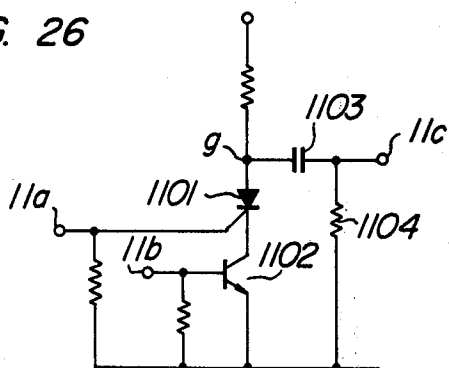


FIG. 26



ELECTRICAL FUEL INJECTION CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES

CROSS REFERENCE TO RELATED APPLICATION

This application is a continuation-in-part of copending U.S. Pat. application Ser. No. 97,880 filed Dec. 14, 1970 now abandoned.

BACKGROUND OF THE INVENTION

1. Field of the Invention

This invention relates to an electrical fuel injection control system for a multi-cylinder internal combustion engine for electrically controlling the injection of fuel into the individual cylinders of the engine.

2. Description of the Prior Art

In a conventional electrical fuel injection control system for a multi-cylinder internal combustion engine, electromagnetic or solenoid operated valves are successively urged to the open position to inject fuel under constant pressure into the cylinders through the associated nozzles, and the amount of injected fuel is determined by the length of time during which each individual solenoid operated valve is kept in its open position, that is, the length of time during which current is supplied to the solenoid operated valve. However, in the range in which the multi-cylinder engine is rotating at high speed, it frequently occurs that the current supply to the solenoid operated valve associated with the next cylinder is started while the current is being supplied to the solenoid operated valve associated with the preceding cylinder. It has therefore been the common practice to inject fuel into a few cylinders at the same time in a high speed rotation range of the engine or to employ a plurality of fuel injection duration signal generators generating a fuel injection duration signal for urging the solenoid operated valves to their open position sequentially. However, the injection of fuel into a few cylinders at the same time is undesirable for the satisfactory operation of the engine because the operating timing of the suction valves of some cylinders may not be in accord with their fuel injection timing. Thus, from the viewpoint of the acceleration characteristic, etc. of the engine, this method has a serious defect in that it is inferior to the method of sequentially distributing the fuel into individual cylinders with properly controlled timing. The system employing a plurality of fuel injection duration signal generators is also defective in that the signal generators must be regulated so as to deliver the same signal of the same duration and it is extremely difficult to regulate the fuel injection duration signal generators for the respective cylinders to suit the above demand over the entire driving conditions.

SUMMARY OF THE INVENTION

It is an object of the present invention to provide an electrical fuel injection control system for a multi-cylinder internal combustion engine which includes a single fuel injection duration signal generator for equalizing the duration of fuel injection for the individual cylinders and injecting fuel with appropriate timing into the individual cylinders so that the fuel injection duration signal itself can be distributed to the cylinders in a low speed rotation range of the engine, while in a high speed rotation range of the engine where the period of time of fuel injection for one cylinder may overlap that of another cylinder, a plurality of fuel injection duration signals for the respective cylinders are pro-

duced on the basis of the signal generated by the single fuel injection duration signal generator and are distributed to the fuel injection means associated with the respective cylinders thereby to solve the problem of non-uniformity of the duration of fuel injection for the individual cylinders, to make it possible to inject the fuel into the cylinders with different timing, and to eliminate undesirable pulsation of the fuel pressure and electrical outputs.

Another object of the present invention is to provide an electrical fuel injection control system for a multi-cylinder internal combustion engine in which, in a low speed rotation range of the engine where it is difficult to produce a plurality of fuel injection duration signals, on the basis of the fuel injection duration signal the fuel injection duration signal generator produces a fuel injection timing signal to be distributed to the individual cylinders so that the engine can accurately operate even in the low speed range.

In accordance with the present invention, there is provided an electrical fuel ignition control system for a multi-cylinder internal combustion engine for electrically controlling the injection of fuel into the individual cylinders comprising a first fuel injection starting signal generator for generating a first fuel injection starting signal defining the fuel injection starting timing for a specific cylinder among the cylinders, a second fuel injection starting signal generator for generating a second fuel injection starting signal for the individual cylinders, a fuel injection duration signal generator for generating at least one for the specific cylinder of fuel injection duration signals for the individual cylinders conforming to a required duration of fuel injection in response to the application of at least one for the specific cylinder of the fuel injection starting signals, a fuel injection ending signal generator for generating a fuel injection ending signal for the individual cylinders in response to the application of said fuel injection duration signal and said second fuel injection starting signal, a fuel injection ending signal distributor for distributing said fuel injection ending signal to the fuel injection means associated with the individual cylinders taking said first fuel injection starting signal as a reference, and a fuel injection starting signal distributor for distributing said second fuel injection starting signal to said fuel injection means associated with the individual cylinders taking said first fuel injection starting signal as a reference, said system further comprising as required a first discriminator for applying to said fuel injection duration signal generator a signal corresponding to the fuel injection starting signal generated by said second fuel injection starting signal generator when the speed of the engine is lower than a predetermined speed so that said fuel ignition duration signal generator generates a fuel injection duration signal for the individual cylinders, and a second discriminator for producing a fuel injection ending signal for the individual cylinders directly from the fuel injection duration signal generated by said fuel injection duration signal generator in the low speed range so that said fuel injection ending signal distributor distributes the fuel injection ending signal to the individual cylinders.

The present invention having the features set forth in the above provides the following advantages:

1. The provision of only one fuel injection duration signal generator is advantageous over a conventional system including a plurality of fuel injection duration

signal generators in that the duration of fuel injection for the individual cylinders is free from any fluctuation and is uniform.

2. In a high speed range of the engine in which the period of time of fuel injection for one cylinder may overlap that of another cylinder, a fuel injection ending signal for the individual cylinders is newly produced on the basis of the fuel injection duration signal for a predetermined specific cylinder. Thus, an appropriate amount of fuel can be sequentially injected into the individual cylinders with optimum fuel injection timing in such a high speed range. As a result, the engine can fully develop its output and any undesirable pulsation of pressure applied to the fuel as well as electrical pulsation can be reduced to a minimum.

3. In a low speed range of the engine, the single fuel injection duration signal generator generates a fuel injection duration signal for the individual cylinders in accordance with the instructions given by the first discriminator, and this signal is applied to the second discriminator to be distributed to the individual cylinders by way of the fuel injection ending signal distributor. Thus, the fuel injection can be accurately carried out even in a very low speed range such as when the engine is started from the non-operative condition.

By virtue of the above advantages, an ideal fuel injection characteristic can be obtained throughout the entire operating conditions of the engine ranging from the starting to its maximum speed.

BRIEF DESCRIPTION OF THE DRAWING

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

FIG. 2 is an electrical circuit diagram of a fuel injection starting signal generator for a specific cylinder.

FIGS. 3a through 3f show voltage waveforms appearing at various parts of the circuit shown in FIG. 2.

FIG. 4 is an electrical circuit diagram of a fuel injection starting signal generator for the individual cylinders.

FIGS. 5a through 5c show voltage waveforms appearing at various parts of the circuit shown in FIG. 4.

FIG. 6 is an electrical circuit diagram of a fuel injection duration signal generator.

FIGS. 7a through 7c show voltage waveforms appearing at various parts of the circuit shown in FIG. 6.

FIG. 8 is a block diagram of a fuel injection ending signal generator.

FIGS. 9 through 11 are electrical circuit diagrams of various electrical circuits shown by the blocks in FIG. 8.

FIGS. 12a through 12e show voltage waveforms appearing at various parts of the circuits shown in FIGS. 9 through 11.

FIG. 13 is an electrical circuit diagram of a fuel injection ending signal distributor.

FIGS. 14a and 14b show waveforms of inputs applied to the circuit shown in FIG. 13.

FIGS. 15a through 15d show waveforms of outputs delivered from the circuit shown in FIG. 13.

FIG. 16 is an electrical circuit diagram of a fuel injection starting signal distributor.

FIGS. 17a and 17b show the waveforms of inputs applied to the circuit shown in FIG. 16.

FIGS. 18a through 18d show the waveforms of outputs delivered from the circuit shown in FIG. 16.

FIG. 19 is an electrical circuit diagram of a fuel injection circuit.

FIGS. 20a through 20h show waveforms of inputs applied to the fuel injection circuit from the fuel injection ending signal distributor and fuel injection starting signal distributor.

FIGS. 21a through 21m show voltage waveforms appearing at various parts of the fuel injection circuit shown in FIG. 19.

FIGS. 22a through 22m show voltage waveforms appearing at various parts of the fuel injection circuit shown in FIG. 19 when the duration of fuel injection is varied.

FIG. 23 is a block diagram of another embodiment of the present invention.

FIG. 24 is an electrical circuit diagram of a first discriminator.

FIG. 25 is an electrical circuit diagram of a second discriminator.

FIG. 26 is an electrical circuit diagram of a third discriminator.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIG. 1 which shows a block diagram of an embodiment of the present invention, a fuel injection starting signal generator 1 generates a signal representing the fuel injection starting timing for a predetermined specific cylinder which may, for example, be the first cylinder of a four-cylinder internal combustion engine. Another fuel injection starting signal generator 2 generates a signal representing the fuel injection starting timing for the individual cylinders. In response to the application of the fuel injection starting signal from the fuel injection starting signal generator 1 for the specific cylinder, a fuel injection duration signal generator 4 generates a fuel injection duration signal having a pulse width which is in accord with the duration of fuel injection for the specific cylinder. The fuel injection starting signal for the individual cylinders delivered from the fuel injection starting signal generator 2 and the fuel injection duration signal for the specific cylinder delivered from the fuel injection duration signal generator 4 are applied to a fuel injection ending signal generator 6 which produces, on the basis of the fuel injection duration signal applied thereto, fuel injection ending signals instructing the end of the fuel injection into the individual cylinders sequentially. A fuel injection ending signal distributor 8 distributes the fuel injection ending signals to the individual cylinders in response to the application of the signals from the fuel injection ending signal generator 6. A fuel injection starting signal distributor 9 distributes the fuel injection starting signal to the individual cylinders in response to the application of the fuel injection starting signal for the individual cylinders from the fuel injection starting signal generator 2 and the fuel injection starting signal from the fuel injection starting signal generator 1 for the specific cylinder. The fuel injection starting signal and the fuel injection ending signal for the individual cylinders are applied to a fuel injection circuit 10 which includes means for energizing and de-energizing the solenoid operated valves associated with the respective cylinders. An inverter 12 is connected between the fuel injection starting signal generator 2 and the injection starting signal distributor 9, and also another inverter

13 between the injection ending signal generator 6 and the injection ending signal distributor 8.

The fuel injection starting signal generator 1 for the specific cylinder may be composed of means incorporated in the ignition signal distributor for detecting a predetermined position during the operating cycle of the specific cylinder which is herein the first cylinder and a wave shaping circuit for subjecting the output from the detecting means to wave shaping. The operating position of the specific cylinder can be detected by a method in which a signal responsive to the operation of the specific cylinder has a special shape or magnitude or a method in which a signal is produced solely at the fuel injection starting timing of the specific cylinder. In the former case, a generator may generate a higher voltage in response to the operation of the specific cylinder than when the remaining cylinders are in operation. In the latter case, a switch which is urged to open or close at the fuel injection starting timing of the specific cylinder may be employed. The wave shaping circuit may include a suitable combination of an amplifier, a Schmitt circuit and a differentiator for detecting the fuel injection starting timing of the specific cylinder.

A practical circuit diagram of the fuel injection starting signal generator 1 for the specific cylinder is shown in FIG. 2. Referring to FIG. 2, a signal generator G_1 is mounted rotatably in synchronism with rotation of the engine (not shown) for producing a signal responsive to the operating position of the specific cylinder. The signal generator G_1 is connected to a Schmitt circuit which includes an input resistor 101, bias resistors 102 and 103, a pair of transistors 104 and 107, a load resistor 105 for the transistor 104, a coupling resistor 106, a resistor 108 for determining a Schmitt level L_1 , shown in FIG. 3a, a common emitter resistor 109 for the transistors 104 and 107, and a load resistor 110 for the transistor 107. A capacitor 111 and a resistor 112 constitute a differentiator. An amplifying transistor 113 is connected to the differentiator and has a load resistor 114. A resistor 121 in combination with capacitor 220 as shown in FIG. 4 acts to differentiate and produce a synchronizing signal S_Y , described later, which appears at input terminal 1a. A transistor 122 and a silicon controlled rectifier 123 constitute a flip-flop circuit which has a load resistor 124 connected therewith. A capacitor 125 and a resistor 126 constitute a differentiator which is connected to an output terminal 1b through a coupling capacitor 127.

In operation, the signal generator G_1 generates a signal having a waveform as shown in FIG. 3a at the start of the fuel injection for the specific cylinder. When no signal is applied from the signal generator G_1 to the Schmitt circuit composed of the circuit elements 101 through 110, the transistor 104 is cut off and the transistor 107 is conducting by the biasing action of the resistors 101, 102 and 103. Then, when the signal generated by the signal generator G_1 attains a positive level above the Schmitt level L_1 , the transistor 104 conducts and the transistor 107 is cut off. As the angular position of rotation of the engine crankshaft is further advanced until the voltage level of the signal generated by the signal generator G_1 becomes lower than the Schmitt level L_1 again, the transistor 104 is cut off and the transistor 107 conducts again with the result that a rectangular waveform appears across the resistor 110. FIG. 3b shows such a voltage waveform appearing at point B.

Although, actually, there is a slight hysteresis in the action of the Schmitt circuit, the hysteresis is not taken into consideration herein since it is negligible. This rectangular waveform is then differentiated by the differentiator composed of the capacitor 111 and the resistor 112 so that a waveform as shown in FIG. 3c appears at point C. The negative pulse appearing at point C is amplified and inverted in polarity by the transistor 113. The collector of the transistor 113 is connected to the gate of the silicon controlled rectifier 123, which is therefore urged to conduct by the positive pulse obtained by the amplification and polarity inversion of the negative pulse. When a negative pulse S_Y (which is described hereafter) shown in FIG. 3d is applied to the input terminal 1a with the further rotation of the engine crankshaft, the transistor 122 is cut off thereby to turn off the silicon controlled rectifier 123. As a result, a voltage waveform as shown in FIG. 3e appears at point E. This waveform is differentiated by the differentiator composed of the capacitor 125 and the resistor 126 so that an output signal as shown in FIG. 3f appears at point F. This output signal appears through the capacitor 127 at the output terminal 1b to be applied to the fuel injection duration signal generator 4 and fuel injection starting signal distributor 9.

The structure of the second fuel injection starting signal generator 2 may be similar to that of the first fuel injection starting signal generator 1 for the specific cylinder. Thus, the second fuel injection starting signal generator 2 may include means such as a signal generator or breaker point generating a signal at the fuel injection timing of the individual cylinders and a wave shaping circuit for accurately detecting the fuel injection starting timing of the individual cylinders as in the case of the fuel injection starting signal generator 1 for the specific cylinder.

Referring to FIG. 4, a signal generator G_2 , which is mounted rotatably in synchronism with rotation of the engine (not shown), generates a voltage signal having a waveform as shown in FIG. 5a at the fuel injection starting timing of the individual cylinders and is connected to a Schmitt circuit composed of an input resistor 210, bias resistors 211 and 212, a pair of transistors 217 and 218, a load resistor 213 for the transistor 217, a coupling resistor 214, a common emitter resistor 215, a resistor 216 for determining a Schmitt level L_2 shown in FIG. 5a, and a load resistor 219 for the transistor 118. In the Schmitt circuit, the transistor 217 is cut off at the Schmitt level L_2 from the previous conducting state and therefore the transistor 218 is urged to conduct from the previous cut-off state with the result that an output having a rectangular waveform as shown in FIG. 5b is delivered from the Schmitt circuit. The resistor 216 is suitably selected to provide the Schmitt level L_2 described above. Since it is preferable that a sufficient triggering action can be ensured even when the waveform of the output from the signal generator G_2 has a small amplitude and that the level L_2 is desirably as close to the zero as possible in order to accurately detect a reference position θ_{10} , the resistors 210, 211, 212, 214, 215 and 216 are designed to suit the above purpose. The output from the Schmitt circuit is differentiated by a differentiator composed of a capacitor 220 and a resistor 121 as shown in FIG. 2 so that negative pulses S_Y appear in synchronism with angular positions θ_{10} , θ_{20} , θ_{30} , . . . as shown in FIG. 5c. The output pulse S_Y appears through the differentiator capacitor

220 at an output terminal 2a to be applied therefrom to the fuel injection starting signal generator 1 for the specific cylinder, fuel injection ending signal generator 6 and fuel injection starting signal distributor 9.

Referring to FIG. 6 showing an electrical circuit diagram of the fuel injection duration signal generator 4, it comprises a saw-tooth wave resetting transistor 400, a bias resistor 401 for the transistor 400, a capacitor 402 across which a saw-tooth waveform appears, a resistor 403 for determining a fixed time constant of the saw-tooth waveform appearing across the capacitor 402, an amplifying transistor 404 of an emitter follower configuration, a load resistor 405 for the emitter follower transistor 404, a reference voltage generator 406 generating a reference voltage corresponding to the amount of injected fuel required by the engine, a comparator and rectangular wave generator 407 (hereinafter to be referred to merely as a comparator), a coupling resistor 408, an amplifying transistor 409, a load resistor 410 for the transistor 409, a feedback resistor 411, a signal input terminal 4a, and a signal output terminal 4b.

In operation, the transistor 400 conducts in response to the application of the signal or a pulse V_i as shown in FIG. 7a from the fuel injection starting signal generator 1 for the specific cylinder to the input terminal 4a. Upon conduction of the transistor 400, the charge stored in the capacitor 402 is discharged across the collector and emitter of the transistor 400. Since the pulse V_i applied to the base of the transistor 400 lasts for a very short period of time, the completely discharged capacitor 402 is recharged soon. Voltage waveforms appearing at various parts of the generator 4 are shown in FIGS. 7a through 7c. The input pulse signal V_i having a waveform as shown in FIG. 7a is applied to the input terminal 4a, thence to the base of the transistor 400 at time t_0 . The transistor 400 conducts to cause the capacitor 402 to discharge and a voltage V_s varying in a manner as shown in FIG. 7b appears across the capacitor 402. The input pulse V_i disappears soon and the capacitor 402 is charged through the resistor 403 again. The capacitor 402 discharges through the transistor 400 in response to the application of the next input pulse V_i to the input terminal 4a at time t_2 . Thus, a saw-tooth waveform V_s having a fixed gradient determined by the capacitance of the capacitor 402 and the resistance of the resistor 403 appears across the capacitor 402 as shown in FIG. 7b. The voltage across the capacitor 402 appears across the resistor 405 through the transistor 404 to be applied to one of the input terminals of the comparator 407. On the other hand, a reference voltage V_L corresponding to the amount of injected fuel required by the engine is applied to the other input terminal of the comparator 407 in which this reference voltage V_L is compared with the saw-tooth waveform V_s . As a result, a rectangular waveform S_f as shown in FIG. 7c appears at the output terminal of the comparator 407, and has a pulse width t_f ranging from time t_0 at which the saw-tooth waveform V_s starts to rise to time t_1 at which the voltage level of the reference voltage V_L is equal to that of the sawtooth waveform V_s . This rectangular waveform S_f is applied through the resistor 408 to the transistor 409 to be amplified thereby and appears across the resistor 410. Since the time constant of the saw-tooth waveform V_s is fixed, the pulse width t_f of the rectangular pulse S_f is determined depending on the level of the reference

voltage V_L . When especially the fixed time constant of the saw-tooth waveform V_s is sufficiently large compared with the pulse width (duration of fuel injection) t_f shown in FIG. 7c, the pulse width t_f of the rectangular waveform S_f representing the duration of fuel injection is approximately proportional to the reference voltage V_L . The purpose of the feedback resistor 411 is to prevent the rectangular waveform S_f from undesirable fluctuation which may occur at time t_1 due to noises or any other causes. In this manner, a rectangular waveform signal having a pulse width t_f which is in accord with the required duration of fuel injection can be derived from the output terminal 4b of the fuel injection duration signal generator 4.

The duration of fuel injection for one of the cylinders would not overlap the duration of fuel injection for another cylinder when the number of revolutions of the engine is low. When, however, the engine rotates at high speed and the load on the engine is large, a large amount of fuel is required in one cycle of the engine, and to meet this requirement, current must be supplied for an extended period of time to the solenoid operated valves supplying fuel to the engine. However, the single fuel injection duration signal generator 4 cannot satisfactorily function in a situation in which the injection of fuel into the next cylinder takes place before the injection of fuel into preceding cylinder is not finished, that is, an overlap occurs in the period of time of fuel injection. In such a situation, especially in a high speed range of the engine operation, a fuel injection duration signal which is the same as the fuel injection duration signal for the specific cylinder must be produced with a predetermined time lag or in an out-of-phase relationship. The function is attained by the fuel injection ending signal generator 6 which produces, on the basis of the fuel injection duration signal for the specific cylinder delivered from the fuel injection duration signal generator 4, a signal instructing the end or termination of fuel injection into all the cylinders except for the specific cylinder.

Referring to FIG. 8 showing a block diagram of the fuel injection ending signal generator 6, it comprises a saw-tooth wave generator 60, a detector 63 for detecting the end of the fuel injection duration signal for the specific cylinder supplied from the fuel injection duration signal generator 4, and an imitative signal generator 66 for producing a signal instructing the end of fuel injection into all the cylinders except for the specific cylinder on the basis of a signal delivered from the detector 63, that is, on the basis of the end of the fuel injection duration signal for the specific cylinder. The fuel injection starting signal S_v for the individual cylinders delivered from the fuel injection starting signal generator 2 is supplied to the saw-tooth wave generator 60 as a resetting signal so that the saw-tooth wave generator 60 generates a saw-tooth waveform of constant peak magnitude which is independent of the number of revolutions per unit of time of the engine. In response to the delivery of the signal from the detector 63 which detects the end of the fuel injection duration signal for the specific cylinder supplied from the fuel injection duration signal generator 4, the imitative signal generator 66 stores therein the memory of the level of the saw-tooth waveform at that moment. Then, when the saw-tooth waveform attains the specific level again, the imitative signal generator 66 generates pulses each time that level is attained. Among these pulses, the

pulses which are not in accord with the resetting position or falling point of the saw-tooth waveform are taken as a fuel injection ending signal for ending the injection of fuel into the individual cylinders and this signal appears at the output terminal 6i.

Voltage waveforms appearing at various parts of the fuel injection ending signal generator 6 are shown in FIGS. 12a through 12e. FIG. 12a shows the voltage waveform of the fuel injection duration signal S_f for the specific cylinder supplied from the fuel injection duration signal generator 4. FIG. 12b shows the voltage waveform of the saw-tooth wave V_f . FIG. 12c shows pulses V_d obtained as a result of the detection of the end of the fuel injection duration signal S_f . The pulses include a memory capacitor resetting pulse P_A and a setting pulse P_B . FIG. 12d shows a rectangular waveform V_E which falls to the zero level at the time corresponding to the end of fuel injection into the individual cylinders. This rectangular waveform V_E is subject to differentiation to appear as pulses V_{EP} as shown in FIG. 12e so that the negative pulses among them are utilized as the fuel injection ending signal for supply to the individual cylinders.

The operation and detailed structure of the fuel injection ending signal generator 6 will be described with reference to FIGS. 9, 10 and 11. Referring to FIG. 9 showing the structure of the saw-tooth wave generator 60, it comprises a transistor 601 disposed in the discharging path of a capacitor 604 across which a saw-tooth wave appears, a leakage resistor 603, a transistor 605 which conducts for a very short period of time for charging the capacitor 604 in response to the application of the fuel injection starting signal S_f from the fuel injection starting signal generator 2 to the input terminal 6a, a bias resistor 619 for normally keeping the transistor 605 in the non-conducting state, emitter follower transistor 606 and 607, a load resistor 608 for the transistor 607, resistors 609 and 611 and capacitors 610 and 612 constituting an integrator, an emitter follower transistor 613 for amplifying the output from the integrator, a load resistor 614 for the transistor 613, a differential amplifier 615 for comparing the output from the integrator with a reference voltage given by a variable resistor 617, a feedback resistor 616, a coupling resistor 618, and an output terminal 6b from which the saw-tooth waveform V_f is delivered.

In operation, the transistor 605 conducts to charge the capacitor 604 up to a power supply voltage in response to the application of a pulse of the fuel injection starting signal S_f to the input terminal 6a from the fuel injection starting signal generator 2. The pulse of the fuel injection starting signal S_f disappears soon and the transistor 605 is cut off. In the meantime, current which is dependent upon the output from the differential amplifier 615 is supplied to the transistor 601, and as a result, discharge takes place in the capacitor 604. By maintaining constant current supplied to the transistor 601 from the differential amplifier 615, a linearly decreasing V_f as shown in FIG. 12b appears across the capacitor 604. The capacitor 604 is reset as the next pulse of the fuel injection starting signal S_f is applied to the input terminal 6a, thence to the base of the transistor 605 after a short while. The voltage across the capacitor 604 is subject to impedance conversion by the transistors 606 and 607 so that a saw-tooth waveform voltage of low impedance appears across the load resistor 608. This saw-tooth waveform is integrated and

smoothed out by the integrator composed of the resistors 609, 611 and the capacitors 610 and 612 and is then subject to impedance conversion by the transistor 613 again. Therefore, a d.c. voltage proportional to the magnitude of the saw-tooth waveform appears across the resistor 614. The differential amplifier 615 compares this d.c. voltage with the reference voltage supplied from the variable resistor 617 to deliver an output representative of the difference between these two voltages. This differential voltage is applied to the base of the transistor 601 so as to reduce the differential voltage. As a result, the magnitude of the saw-tooth waveform voltage appearing across the resistor 608 can be maintained constant. It will thus be understood that a saw-tooth waveform voltage V_f of constant magnitude as shown in FIG. 12b can be generated in synchronism with the rotation of the engine and the magnitude is independent of the number of revolutions per unit time of the engine.

FIG. 10 shows the structure of the detector 63 for detecting the end of the fuel injection duration signal for the specific cylinder delivered from the fuel injection duration signal generator 4. Referring to FIG. 10, the detector 63 comprises a first differentiator composed of a capacitor 631 and a resistor 632, a first differentiated pulse amplifying transistor 633, a load resistor 634 for the transistor 633, a second differentiator composed of a capacitor 635 and a resistor 636, a second differentiated pulse amplifying transistor 637, a load resistor 638 for the transistor 637, a third differentiator composed of a capacitor 639 and a resistor 640, a third differentiated pulse amplifying transistor 641, a load resistor 642 for the transistor 641, a phase inverting transistor 643, a load resistor 644 for the transistor 643, an input terminal 6k, and output terminals 6c and 6d.

In operation, the fuel injection duration signal for the specific cylinder supplied from the fuel injection duration signal generator 4 to the input terminal 6k disappears at time to in FIG. 12a and a negative pulse produced by the capacitor 631 and the resistor 632 constituting the first differentiator is applied to the base of the transistor 633 at this moment to cut off the transistor 633. In response to the cut-off of the transistor 633, a positive pulse appears across the load resistor 634 for the transistor 633. The rising point of the positive pulse is detected by the capacitor 639 and the resistor 640 constituting the third differentiator and the pulse is amplified by the transistors 641 and 643 so that a pulse P_A appears at the output terminal 6c. The falling point of the positive pulse appearing across the load resistor 634 for the transistor 633 is subsequently detected by the capacitor 635 and the resistor 636 constituting the second differentiator and the pulse is amplified and subjected to inversion in sign by the transistor 637 so that a pulse P_B appears at the output terminal 6d with a slight delay relative to the pulse P_A as shown in FIG. 12c.

Referring to FIG. 11 showing the structure of the imitative signal generator 66, it comprises a coupling resistor 661, a comparator 662, a coupling resistor 663, an amplifying and inverting transistor 664, a load resistor 665 for the transistor 664, a coupling resistor 666, a NAND circuit 667, a coupling resistor 668, an amplifying and inverting transistor 669, a load resistor 670 for the transistor 669, a coupling resistor 671, a transistor 672 disposed in the charging circuit for a memory ca-

capacitor 673, a resetting transistor 674, a bias resistor 675 for the transistor 674, an amplifying transistor 676 of emitter follower configuration, a load resistor 677 for the transistor 676, coupling resistors 678 and 679, a comparator 680, a coupling resistor 681, an amplifying and inverting transistor 682, a load resistor 683 for the transistor 682, and a capacitor 687 and a resistor 686 constituting a differentiator. Input terminals 6e and 6f are connected to the output terminal 6b of the saw-tooth wave generator 60 shown in FIG. 9 so that the saw-tooth waveform V_f shown in FIG. 12b is applied to the input terminals 6e and 6f from the saw-tooth wave generator 60. Another input terminal 6g is connected to the output terminal 6c of the detector 63 shown in FIG. 10 so that the pulse P_A shown in FIG. 12c is applied to the input terminal 6g from the detector 63. A further input terminal 6h is connected to the output terminal 6d of the detector 63 shown in FIG. 10 so that the pulse P_B shown in FIG. 12c is applied to the input terminal 6h from the detector 63.

In operation, the transistor 674 conducts in response to the application of the pulse P_A to the input terminal 6g and the capacitor 673 discharges across the collector and emitter of the transistor 674. With the decrease in the voltage across the capacitor 673, the emitter voltage of the emitter follower transistor amplifier 676 is also decreased and the decreased emitter voltage is applied to one of the input terminals of the comparator 662 through the resistor 678. On the other hand, the saw-tooth waveform voltage V_f delivered from the saw-tooth wave generator 60 is applied to the input terminal 6e, thence to the other input terminal of the comparator 662 through the resistor 661, and the saw-tooth waveform voltage V_f is compared with the emitter voltage of the transistor 676 in the comparator 662. Since, in this instance, the capacitor 673 is discharging through the transistor 674, the comparator 662 delivers a voltage instructing the charging of the capacitor 673 through the transistor 664, NAND circuit 667 and transistors 669 and 672. However, the NAND circuit 667 does not instruct the charging of the capacitor 673 since the pulse P_B is not applied to the input terminal 6h yet at this time. The NAND circuit 667 instructs the charging of the capacitor 673 as soon as the pulse P_B is applied to the input terminal 6h and the NAND logic of the NAND circuit 667 holds. Since the pulse P_A has disappeared at this time, the transistor 674 has been already cut off, and therefore, the capacitor 673 is charged through the transistor 672. The voltage appearing across the capacitor 673 is applied through the emitter follower transistor amplifier 676 to the input terminal of the comparator 662 to be compared with the saw-tooth waveform voltage V_f applied to the other terminal of the comparator 662. When these two voltages are equal to each other, the comparator 662 applies instructions to the NAND circuit 667 through the transistor 664 so as to stop the charging of the capacitor 673. Consequently, the transistor 672 is cut off immediately and the charging of the capacitor 673 is ceased. After a short while, the pulse P_B disappears. The capacitor 673 would not be charged again even when the voltage across the capacitor 673 may become lower than the saw-tooth waveform voltage V_f unless the next pulses P_A and P_B are applied to the respective input terminals 6g and 6h again. Thus, the capacitor 673 is neither charged nor discharged and the voltage thereacross is maintained at a fixed level. In other

words, the capacitor 673 stores therein a fixed level V_{S1} (FIG. 12b) of the saw-tooth waveform voltage V_f corresponding to the end (at time t_0 in FIG. 12a) of the fuel injection duration signal V_i for the specific cylinder shown in FIG. 12a. Further, the voltage across the memory capacitor 673 is applied to one of the input terminals of the comparator 680, while the saw-tooth waveform voltage V_f is applied to the other input terminal of the comparator 680 through the input terminal 6f. After the voltage across the capacitor 673 has attained the fixed level, the saw-tooth waveform is reset again and then the saw-tooth waveform voltage V_f attains a level equal to the voltage level across the capacitor 673 again. At this point, the comparator 680 acts to urge the transistor 682 from the cut-off to the conducting state. In this manner, a rectangular waveform V_E as shown in FIG. 12d can be obtained, and the end of the fuel injection into each of the cylinders other than the specific cylinder can be detected. This end lies in the same angular position of rotation of the engine crankshaft as the end of the fuel injection duration signal for the specific cylinder and is in synchronism with the rotation of the engine. The rectangular waveform V_E is differentiated by the differentiator composed of the capacitor 687 and the resistor 686 to obtain positive and negative pulses, and the negative pulses V_{EP} shown in FIG. 12e responsive to the transition of the transistor 687 from its cut-off to conducting state are selectively derived from the output terminal 6i to utilize same as a fuel injection ending signal for the cylinders other than the specific cylinder. It will thus be understood that the fuel injection ending signal for the cylinders other than the specific cylinder is produced on the basis of the fuel injection duration signal for the specific cylinder and this fuel injection ending signal is successively distributed so that the duration of fuel injection can be rendered entirely the same for all the cylinders.

The fuel injection ending signal distributor 8 has a structure as shown in FIG. 13 and is actually a sort of a ring counter. The fuel injection ending signal distributor 8 comprises fuel injection ending signal distributor sections 81, 82, 83 and 84 for the first, second, third and fourth cylinders, respectively. The fuel injection ending signal for the specific cylinder derived from the detector 63 of the fuel injection ending signal generator 6 is applied to an input terminal 8A, while the injection interruption pulse from the imitative generator 66 of the fuel injection ending signal generator 6 is applied to an input terminal 8B. The fuel injection ending signal distributor 8 has four output terminals 8a, 8b, 8c and 8d. A diode 81a is connected to the input terminal 8A, while diodes 82a, 83a and 84a are connected to the input terminal 8B. The fuel injection ending signal distributor section 81 includes a resistor 81b grounded at one end thereof, a resistor 81c, a silicon controlled rectifier 81d, a load resistor 81e for the silicon controlled rectifier 81d, and a capacitor 81f connected between the anode of the silicon controlled rectifier 81d and ground. The fuel injection ending signal distributor section 82 includes resistors 82b and 82c, a silicon controlled rectifier 82d, a load resistor 82e for the silicon controlled rectifier 82d, a capacitor 82f connected between the anode of the silicon controlled rectifier 82d and ground, and a capacitor 82g connected between the gate of the silicon controlled rectifier 82d and the junction point between the diode 82a and the resistor

82b. The fuel injection ending signal distributor section 83 includes resistors 83b and 83c, a silicon controlled rectifier 83d, a load resistor 83e for the silicon controlled rectifier 83d, a capacitor 83f connected between the anode of the silicon controlled rectifier 83d and ground, and a capacitor 83g connected between the gate of the silicon controlled rectifier 83d and the junction point between the diode 83a and the resistor 83b. The fuel injection ending signal distributor section 84 includes resistors 84b and 84c, a silicon controlled rectifier 84d, a load resistor 84e for the silicon controlled rectifier 84d, a capacitor 84f connected between the anode of the silicon controlled rectifier 84d and ground, and a capacitor 84g connected between the gate of the silicon controlled rectifier 84d and the junction point between the diode 84a and the resistor 84b. An inductance 84h is connected between the cathode of the silicon controlled rectifier 81d, 82d, 83d and 84d and ground, and a capacitor 84i is connected in parallel with the inductance 84h.

The operation of the fuel injection ending signal distributor 8 having the above structure will be described with reference to FIGS. 14a and 14b and FIGS. 15a through 15d. The input signal having a waveform as shown in FIG. 14a is applied from 6c of the detector 63 of the fuel injection ending signal generator 6 to the input terminal 8A, while the input signal having a waveform as shown in FIG. 14b is applied by inverting the pulses as shown in FIG. 12e from the fuel injection ending signal generator 6 to the input terminal 8B. At time T, all the silicon controlled rectifiers 81d - 84d are in the cut-off state and the capacitors 82g - 84g are charged through the load resistors 81e - 84e and the resistors 82b - 84b and 82c - 84c, respectively. Therefore, none of the diodes 82a - 84a is conducting and none of the silicon controlled rectifiers 82d - 84d as well as the silicon controlled rectifier 81d is conducting. At time t_1 , a pulse P_4 representing the fuel injection ending signal for the specific cylinder is applied to the input terminal 8A to urge the diode 81a and the silicon controlled rectifier 81d to conduct, while the remaining silicon controlled rectifiers 82d - 84d are still kept in the cut-off state. At time t_2 , a pulse of the fuel injection ending signal is applied to the input terminal 8B. At this time, the charge stored in the capacitor 82g has been completely discharged through the resistors 82b and 82c, silicon controlled rectifier 81d and inductance 84h. Thus, the diode 82a conducts and the silicon controlled rectifier 82d is urged to conduct from its previous cut-off state, while the silicon controlled rectifiers 83d and 84d are still kept in the cut-off state due to the fact that the capacitors 83g and 84g are in the completely charged state and the diodes 83a and 84a do not conduct. Before the silicon controlled rectifier 82d conducts, the capacitor 82f is charged through the resistor 82e, but in response to the conduction of the silicon controlled rectifier 82d, the capacitor 82f discharges through the silicon controlled rectifier 82d, inductance 84h and capacitor 84i. Thus, the potential at the cathode of the silicon controlled rectifiers 81d - 84d increases for a period of time which is determined by the capacitances of the capacitors 82f and 84i and the value of the inductance 84h, and the cathode potential is determined by these constants. As a result, the silicon controlled rectifier 81d is urged to cut off from the previous conducting state. This is because the potential at the anode of the silicon controlled rectifier

81d is equal to the ground potential due to the discharging of the capacitor 81f and the increase in the cathode potential results in the flow of a reverse current through the cathode and anode of the silicon controlled rectifier 81d and the capacitor 81f. At time t_3 , the silicon controlled rectifier 83d is urged to conduct and the silicon controlled rectifier 82d is cut off, while the remaining silicon controlled rectifiers 81d and 84d are kept in the cut-off state. At time t_4 , the silicon controlled rectifier 84d is now urged to conduct and the silicon controlled rectifier 83d is cut off. At time t_1' , a pulse is applied to the input terminal 8A in addition to the application of a pulse to the input terminal 8B as shown in FIGS. 14a and 14b so that the diodes 82a, 83a and 84a do not conduct and the diode 81a solely conducts, resulting in the conduction of the silicon controlled rectifier 81d and the cut-off of the silicon controlled rectifier 84d in a manner as described above. Needless to say, the silicon controlled rectifiers 82d and 83d are kept in the cut-off state.

Briefly stating the operation of the fuel injection ending signal distributor 8 again, the silicon controlled rectifiers 81d, 82d, 83d and 84d are successively urged to conduct and cut off starting from the silicon controlled rectifier 81d in response to the application of the input signals shown in FIGS. 14a and 14b to the respective input terminals 8A and 8B. Thus, an output signal as shown in FIG. 15a appears at the output terminal 8a, an output signal as shown in FIG. 15b appears at the output terminal 8b, an output signal as shown in FIG. 15c appears at the output terminal 8c, and an output signal as shown in FIG. 15d appears at the output terminal 8d. While the operation of the distributor 8 during the period of from time t_1 to t_4 has been described, similar operation is repeated during the period of from time t_1' to t_4' and so on so that such output signals appear successively at the output terminals 8a, 8b, 8c and 8d.

The fuel injection starting signal distributor 9 has a structure as shown in FIG. 16 and is actually a sort of a ring counter. As seen in FIG. 16, the structure of the fuel injection starting signal distributor 9 is entirely the same as that of the fuel injection ending signal distributor 8, and the signal distributor 9 operates in the entirely the same manner as the signal distributor 8. Hence, any detailed description of the structure and operation of the fuel injection starting signal distributor 9 is unnecessary. Thus, output signals as shown in FIGS. 18a through 18d appears at respective output terminals 9a, 9b, 9c and 9d of the signal distributor 9 in response to the application of the input signals shown in FIGS. 17a and 17b to respective input terminals 9A and 9B. The input signals shown in FIG. 17a are pulses from the fuel injection starting signal generator 1 as shown in FIG. 3f. The input signals shown in FIG. 17b are the pulses from the fuel injection starting signal generator 2 obtained by inverting the pulses as shown in FIG. 3d. The times T, $t_1, \dots, t_1'''$ shown in FIGS. 17a and 17b as well as FIGS. 18a through 18d are not the same as the times T, $t_1, \dots, t_1'''$ shown in FIGS. 14a and 14b as well as FIGS. 15a through 15d, and the former is delayed in phase from the latter.

Signals as shown in FIGS. 20e through 20h are applied to input terminals A₁, B₁, C₁ and D₁ and to input terminals A₂, B₂, C₂ and D₂ of the fuel injection circuit 10 shown in FIG. 19 in response to the appearance of voltages as shown in FIGS. 20a through 20d at the out-

put terminals of the fuel injection ending signal distributor 8 and fuel injection starting signal distributor 9.

Referring to FIG. 19, the fuel injection circuit 10 comprises solenoid operated fuel injection valves N_1 , N_2 , N_3 and N_4 for the first, second, third and fourth cylinders, respectively. The fuel injection valve N_1 for the first cylinder is controlled by fuel injection starting means 1001 and fuel injection ending means 1002. The fuel injection starting means 1001 includes a resistor 1001a, a capacitor 1001b, an inverting capacitor 1001c, a silicon controlled rectifier 1001d, and a gate resistor 1001e and a gate trigger capacitor 1001f for the silicon controlled rectifier 1001d. The fuel injection ending means 1002 includes a silicon controlled rectifier 1002d, and a load resistor 1002a, a gate resistor 1002e and a gate trigger capacitor 1002f for the silicon controlled rectifier 1002d. The fuel injection valve N_2 for the second cylinder is controlled by fuel injection starting means 1003 and fuel injection ending means 1004. The fuel injection starting means 1003 includes a resistor 1003a, a capacitor 1003b, an inverting capacitor 1003c, a silicon controlled rectifier 1003d, and a gate resistor 1003e and a gate trigger capacitor 1003f for the silicon controlled rectifier 1003d. The fuel injection ending means 1004 includes a silicon controlled rectifier 1004d, and a load resistor 1004a, a gate resistor 1004e and a gate trigger capacitor 1004f for the silicon controlled rectifier 1004d. The fuel injection valve N_3 for the third cylinder is controlled by fuel injection starting means 1005 and fuel injection ending means 1006. The fuel injection starting means 1005 includes a resistor 1005a, a capacitor 1005b, an inverting capacitor 1005c, a silicon controlled rectifier 1005d, and a gate resistor 1005e and a gate trigger capacitor 1005f for the silicon controlled rectifier 1005d. The fuel injection ending means 1006 includes a silicon controlled rectifier 1006d, and a load resistor 1006a, a gate resistor 1006e and a gate trigger capacitor 1006f for the silicon controlled rectifier 1006d. The fuel injection valve N_4 for the fourth cylinder is controlled by fuel injection starting means 1007 and fuel injection ending means 1008. The fuel injection starting means 1007 includes a resistor 1007a, a capacitor 1007b, an inverting capacitor 1007c, a silicon controlled rectifier 1007d, and a gate resistor 1007e and a gate trigger capacitor 1007f for the silicon controlled rectifier 1007d. The fuel injection ending means 1008 includes a silicon controlled rectifier 1008d, and a load resistor 1008a, a gate resistor 1008e and a gate trigger capacitor 1008f for the silicon controlled rectifier 1008d. The input terminal A_1 of the fuel injection starting means 1001 is connected to the output terminal 9a of the fuel injection starting signal distributor 9. The input terminal A_2 of the fuel injection ending means 1002 is connected to the output terminal 8a of the fuel injection ending signal distributor 8. Similarly, the input terminals B_1 , C_1 and D_1 of the fuel injection starting means 1003, 1005 and 1007 are connected to the output terminals 9b, 9c and 9d of the fuel injection starting signal distributor 9, while the input terminals B_2 , C_2 and D_2 of the fuel injection ending means 1004, 1006 and 1008 are connected to the output terminals 8b, 8c and 8d of the fuel injection ending signal distributor 8, respectively.

The fuel injection circuit 10 having a structure as shown in FIG. 19 operates in a manner as described below in response to the application of input signals as shown in FIGS. 21a, 21e, 21b, 21f, 21c, 21g, 21d and

21h to the respective input terminals A_1 , A_2 , B_1 , B_2 , C_1 , C_2 , D_1 and D_2 . FIG. 21i shows the duration of current supplied to the solenoid operated fuel injection valve N_1 for the first cylinder, that is, the fuel injection starting timing and the duration of fuel injection when the input signals shown in FIGS. 21a and 21e are applied to the respective input terminals A_1 and A_2 . Referring to FIG. 19, the silicon controlled rectifier 1001d is urged to conduct in response to the application of the fuel injection starting signal to the input terminal A_1 at time t_1 . As a result, the solenoid operated fuel injection valve N_1 for the first cylinder is energized to start injection of fuel. At the same time, the capacitor 1001c is charged through the circuit including the resistor 1002a and the silicon controlled rectifier 1001d. At time T_1 , the silicon controlled rectifier 1002d is urged to conduct in response to the application of the fuel injection ending signal to the input terminal A_2 . (The difference between time T_1 and t_1 , that is, the period of from time t_1 to T_1 is the duration of fuel injection which is determined by the signals supplied from the fuel injection starting signal generator and fuel injection ending signal generator.) In response to the conduction of the silicon controlled rectifier 1002d, the capacitor 1001c in the charged state discharges through the resistor 1001a, capacitor 1001b, solenoid of the fuel injection valve N_1 and silicon controlled rectifier 1002d, and after the capacitor 1001c is completely discharged, it is charged in a direction opposite to the direction in which it was previously charged. A negative potential appears at the anode of the silicon controlled rectifier 1001d due to the discharge of the capacitor 1001c, the silicon controlled rectifier 1001d is cut off as soon as the silicon controlled rectifier 1002d conducts. At time t_2 , the fuel injection starting signal is applied to the input terminal B_1 , and at time T_2 , the fuel injection ending signal is applied to the input terminal B_2 . In response to the application of the fuel injection starting signal to the input terminal B_1 , the silicon controlled rectifier 1003d is urged to conduct so that the solenoid operated fuel injection valve N_2 for the second cylinder starts injection of fuel. In response to the application of the fuel injection ending signal applied to the input terminal B_2 thereafter, the silicon controlled rectifier 1004d is now urged to conduct and the silicon controlled rectifier 1003d is cut off so that the fuel injection valve N_2 ceases injection of fuel. Since, in this case, no input signals are applied to the input terminals A_1 , A_2 , C_1 , C_2 , D_1 and D_2 , the silicon controlled rectifiers 1005d, 1006d, 1007d, 1008d and 1001d are in the cut-off state while the silicon controlled rectifier 1002d is in the conducting state. Similarly, the silicon controlled rectifiers 1005d and 1007d are urged to conduct at times t_3 and t_4 and cut off at times T_3 and T_4 , while the silicon controlled rectifiers 1006d and 1008d are urged to conduct at times T_3 and T_4 , respectively. Thus, the fuel injection valves N_3 and N_4 inject fuel during the period of from time t_3 to T_3 and the period of from time t_4 to T_4 , respectively. Then, when the fuel injection starting signal is applied to the input terminal A_1 again at time t_1' , the silicon controlled rectifier 1001d is urged to conduct and the solenoid operated fuel injection valve N_1 for the first cylinder starts injection of fuel. The capacitor 1001c in the completely charged state discharges through the resistor 1002a and silicon controlled rectifier 1001d, and after the capacitor 1001c is completely discharged, charging starts in a di-

rection opposite to the direction of previous charging. A negative potential appears at the anode of the silicon controlled rectifier **1002d**, which is thereby cut off. After a short while, the capacitor **1001c** is completely charged in such a manner that the terminal connected to the resistor **1002a** is positive relative to the other terminal. In response to the application of the fuel injection ending signal to the input terminal A_2 at time T_1' , the silicon controlled rectifier **1002d** conducts while the silicon controlled rectifier **1001d** is cut off so that the solenoid operated fuel injection valve N_1 ceases injection of fuel. The fuel injection valves N_2 , N_3 and N_4 inject fuel successively in a manner as described above.

The operation of the fuel injection circuit **10** given with reference to FIGS. **21a** through **21m** refers to the case in which the amount of injected fuel is relatively small and the period of time of fuel injection for the individual cylinders does not overlap each other. The next description given with reference to FIGS. **22a** through **22m** refers to the case in which the amount of injected fuel is increased to such an extent that the period of time of fuel injection for the individual cylinders overlaps each other.

In response to the application of input signals as shown in FIGS. **22a**, **22b**, **22c** and **22d** to the input terminals A_1 , B_1 , C_1 and D_1 of the fuel injection starting means **1001**, **1003**, **1005** and **1007** at times j_1 , j_2 , j_3 and j_4 , the silicon controlled rectifiers **1001d**, **1003d**, **1005d** and **1007d** conduct at the times j_1 , j_2 , j_3 and j_4 , respectively. Due to the conduction of the silicon controlled rectifiers **1001d**, **1003d**, **1005d** and **1007d**, the solenoid operated fuel injection valves N_1 , N_2 , N_3 and N_4 start injection of fuel at the times j_1 , j_2 , j_3 and j_4 , respectively. Thereafter, in response to the application of input signals as shown in FIGS. **22e**, **22f**, **22g** and **22h** to the input terminals A_2 , B_2 , C_2 and D_2 of the fuel injection ending means **1002**, **1004**, **1006** and **1008** at times J_1 , J_2 , J_3 and J_4 , the silicon controlled rectifiers **1002d**, **1004d**, **1006d** and **1008d** conduct, while the silicon controlled rectifiers **1001d**, **1003d**, **1005d** and **1007d** are cut off, respectively. Therefore, the solenoid operated fuel injection valves N_1 , N_2 , N_3 and N_4 cease injection of fuel at the times J_1 , J_2 , J_3 and J_4 . Thus, the period of times of fuel injection by the solenoid operated fuel injection valves N_1 , N_2 , N_3 and N_4 ranges from time j_1 to J_1 as seen in FIG. **22i**, from time j_2 to J_2 as seen in FIG. **22j**, from time j_3 to J_3 as seen in FIG. **22k**, and from time j_4 to J_4 as seen in FIG. **22m**, respectively. It will be seen that the four fuel injection valves inject fuel in overlapped relation with the fuel injection starting and ending timing of these injection valves being out of phase relative to one another. At times j_1' , j_2' , j_3' , j_4' , ... j_2'' and J_1' , J_2' , J_3' , J_4' , ... J_2'' and later, operation similar to that above described is repeated so that the solenoid operated fuel injection valves N_1 , N_2 , N_3 and N_4 inject a controlled amount of fuel into the respective cylinders for the period of time which is determined by the signals supplied from the fuel injection duration signal generator **4** and fuel injection ending signal generator **6**.

While the above description has merely referred to two different time intervals between the fuel injection starting signal and the fuel injection ending signal for the individual cylinders as shown in FIGS. **21a** - **21m** and FIGS. **22a** - **22m** by way of example, the time interval may have any desired value, that is, the time interval between t_1 and T_1 or j_1 and J_1 is suitably variable de-

pending on the amount of injected fuel required for the engine. Further, the time interval may vary to any desired value at any time. In other words, the time interval between the pulses of the fuel injection starting signal in the case of the first cylinder is variable from that shown in FIG. **21a** to that shown in FIG. **22a** or to any other value at any time. The same applies also to the second, third and fourth cylinders.

In the first embodiment described above, the time intervals for fuel injection of the respective cylinders in each operating cycle of the engine are determined commonly by the fuel injection duration signal which has been determined on the basis of the operating condition of the specific cylinder in that operating cycle and therefore, strictly speaking, if, for example, the acceleration pedal is moved by a driver and the operating condition of the engine changes during the same operating cycle, the time interval for fuel injection determined in the above manner might not be ideal for some of the cylinders other than the specific cylinder in view of, for example, the ratio of fuel to air. However, this is not serious practically at all in a high speed range of the engine. For example, assuming that a four-cylinder four-cycle engine is rotating at 50 revolutions per second, that is, it takes 40 milliseconds for the engine to turn two revolutions and that it takes about 400 milliseconds for a driver to depress the acceleration pedal from its highest position to the lowest position, then the engine will work ten operating cycles while the driver depresses the acceleration pedal to the lowest position. During the depression of the pedal, the time interval for fuel injection changes stepwise ten times in accordance with change of the pedal position. Therefore, the actual ratio of fuel to air is not seriously deviated in any cylinder from the ideal ratio. However, if the engine is running at a low speed range, the deviation from the ideal ratio might become not negligible for the following reasons:

1. The capacitor **673** in the imitative signal generator **66** discharges with time through the circuit connected in parallel therewith and the voltage across the capacitor **673** varies with time resulting in a variation in the originally stored level with time.

2. In a very low speed range of the engine, the period of the saw-tooth waveform generated by the saw-tooth wave generator **60** is approximately equal to the time constant of the integrator constituted by the resistors **609**, **611** and the capacitors **610**, **612**. As a result, interference occurs between the saw-tooth waveform and the time constant so that the saw-tooth waveform has not always a constant magnitude.

3. The saw-tooth waveform has a small inclination in a low speed range of the engine, and the output delivered from the comparator **680** in the imitative signal generator **66** in response to the application of the two inputs thereto is greatly affected in respect of time resulting in errors relative to time.

A second embodiment of the present invention which will be described now provides an improvement over the first embodiment in this respect. The second embodiment is so arranged that, in a low speed range of the engine in which no overlap may occur between the periods of time of fuel injection for the individual cylinders, the fuel injection timing signal generator **4** generates a fuel injection timing signal for supplying same to the individual cylinders including the specific cylinder and the signal is directly distributed to the individual

cylinders for eliminating the errors described above. In order that the fuel injection system can operate in the manner described above, the following conditions are essentially required:

1. A predetermined value should be taken as a reference to identify a specific speed range in which an overlap may or may not occur between the periods of time of fuel injection for the individual cylinders.

2. If the specific speed range is a low speed range in which no overlap may occur, the fuel injection duration signal generator 4 generates a fuel injection duration signal for supply to the individual cylinders.

3. If the specific speed range is a high speed range in which an overlap may occur, the fuel injection duration signal generator 4 generates a fuel injection duration signal for supply to the specific cylinder only.

4. In the low speed range, the fuel injection duration signal generated by the fuel injection duration signal generator 4 is distributed to the individual cylinders.

5. In the high speed range, the fuel injection ending signal generated by the fuel injection ending signal generator 6 is used to cease the fuel injection in the individual cylinders.

The second embodiment has a structure as shown in FIG. 23 in which it will be seen that an r.p.m. detector 3, a first discriminator 5, a second discriminator 7 and a third discriminator 11 are added to the first embodiment shown in FIG. 1 so that the r.p.m. detector 3 and the first discriminator 5 meet the conditions (1), (2) and (3) and the second and third discriminators 7 and 11 meet the conditions (4) and (5) set forth in the above.

The r.p.m. detector 3 generates a signal proportional to the r.p.m. of the engine in response to the output signal applied from the fuel injection starting signal generator 2. Upon receiving the output signal of the r.p.m. detector 3, the first discriminator 5 discriminates the speed range of the engine, either high or low, and applies a signal representative of the speed range of the engine to the second discriminator 7. When the engine is rotating in the low speed range, the first discriminator 5 applies to the fuel injection duration signal generator 4 a signal corresponding to the input signal applied from the fuel injection starting signal generator 2. An inverter 12 is connected between the fuel injection starting signal generator 2 and the injection starting signal distributor 9 similarly to the embodiment of FIG. 1.

Referring to FIG. 24, the first discriminator 5 comprises a variable resistor 501 for setting a reference voltage, a comparator 502, a coupling resistor 503, an amplifying transistor 504, a load resistor 505 for the transistor 504, a hysteresis resistor 506, an output coupling resistor 507, a coupling resistor 508, a logic element 509, a coupling resistor 510, an amplifying transistor 511, a load resistor 512 for the transistor 511, and a coupling capacitor 513. The voltage representative of the r.p.m. of the engine is applied to an input terminal 5a from the output terminal 3b of the r.p.m. detector 3. An output signal representative of the result of discrimination as to the high or low speed range, hence the possibility of an overlap or no overlap appears at an output terminal 5b. The fuel injection starting signal delivered from the fuel injection starting signal generator 2 is applied to an input terminal 5c. An output signal corresponding to the fuel injection starting signal applied from the fuel injection starting signal

generator 2 appears at an output terminal 5e depending on the result of discrimination.

In operation, a voltage corresponding to a predetermined r.p.m. of the engine is applied to one of the input terminals of the comparator 502 from the variable resistor 501, while a voltage representative of the actual r.p.m. of the engine is applied to the other input terminal of the comparator 502 from the r.p.m. detector 3, and these two voltages are compared with each other in the comparator 502 so that a positive signal and a negative signal appear at the output terminal of the comparator 502, hence at the output terminal 5b, depending on the low speed range and the high speed range, respectively, of the engine thereby to discriminate between the high and the low speed range. The signal delivered from the comparator 502 is amplified by the transistor 504 to be applied to one of the input terminals of the logic element 509. The hysteresis resistor 506 provides a hysteresis so as to prevent hunting at the change-over point between the high and low speed ranges. The fuel injection starting signal generated by the fuel injection starting signal generator 2 is applied to the other input terminal of the logic element 509 which takes the logical product of the fuel injection starting signal and the signal applied from the comparator 502. Thus, in the low speed range of the engine, a signal corresponding to the fuel injection starting signal applied from the fuel injection starting signal generator 2 appears at the output terminal 5e through the capacitor 513. On the contrary, no signal appears through the capacitor 513 at the output terminal 5e in the high speed range of the engine. It will thus be seen that the first discriminator 5 delivers an output signal corresponding to the fuel injection starting signal applied from the fuel injection starting signal generator 2 only when the engine is in its low speed range, and such output signal is applied from the output terminal 5e to the input terminal 4a of the fuel injection duration signal generator 4. Therefore, in the low speed range of the engine, both the output signal of the fuel injection starting signal generator 1 for the specific cylinder and the output signal of the first discriminator 5 corresponding to the output signal of the fuel injection starting signal generator 2 are applied to the fuel injection duration signal generator 4 so that it operates in a manner as previously described to generate a fuel injection duration signal for the individual cylinders to apply same to the second and third discriminators 7 and 11 from the output terminal 4b. In response to the application of the signal from the fuel injection starting signal generator 1 for the specific cylinder and the fuel injection duration signal from the fuel injection duration signal generator 4, the third discriminator 11 selects the fuel injection duration signal for the specific cylinder and detects the end of this signal thereby to apply a pulse signal to the fuel injection ending signal distributor 8. A fuel injection ending signal for the individual cylinders is applied to the input terminal 8b of the fuel injection ending signal distributor 8 from the second discriminator 7 in a manner as will be described later, and the fuel injection ending signal for the specific cylinder applied from the third discriminator 11 is used as a reference to discriminate as to which signal is to be directed to which cylinder.

Referring to FIG. 25, the second discriminator 7 comprises a signal inverting transistor 701, a first discriminating transistor 702, a bias resistor 703 and a

load resistor 704 for the transistor 702, a coupling resistor 705, a load resistor 706 for the transistor 701, a first output transistor 707, a load resistor 708 for the transistor 707, a second discriminating transistor 709, a bias resistor 710 for the transistor 709, a coupling resistor 711, a second output transistor 712, and a bias resistor 713 for the transistor 712. Input terminals 7a and 7b are connected to the output terminal 5b of the first discriminator 5 shown in FIG. 24. Another input terminal 7c is connected to the output terminal 4b of the fuel injection duration signal generator shown in FIG. 6. A further input terminal 7d is connected to the output terminal 6i of the imitative signal generator 66 shown in FIG. 11. The second discriminator 7 has a signal output terminal 7e.

In operation, the transistor 701 conducts and the transistor 702 is cut off in response to the application of the positive signal appearing at the output terminal 5b of the first discriminator 5 to the input terminal 7a in the low speed range of the engine. Thus, the output signal of the fuel injection duration signal generator 4 is applied directly to the base of the transistor 707 through the input terminal 6c, and the transistor 707 is repeatedly urged to conduct and cut off in response to the signal applied to the input terminal 7c. On the other hand, the transistor 709 is conducting due to the fact that the positive voltage is also applied to the input terminal 7b. Since the transistor 709 is conducting, the output signal of the imitative signal generator 66 applied to the input terminal 7d is shorted to ground across the collector and emitter of the transistor 709 before being applied to the base of the transistor 712, and as a result, the fuel injection duration signal applied to the input terminal 7c from the fuel injection duration signal generator 4 appears in an inverted form across the resistor 708, hence at the output terminal 7e.

In the high speed range of the engine, a negative voltage is applied to the input terminals 7a and 7b of the second discriminator 7. Due to the application of the negative voltage, the transistor 701 is cut off and the transistor 702 conducts with the result that the signal applied to the input terminal 7c is shorted to ground across the collector and emitter of the transistor 702. On the other hand, due to the fact that the negative signal is applied to the input terminal 7b, the transistor 709 is cut off and the transistor 712 is urged to conduct and cut off in response to the output signal of the imitative signal generator 66 applied to the input terminal 7d. As a result, the input signal applied to the input terminal 7d appears in an inverted form at the output terminal 7e.

It will be seen that the output signal of the fuel injection duration signal generator 4 appears at the output terminal 7e as the output signal of the second discriminator 7 when the engine is in its low speed range, while the output signal of the fuel injection ending signal generator 6 appears at the output terminal 7e as the output signal of the second discriminator 7 when the engine is in the high speed range in which the period of time of fuel injection for one cylinder may overlap that for another cylinder. By virtue of the operation of the second discriminator 7 in the manner described above, it is possible to eliminate the inaccuracy of the fuel injection ending signal due to the small inclination and fluctuation in magnitude, etc. of the saw-tooth waveform generated by the saw-tooth wave generator 60 in a low r.p.m. range of the engine and the fuel injection signal

can be maintained stable throughout the entire operating conditions of the engine ranging from the starting up to its maximum speed.

The third discriminator 11 comprises a bistable circuit which is reset by the output signal of the fuel injection starting signal generator 1 for the specific cylinder and generates a signal in response to the end or falling point of the fuel injection duration signal generated by the fuel injection duration signal generator 4. The third discriminator 11 can be realized by a flip-flop circuit as shown in FIG. 26. Referring to FIG. 26, the fuel injection starting signal for the specific cylinder and the fuel injection duration signal are simultaneously applied to respective input terminals 11a and 11b. A silicon controlled rectifier 1101 conducts in response to the application of the fuel injection starting signal for the specific cylinder to the input terminals 11a, and simultaneously a transistor 1102 conducts in response to the application of the fuel injection duration signal to the input terminal 11b. As a result, the potential at a point g is reduced to substantially ground potential. The pulse of the fuel injection starting signal for the specific cylinder soon disappears, but the silicon controlled rectifier 1101 remains in the conducting state. After a predetermined period of time of fuel injection, the fuel injection duration signal disappears to cut off the transistor 1102 and the potential at the point g starts to rise again. Thus, in response to the simultaneous application of the fuel injection starting signal for the specific cylinder and the fuel injection duration signal, a rectangular waveform which lasts for a period of time corresponding to the predetermined duration of fuel injection appears at the point g. This rectangular waveform is differentiated by a differentiator composed of a capacitor 1103 and a resistor 1104 so as to derive a negative and a positive pulse at the rising point and the falling point, respectively, of the rectangular waveform. This pulse signal appears at an output terminal 11c to be applied to the fuel injection ending signal distributor 8.

We claim:

1. A system for electrically controlling fuel injection in a multi-cylinder internal combustion engine comprising in combination:

- a first starting signal generator for generating a first fuel injection starting signal at a predetermined angle in each cycle of operation of a selected reference cylinder, said starting signal being generated in synchronism with the rotation of said engine,
- a second starting signal generator for generating a plurality of succeeding fuel injection starting signals in synchronism with the rotation of said engine, each of said succeeding fuel injection starting signals defining the time at which fuel injection to a corresponding one of the remaining cylinders in said engine is initiated,
- a duration signal generator connected to said first starting signal generator for generating a fuel injection duration signal, said signal having a time duration proportional to the quantity of fuel to be injected into said cylinders,
- an ending signal generator connected to said second starting signal generator and to said duration signal generator for generating fuel injection termination signals, each of said signals defining the time at which fuel injection to a corresponding one of the cylinders is terminated, said ending signal genera-

- tor comprising means for generating a saw-tooth waveform in synchronism with said succeeding fuel injection starting signals, means responsive to said duration signal for generating a duration signal termination signal, and means responsive to said saw-tooth waveform and said duration termination signal for generating fuel injection termination signals for each of said cylinders,
- a fuel injection termination signal distributor connected to said ending signal generator for distributing said fuel injection termination signals successively to each of said cylinders in a predetermined order, and
 - a starting signal distributor connected to said first and second starting signal generators for distributing said succeeding fuel injection starting signals to said cylinders in said predetermined order.
2. A system for electrically controlling fuel injection in a multi-cylinder internal combustion engine comprising:
- a first starting signal generator for generating a first fuel injection starting signal at a predetermined angle in each cycle of operation of a selected reference cylinder, said starting signal being generated in synchronism with the rotation of said engine,
 - a second starting signal generator for generating a plurality of succeeding fuel injection starting signals in synchronism with the rotation of said engine, each of said succeeding fuel injection starting signals defining the time at which fuel injection to a corresponding one of the remaining cylinders in said engine is initiated,
 - a duration signal generator connected to said first starting signal generator for generating a fuel injection duration signal, said duration signal having a time duration which varies with at least one operating parameter of said engine,
 - an ending signal generator connected to said second starting signal generator and said duration signal generator for generating fuel injection termination signals, each of said termination signals defining the time at which fuel injection to a corresponding one of the cylinders is terminated, said ending signal generator comprising means for generating a saw-tooth waveform in synchronism with said succeeding fuel injection starting signals, means responsive to said duration signal for generating a duration signal termination signal, and means responsive to said saw-tooth waveform and said fuel injection termination signal for memorizing the level of said saw-tooth waveform when said termination signal for said selected reference cylinder is generated, and means for generating said fuel injection termination signals for each of said succeeding cylinders when the saw-tooth waveform reaches said memorized level,
 - a fuel injection termination signal distributor connected to said ending signal generator for distributing said fuel injection termination signals successively to each of said cylinders in a predetermined order, and
 - a starting signal distributor connected to said first and second starting signal generators for distributing said succeeding fuel injection starting signals to said cylinders in said predetermined order.
3. The system as recited in claim 1, in which said first starting signal generator comprises means for generat-

ing a signal at a predetermined position in the operating cycle of the specific cylinder, and means for subjecting said signal to wave shaping to obtain a pulse signal.

4. The system as recited in claim 1, in which said second starting signal generator comprises means for generating a signal at a predetermined position in the operating cycle of the individual cylinders, and means for subjecting said signal to wave shaping to obtain a pulse signal.

5. The system as recited in claim 1, in which said duration signal generator comprises means for generating a saw-tooth waveform having a fixed time constant in response to the application of a pulse signal input, and means for generating a rectangular waveform the duration of which ranges from the rising point of said saw-tooth waveform to a point at which said saw-tooth waveform attains a predetermined level.

6. The system as recited in claim 1, in which said ending signal distributor comprises a plurality of ending signal distributing means connected in cascade, the number of said distributing means being equal to the number of the cylinders, and said ending signal distributing means disposed in the first stage operates in response to a first input pulse signal, while the remainder of said ending signal distributing means disposed in the second and following stages operate sequentially in response to a second input pulse signal.

7. The system as recited in claim 1, in which said starting signal distributor comprises a plurality starting signal distributing means connected in cascade, the number of said distributing means being equal to the number of the cylinders, and said starting signal distributing means disposed in the first stage operates in response to a first input pulse signal, while the remainder of said starting signal distributing means disposed in the second and following stages operate sequentially in response to a second input pulse signal.

8. The system as recited in claim 1, which comprises further a first discriminator for applying to said duration signal generator a signal generated by said second starting signal generator in a low speed range of the engine which is lower than a predetermined speed, and a second discriminator for producing an ending signal for the individual cylinders on the basis of the duration signal generated by said duration signal generator in the low speed range.

9. The system as recited in claim 8, in which said first discriminator comprises a comparator for discriminating whether the speed of the engine is higher or lower than the predetermined speed, and a NAND circuit for controlling the passage of the input signal applied from said second starting signal generator depending on the result of discrimination by said comparator.

10. The system as recited in claim 8, in which said first discriminator generates a high speed range signal or a low speed range signal by discriminating whether the speed of the engine is higher or lower than the predetermined speed, and said second discriminator operates in such a manner that, when applied with the high speed range signal, the input signal applied from said ending signal generator appears at the output terminal as an output signal, while when applied with the low speed range signal, the input signal applied from said duration signal generator appears at the output terminal as an output signal.

11. The system as recited in claim 8, which comprises further a third discriminator which, in response to the

output signal delivered from said first starting signal generator and the output signal delivered from said fuel injection duration signal generator, selects the duration signal for the specific cylinder from the duration signal applied from said duration signal generator and detects the switching point of the duration signal so selected, and the output from said third discriminator is applied to said ending signal distributor to be utilized as a reference for the distribution of the ending signal.

12. The system as recited in claim 11, in which said third discriminator comprises a bistable multivibrator which is reset by the input signal applied from said first starting signal generator and is triggered by the input signal applied from said duration signal generator.

13. The system as recited in claim 8, which comprises a fuel injection circuit for producing a signal for the individual cylinders in response to the application of the output signals delivered from said ending signal distributor and said signal distributor.

14. The system as recited in claim 13, in which said fuel injection circuit comprises a plurality of fuel injection means each including a solenoid operated fuel injection valve associated with the corresponding cylinder a control element for energizing said fuel injection valve, and another control element for deenergizing said fuel injection valve.

15. The system as recited in claim 2, in which said first starting signal generator comprises:

a first generator for generating a first signal at a predetermined position in the operating cycle of the specific cylinder, and

first means connected in circuit with said first generator for producing the signal initiating the fuel injection starting timing for the specific cylinder by wave-shaping and differentiating said first signal, and

said second starting signal generator comprises:

a second generator for generating second signals each produced at a predetermined position in each of the operating cycles of the individual cylinders, and

second means connected in circuit with said second generator for producing said starting signals for the individual cylinders by wave-shaping and differentiating said second signals.

16. The system as recited in claim 2, in which said first starting signal generator comprises

means connected in circuit with said second starting signal generator for producing said signal of said first starting signal generator in synchronism with a specific one of the starting signals of said second fuel injection starting generator corresponding to the specific cylinder.

17. The system as recited in claim 2, in which said duration signal generator comprises:

a saw-tooth wave generator connecting in circuit with said first starting signal generator for generating a saw-tooth waveform having a fixed gradient in response to application of the signal of said first starting signal generator, and

means connected in circuit with said saw-tooth wave generator for generating said duration signal of a rectangular waveform, the duration of which ranges from the rising point of said saw-tooth waveform to a point where said saw-tooth waveform reaches a level determined by at least one operating parameter of the engine.

18. The system as recited in claim 2, in which said ending signal distributor comprises:

a plurality of ending signal distributing circuits which are connected one another in a ring counter mode and whose number is equal to the number of the cylinders,

a predetermined specific one of said distributing circuits having an input terminal connected in circuit to said ending signal generator for receiving the end signal for the specific cylinder and an output terminal connected in circuit to said fuel injection means,

the remaining distributing circuits each having an input terminal connected in circuit to said fuel injection signal generator together with the input terminals of the other remaining distributing circuits for receiving the end signals for the individual cylinders and an output terminal connected in circuit individually to said fuel injection means,

each of said distributing circuits being switched upon application of one of the ending signals to its input terminal, from a first state to a second state thereby producing at its output terminal an output signal indicative of the fuel injection ending time of the corresponding one of the cylinders only when the preceding distributing circuit is at the second state, and being switched from the second state to the first state when the succeeding distributing circuit is switched from the first state to the second state.

19. The system as recited in claim 2, in which said starting signal distributor comprises:

a plurality of starting signal distributing circuits which are connected one another in a ring counter mode and whose number is equal to the number of cylinders;

a predetermined specific one of said distributing circuits having an input terminal connected in circuit to said first starting signal generator for receiving the starting signal for the specific cylinder and an output terminal connected in circuit to said fuel injection means,

the remaining distributing circuits each having an input terminal connected in circuit to said second starting signal generator together with the input terminals of other remaining distributing circuits for receiving the starting signals for the individual cylinders and an output terminal connected in circuit individually to said fuel injection means,

each of said distributing circuits being switched upon application of one of the starting signals to its input terminal, from a first state to a second state thereby producing at its output terminal an output signal indicative of the fuel injection starting time of the corresponding one of the cylinders only when the preceding distributing circuit is at the second state, and being switched from the second state to the first state when the succeeding distributing circuit is switched from the first state to the second state.

20. The system as recited in claim 2, further comprising:

a first discriminator connected in circuit between said second starting signal generator and the input terminal of said duration signal generator for applying the starting signals for the individual cylinders to said duration signal generator when the engine speed is lower than a predetermined value, whereby said duration signal generator generates

the fuel injection duration signals for the individual cylinders on the basis of said starting signals applied thereto, and further generating a high speed signal when the engine speed is higher than said predetermined value,

a second discriminator connected in circuit with said duration signal generator for producing signals on the basis of said fuel injection duration signals for the individual cylinders, said signals being applicable to said ending signal distributor in place of said ending signals produced by said ending signal generator,

said second discriminator further connected in circuit between said fuel injection ending signal generator and said fuel injection ending signal distributor and in circuit with said first discriminator for applying said signals produced by said ending signal generator from being supplied to said ending signal distributor when said high speed signal is not applied thereto, and for permitting said ending signals to be applied to said ending signal distributor when said high speed signal is applied thereto.

21. The system as recited in claim 20, further comprising:

an r.p.m. detector connected in circuit with said second starting signal generator for producing a voltage signal proportional to the engine speed by detecting the number of said starting signals pro-

duced from said second starting signal generator, in which said first discriminator comprises:

a comparator connected in circuit with said RPM detector for comparing said voltage signal with a reference voltage signal representative of said predetermined value of the engine speed, and for generating said high speed signal when said voltage signal is higher than said reference voltage signal, and generating a low speed signal when said voltage signal is lower than said reference voltage signal,

a logical product circuit connected in circuit with said comparator and said second starting signal generator for applying said starting signals to said duration signal generator when said low speed signal and said starting signals are simultaneously applied thereto.

22. The system as recited in claim 20, further comprising:

a third discriminator connected in circuit between said duration signal generator and said ending signal distributor for applying an ending signal for the specific cylinder to said ending signal distributor, said ending signal for the specific cylinder being produced by detecting the falling point of said duration signal for the specific cylinder selected from said duration signals applied from said duration signal generator.

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