

[54] CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES

[75] Inventors: Kazuo Oishi; Tokuhiko Kurebayashi; Noriyoshi Ando, all of Kariya, Japan

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

[22] Filed: Nov. 2, 1970

[21] Appl. No.: 85,987

[30] Foreign Application Priority Data

Nov. 13, 1969 Japan..... 44/90970

[52] U.S. Cl. 123/117 R, 123/32 EA, 123/148 E, 123/139 E

[51] Int. Cl. F02p 5/04, F02p 1/00, F02b 3/00

[58] Field of Search 123/32 CL, 148 E, 123/32 C

[56] References Cited

UNITED STATES PATENTS

3,277,875	10/1966	Takao	123/117 R
3,592,178	7/1971	Schiff	123/117 R
3,521,611	7/1970	Finch	123/117 R
3,504,657	4/1970	Eichler	123/32 EA
2,845,910	8/1958	Pribble	123/32 EA
2,859,738	11/1958	Campbell	123/32 EA
3,616,784	11/1971	Barr	123/32 EA
3,614,945	10/1971	Schlagmuller	123/32 EA
3,575,146	4/1971	Creighton	123/32 EA
2,918,911	12/1959	Guiot	123/32 EA

2,953,719	9/1960	Guiot	123/148
3,020,897	2/1962	Sekine	123/148
3,314,407	4/1967	Schneider	123/148
3,587,535	6/1971	Kimberley	123/32 AE

Primary Examiner—Laurence M. Goodridge

Assistant Examiner—Ronald B. Cox

Attorney—Cushman, Darby & Cushman

[57]

ABSTRACT

A control system for internal combustion engines in which the outputs from sensors detecting the factors including the amount of air drawn into the engine or the negative pressure in the air intake manifold, the condition of acceleration, the position of the throttle valve, the temperature of the warmed-up engine, the starting signal of the engine, the angular position of rotation of the crankshaft, and the position of a specific cylinder are suitably added together to determine the amount of injected fuel and the ignition timing depending on these outputs thereby obtaining a fuel injection signal and an ignition signal. By virtue of the fact that the sensors serving the individual services are not provided in multiple and yet the ignition and fuel injection are controlled relative to each other, any desired driving conditions can be sufficiently freely established and the system can be applied to any type of engines by merely modifying the parts for the programming of various settings so that standardization of various parts can be easily realized.

4 Claims, 43 Drawing Figures

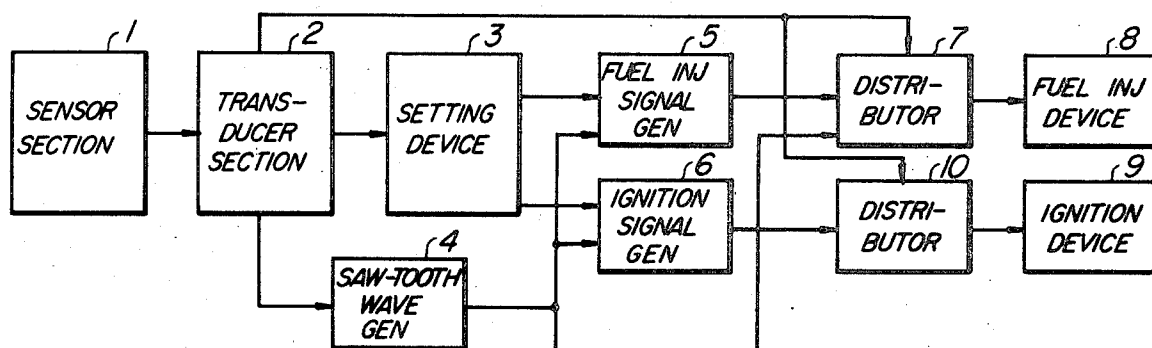


FIG. 1

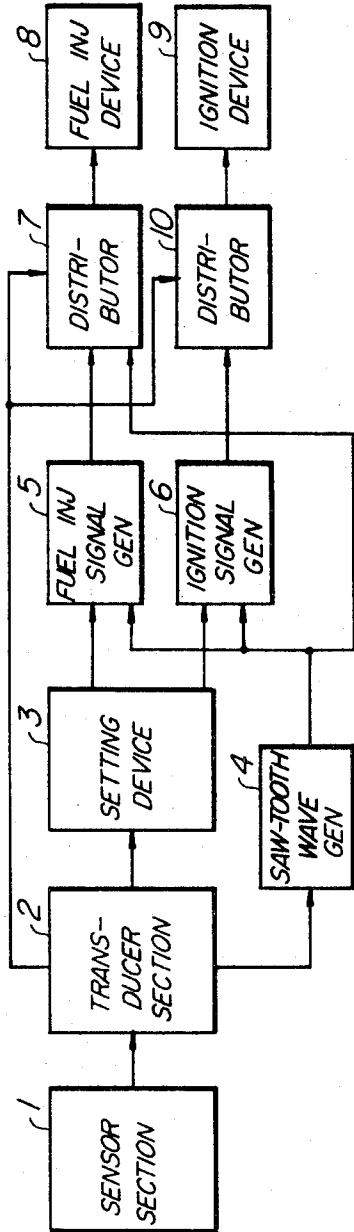
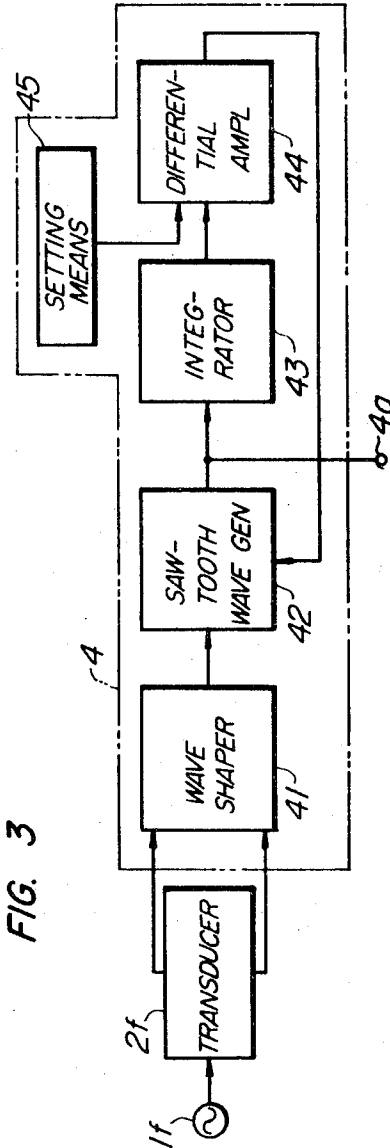


FIG. 3

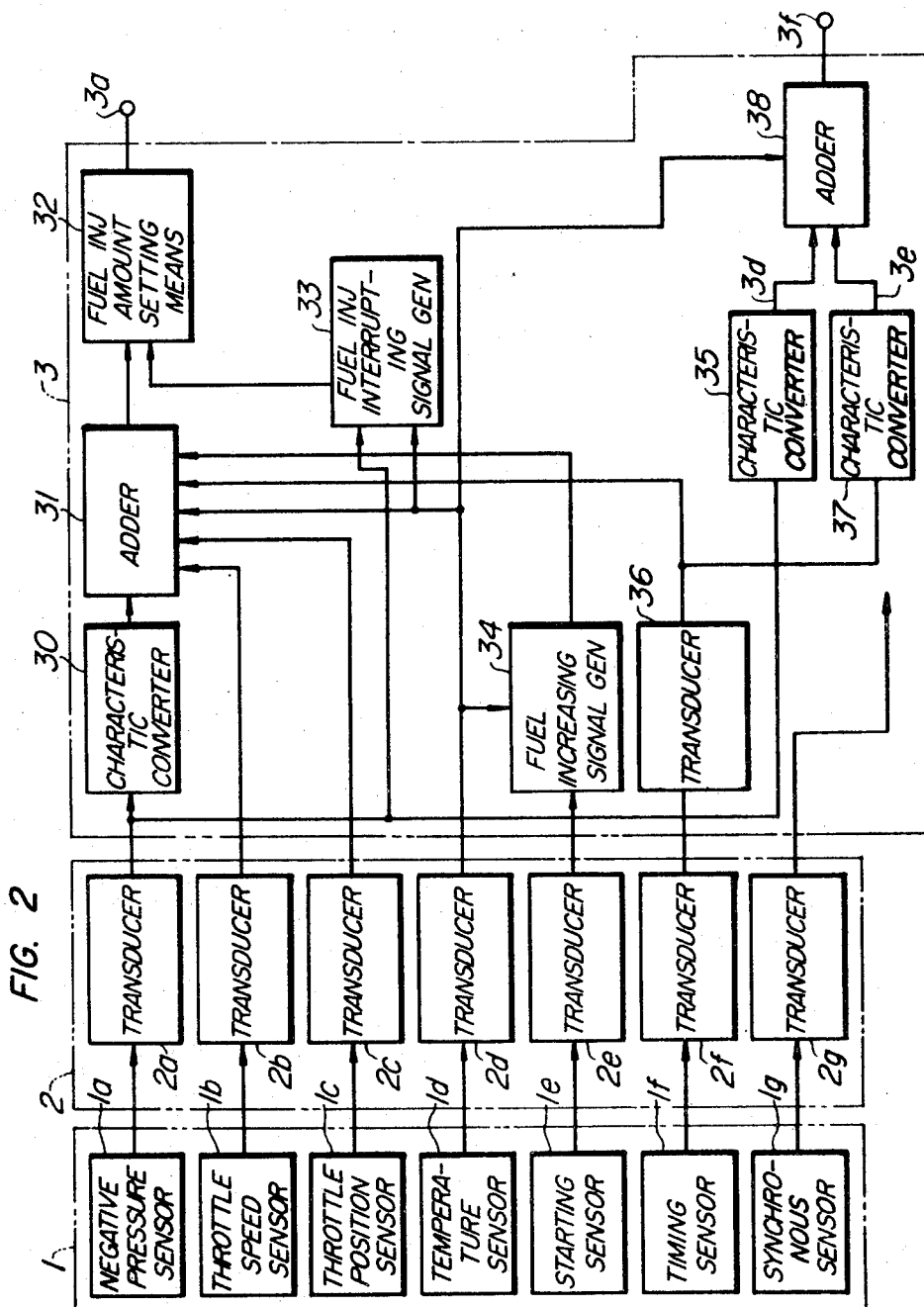


INVENTORS

OSHI et al

BY

Cushman, Darby & Cushman
ATTORNEYS



INVENTORS

OISHI et al

BY

Cushman, Barley & Cushman

ATTORNEYS

FIG. 4

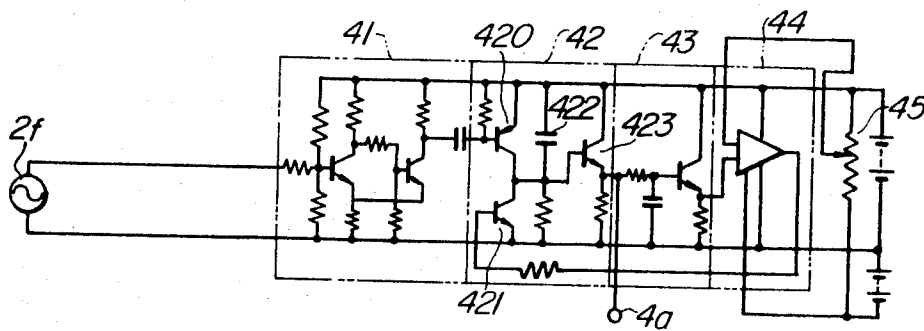


FIG. 5a

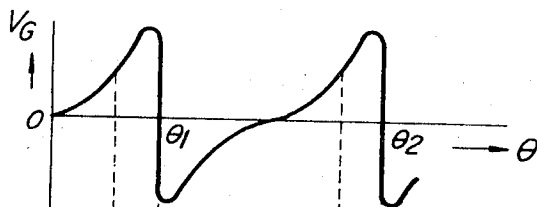


FIG. 5b

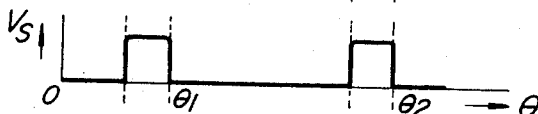


FIG. 5c

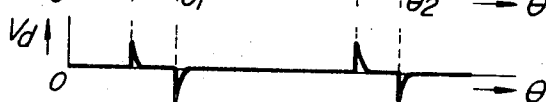


FIG. 5d

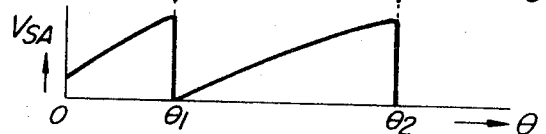
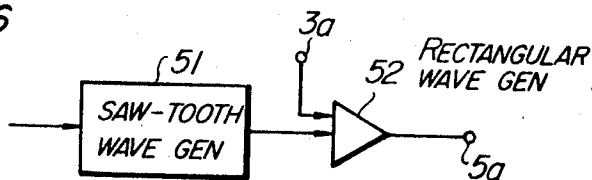


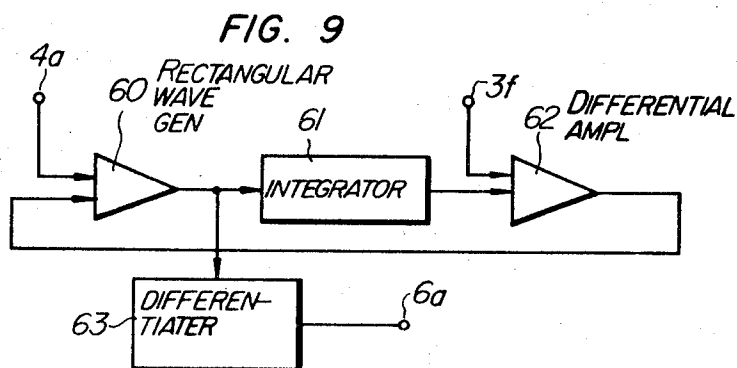
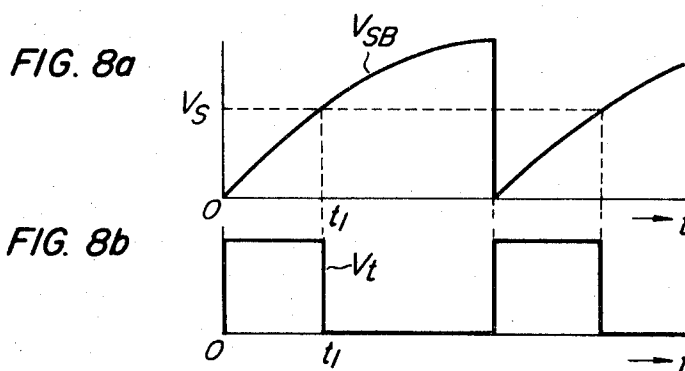
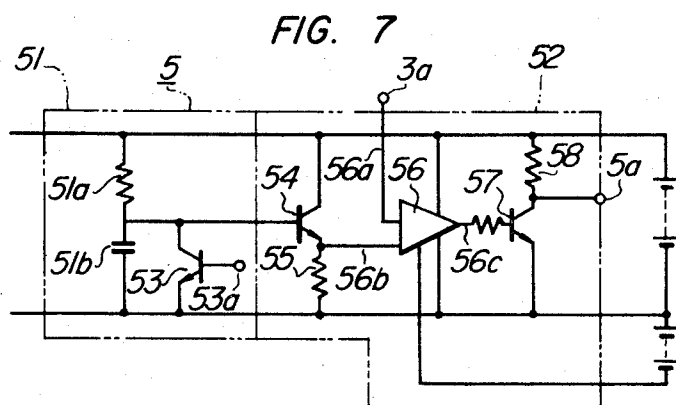
FIG. 6



INVENTORS

OISHI et al

BY *Cushman, Darby & Cushman*
ATTORNEYS



INVENTORS

OISHI et al

BY *Cushman, Darby & Cushman*
ATTORNEYS

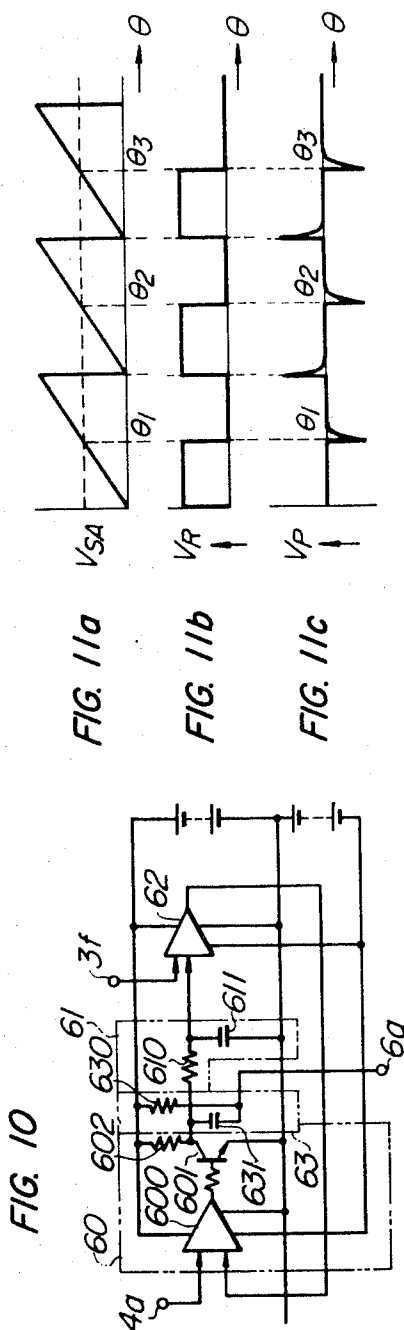
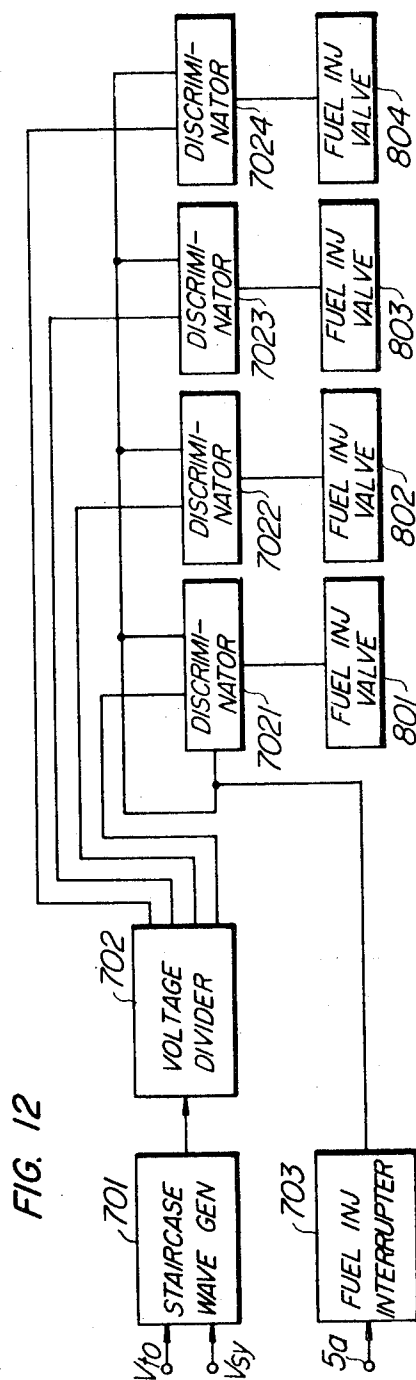


FIG. 11a

FIG. 11b

FIG. 11c



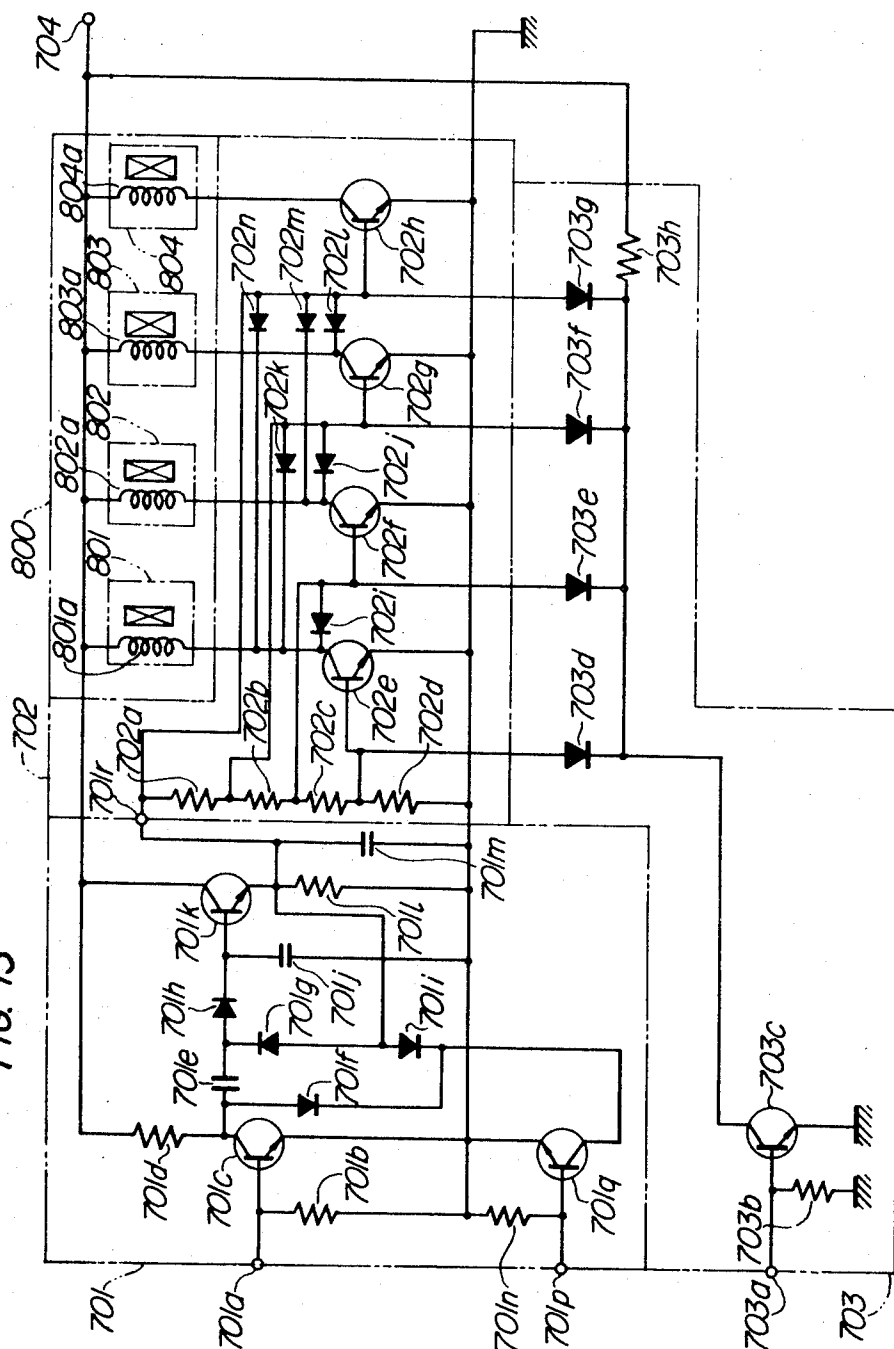
INVENTORS

WISHI-afal

BY

Cushman, Kottley & Cushman
ATTORNEYS

FIG. 13



INVENTOR'S

01541 Tel ul

BY *Cushman, Darby & Cushman*
ATTORNEYS

FIG. 14

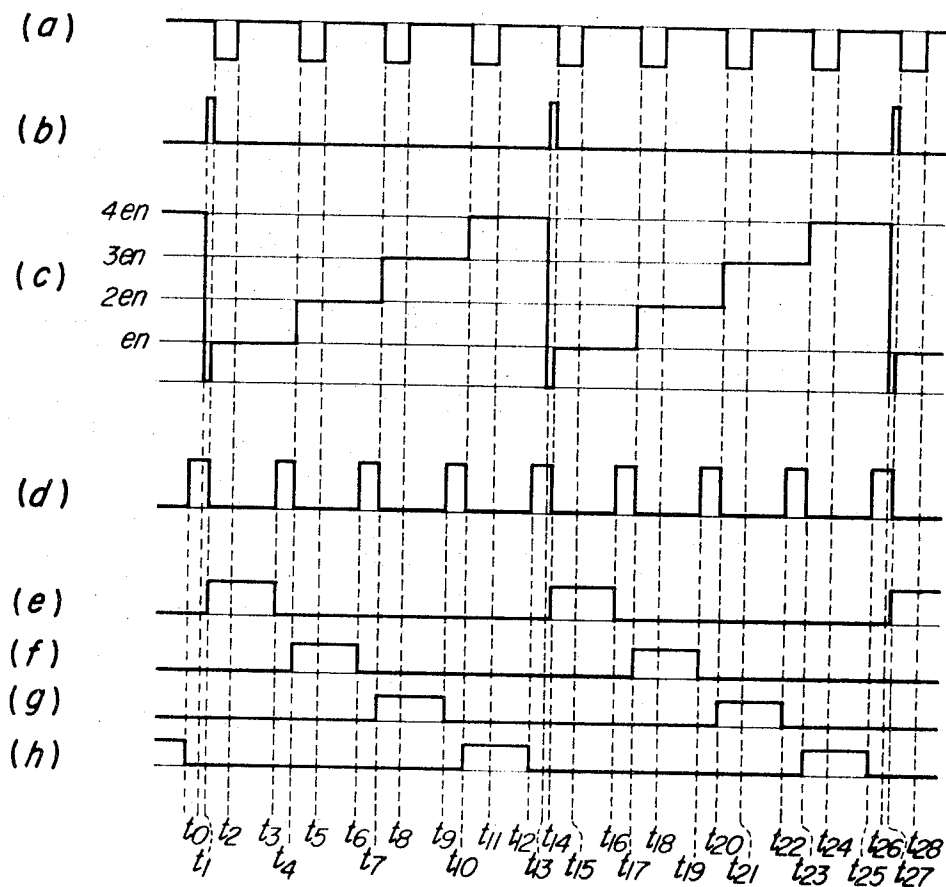
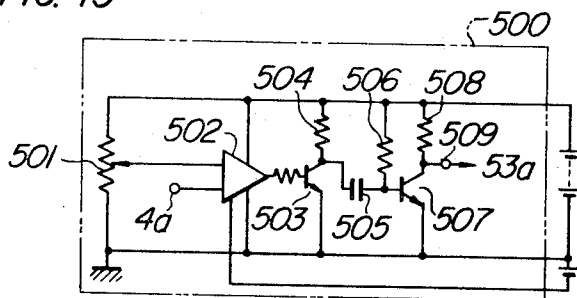


FIG. 15



INVENTORS

01541 746

BY *Cushman, Quinby & Cushman*
ATTORNEYS

FIG. 16

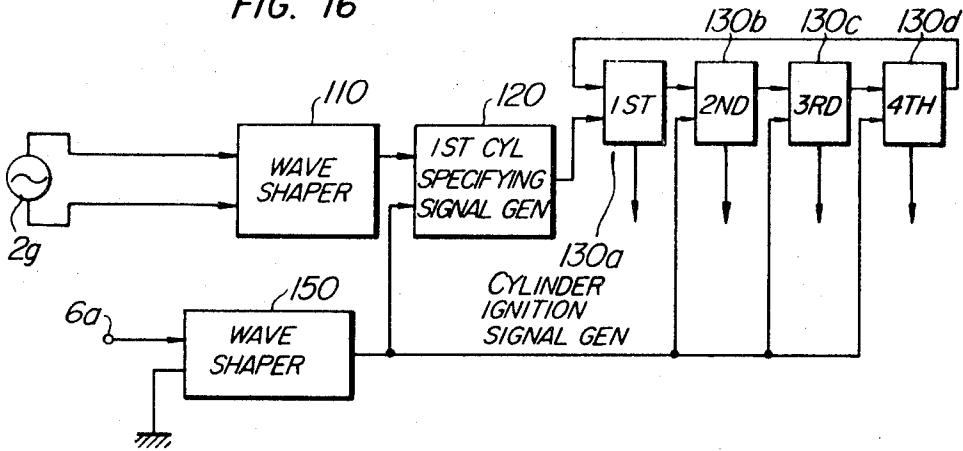
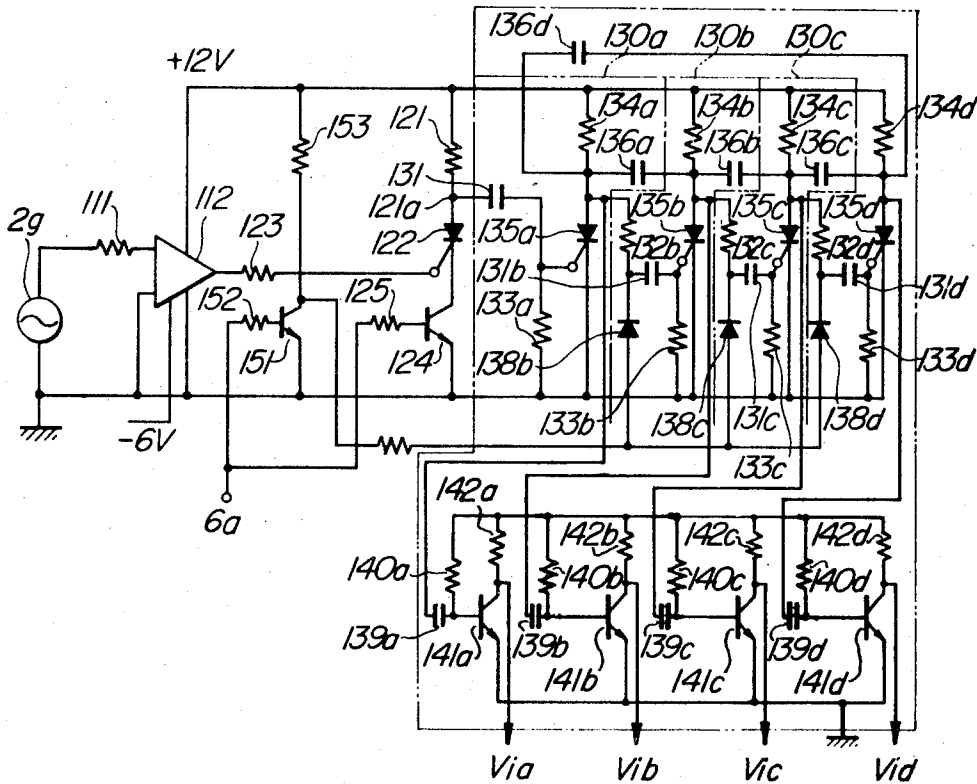


FIG. 17

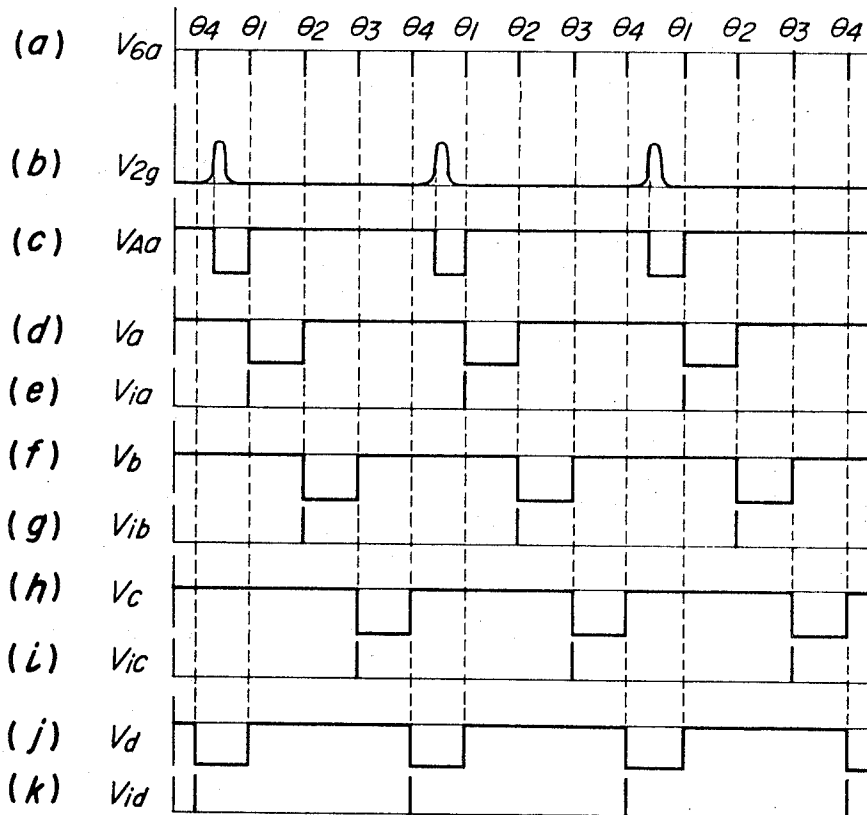


INVENTORS

OISHI et al

BY *Cushman, Darby & Cushman*
ATTORNEYS

FIG. 18



INVENTORS

OSHI et al

BY *Cushman, Quinby & Cushman*
ATTORNEYS

CONTROL SYSTEM FOR INTERNAL COMBUSTION ENGINES

This invention relates to a control system for internal combustion engines in which the fuel supply and ignition which are the principal factors controlling the operation of the engine are controlled by the signals delivered from various sensors so as to suitably and rationally effect the desired control of the engine.

In a heretofore known control system for an internal combustion engine equipped with a fuel injection device having a carburetor or nozzle for injecting gasoline into the engine cylinders, an ignition device which is controlled entirely independently of the fuel injection device has been provided for the fuel ignition. However, according to the prior art engine control system in which the fuel supply system is controlled entirely independently of the ignition system, the individual systems have required sensors for detecting the number of revolutions of the engine, the condition of the load, etc. and great technical difficulties have been encountered in the interrelated operation of these systems. The prior art engine control system has been defective in that the engine can only be satisfactorily controlled under extremely limited conditions because the sensors detecting the conditions of the engine must be provided in multiple and the fuel injection system and the ignition system operate entirely independently of each other.

It is therefore a primary object of the present invention to provide a control system for internal combustion engines comprising negative pressure detecting means for generating an output signal representative of the negative pressure in the air intake manifold of the engine, reference crankshaft position detecting means for generating an output signal by detecting a specific angular position of rotation of the engine crankshaft, revolution detecting means for generating an output signal proportional to the number of revolutions of the engine, a saw-tooth wave generator for generating a saw-tooth wave of a constant amplitude synchronized with the output signal delivered from said reference crankshaft position detecting means in response to the application of said signal, a fuel injection starting signal generator for generating a fuel injection starting signal, temperature detecting means for generating an output signal by detecting the temperature of the engine, a first converter for converting the voltages supplied from said negative pressure detecting means and said temperature detecting means into a voltage indicative of a required amount of fuel to be injected into the engine, means for generating a fuel injection signal depending on the relation between the output delivered from said first converter and the fuel injection starting signal supplied from said fuel injection starting signal generator, specific cylinder detecting means for generating a signal in synchronism with the rotation of the engine immediately before the fuel injection occurs in a specific cylinder, a fuel injection signal distributor for distributing a fuel injection signal to the cylinders in response to the output signals delivered from at least said specific cylinder detecting means and said first rectangular wave generator, angular advance setting means for generating an output signal representative of the angular advance for ignition in response to the output signals delivered from at least said revolution detecting means and said negative pressure detecting means, means for generating an ignition signal in response to

the output of said saw-tooth wave generator and at a point on said saw-tooth wave, and an ignition signal distributor for igniting the cylinders in accordance with a predetermined order.

According to the present invention, the outputs from the means for detecting the negative pressure in the air intake manifold of the engine, the means for detecting the angular position of rotation of the crankshaft, the means for detecting the number of revolutions of the engine and the means for detecting the temperature of the engine are used as the principal factors for determining the amount of injected fuel and the ignition timing required for the engine and are subjected to a characteristic conversion depending on the degree with which the amount of injected fuel and the injection timing are influenced by these factors. Further, the sum of these outputs is sought to determine the amount of injected fuel and the ignition timing. Thus, the present invention provides excellent advantages in that the sensors need not be prepared in multiple for each of the fuel injection system and the ignition system and suitable programming can be made rationally as required, since the pieces of information derived from the sensors are collectively processed and subjected to a characteristic conversion to suit each of the systems as required.

According to the present invention, further, a specific point on the crankshaft is detected as a reference to produce a saw-tooth waveform for detecting the angular position of rotation of the crankshaft. The present invention as such provides the excellent advantages that the angular position of rotation of the crankshaft can be easily detected, the ignition timing and the fuel injection timing can be thereby freely selected, and a single saw-tooth waveform signal makes it possible to extremely reasonably determine the amount of injected fuel, the fuel injection timing and the ignition timing.

According to the present invention, moreover, a source of a saw-tooth wave signal and another source of a cylinder specifying signal synchronous with the rotation of the engine are utilized for the distribution of the fuel injection signal and ignition signal. Thus, the present invention provides the great advantages that no mechanical distributors for the fuel injection and ignition are required since the distribution can be done entirely electrically thereby greatly improving the problem of actual mounting, other mechanical troubles can be substantially eliminated, and the fact that the source of the saw-tooth waveform signal is common to the fuel injection signal distributor and the ignition signal distributor contributes to the rationalization of the system.

Other objects, features and advantages of the present invention will be apparent from the following detailed description of a preferred embodiment thereof taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram of a control system for an internal combustion engine according to the present invention;

FIG. 2 is a block diagram of a sensor section, a transducer section and an angular advance setting device for fuel injection and ignition;

FIG. 3 is a block diagram of a saw-tooth wave generator;

FIG. 4 is an electrical circuit diagram of the saw-tooth wave generator shown in FIG. 3;

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

FIG. 6 is a block diagram of a fuel injection signal generator;

FIG. 7 is an electrical circuit diagram of the fuel injection signal generator shown in FIG. 6;

FIGS. 8a and 8b show voltage waveforms appearing at various parts of the electrical circuit shown in FIG. 7;

FIG. 9 is a block diagram of an ignition signal generator;

FIG. 10 is an electrical circuit diagram of the ignition signal generator shown in FIG. 9;

FIGS. 11a through 11c show voltage waveforms appearing at various parts of the electrical circuit shown in FIG. 10;

FIG. 12 is a block diagram of a fuel injection signal distributor;

FIG. 13 is an electrical circuit diagram of the fuel injection signal distributor shown in FIG. 12;

FIGS. 14a through 14h are voltage waveforms appearing at various parts of the electrical circuit shown in FIG. 13;

FIG. 15 is an electrical circuit diagram of means for determining the fuel injection timing;

FIG. 16 is a block diagram of an ignition signal distributor;

FIG. 17 is an electrical circuit diagram of the ignition signal distributor shown in FIG. 16;

FIGS. 18a through 18k show voltage waveforms appearing at various parts of the electrical circuit shown in FIG. 17; and

FIGS. 19a and 19b are an electrical circuit diagram of the entire system.

Referring first to a block diagram shown in FIG. 1, a sensor section 1 includes a sensor for detecting the negative pressure in the air intake manifold, a throttle speed sensor for detecting the speed with which the throttle valve is moved, a throttle position sensor for detecting the position of the throttle valve, a temperature sensor for measuring the temperature of oil or water in the engine, a starting sensor for detecting the starting of the engine, a timing sensor for detecting the angular position of rotation of the engine crankshaft, and a synchronous sensor for discriminating a specific cylinder which is to be injected with fuel or ignited. The seven sensors in the sensor section 1 are connected to respective transducers in a transducer section 2 so that the outputs from these sensors are transduced into corresponding voltages by the respective transducers. The structure of the sensor section 1 and transducer section 2 will be described in detail later. A setting device 3 connected to the transducer section 2 is operative in setting the amount of injected fuel and the ignition timing in response to the outputs from the sensors in the sensor section 1. A saw-tooth wave generator 4 generates a saw-tooth waveform in response to the signal delivered from the transducer connected to the timing sensor in the sensor section 1. A fuel injection signal generator 5 generates a fuel injection signal upon receiving the outputs from the setting device 3 and the saw-tooth wave generator 4. An ignition signal generator 6 generates an ignition signal when it receives the outputs from the setting device 3 and the saw-tooth wave generator 4. Distributors 7 and 10 distribute the respective output signals from the fuel injection signal

generator 5 and the ignition signal generator 6 to the cylinders. The fuel injection signal so distributed is applied to a fuel injection means 8 including an amplifier for amplifying the fuel injection signal. The ignition signal so distributed is applied to an ignition means 9 for generating a spark across the spark gap of an ignition plug disposed on each cylinder. There are a plurality of such fuel injection means 8 and ignition means 9 depending on the number of cylinders of the engine. Alternatively, one distributor 7, one fuel injection means 8 and one ignition means 9 may be provided and the ignition high voltage may be distributed by a high-voltage distributor.

The operation of the system according to the present invention shown in the block diagram of FIG. 1 will now be briefly described. The outputs from the sensors in the sensor section 1 are transduced into corresponding voltages by the associated transducers in the transducer section 2 to be applied to the next stage. The signals applied to the setting device 3 for determining the amount of injected fuel and the ignition timing are suitably converted by the setting device 3 into voltages representative of the operating conditions of the engine so that the voltage output from the setting device 3 represents how much fuel should be injected at what ignition timing. The output from the transducer which transduces the output from the timing sensor in the sensor section 1 is actually an a.c. voltage and this a.c. voltage is subject to wave shaping in the saw-tooth wave generator 4 to appear as a saw-tooth waveform. This saw-tooth wave is reset at a predetermined angular position of rotation of the engine crankshaft so that it has always a constant magnitude. The saw-tooth waveform output is applied to the fuel injection signal generator 5 wherein the signal is combined with the signal delivered from the setting device 3 so as to determine the duration (amount) of fuel injection and the fuel injection timing. The saw-tooth waveform output is also applied to the ignition signal generator 6 so that the latter generates an ignition signal at the ignition timing determined by both the saw-tooth waveform and the output from the setting device 3. Each time the distributor 7 receives the voltage output from the transducer connected to the synchronous sensor in the sensor section 1 and the saw-tooth waveform output from the saw-tooth wave generator 4, the distributor 7 determines the timing of distribution of the output signal from the fuel injection signal generator 5 to the fuel injection valve associated with each of the cylinders. The fuel injection signal distributed in this manner is applied to the fuel injection valve in the fuel injection means 8 to inject the fuel into the associated cylinder. Similarly, the ignition signal distributed by the distributor 10 is applied to the ignition means 9 to generate a spark across the spark gap of the ignition plug on the associated cylinder.

The structure and operation of the components of the system shown in FIG. 1 will now be described in detail. Referring to FIG. 2, the negative pressure sensor, the throttle speed sensor, the throttle position sensor, the temperature sensor, the starting sensor, the timing sensor and the synchronous sensor are designated by the respective reference numerals 1a, 1b, 1c, 1d, 1e, 1f and 1g. The negative pressure sensor 1a is connected to a negative pressure-voltage transducer 2a which transduces the negative pressure in the air intake manifold into a corresponding voltage. The throttle speed

sensor 1b is connected to a throttle speed-voltage transducer 2b which generates a voltage for controlling fuel supply in response to a sudden change of the throttle position toward its fully opened state. The throttle position sensor 1c is connected to a throttle position-voltage transducer 2c which transduces the detected throttle position into a corresponding voltage thereby generating a voltage signal for switching over between a high output air-fuel ratio, which gives rich mixture near the fully opened throttle position, and an economical air-fuel ratio which gives lean mixture at a throttle position other than the fully opened position. The temperature sensor 1d is connected to a temperature-voltage transducer 2d. The starting sensor 1e is connected to a starting-voltage transducer 2e. The timing sensor 1f is connected to a transducer 2f for transducing a reference position of the crankshaft into a corresponding voltage. The synchronous sensor 1g is connected to a specific cylinder-voltage transducer 2g for generating a voltage in response to a specific angular position of rotation of the crankshaft relative to a specific cylinder. Practically, the sensor 1a and the transducer 2a, the sensor 1b and the transducer 2b, the sensor 1c and the transducer 2c, the sensor 1d and the transducer 2d, the sensor 1e and the transducer 2e, the sensor 1f and the transducer 2f, and the sensor 1g and the transducer 2g are integrally combined to constitute the sensor section.

The structure and operation of the setting device 3 will be described with reference to FIG. 2. The setting device 3 determines the amount of injected fuel and the ignition timing and includes a characteristic converter 30 for suitably applying a conversion to the negative pressure characteristic, an adder 31, a means 32 for setting the amount of fuel to be injected during normal operation, and a fuel injection interrupting signal generator 33. The adder 31 receives the signals from the sensors 1a through 1f through the transducers 2a through 2f, and as a result of the addition of these signals, generates a signal for setting the amount of fuel to be injected during normal driving conditions including increased fuel supply for acceleration and the switch-over between the high output fuel-air ratio and the economical fuel-air ratio. The fuel injection interrupting signal generator 33 generates a signal for interrupting the supply of fuel in response to the application thereto of the negative pressure responsive signal delivered from the negative pressure-voltage transducer 2a and the temperature responsive signal delivered from the temperature-voltage transducer 2d. In other words, the fuel supply is interrupted when the temperature of the engine exceeds a predetermined setting or the engine has been sufficiently warmed up and yet the negative pressure in the air intake manifold is extremely high, namely when the throttle valve is completely closed. The fuel injection interrupting signal generator 33 comprises a comparator having an AND gate. A fuel increasing signal generator 34 compares the output voltage delivered from a time-based voltage generator disposed in the starting-voltage transducer 2e with the output voltage delivered from the temperature-voltage transducer 2d so as to determine the duration of increased supply of fuel to the engine during the starting operation. A characteristic converter 35 applies a further correction to the output from the negative pressure-voltage transducer 2a so that the output from the characteristic converter 35 has a one-to-one relation-

ship with the negative-pressure angular advance characteristic. A revolution-voltage transducer 36 is connected to the reference position-voltage transducer 2f so as to convert the output signal from the reference position-voltage transducer 2f into an output voltage proportional to the number of revolutions of the engine. A characteristic converter 37 applies a correction to the output from the revolution-voltage transducer 36 so that the output from the characteristic converter 37 has a one-to-one relationship with the revolution angular advance characteristic. The output voltage appearing at the output lead 3d of the characteristic converter 35 and the output voltage appearing at the output lead 3e of the characteristic converter 37 are added together in an adder 38 from which an output signal representative of the composite angular advance characteristic appears at an output terminal 3f.

The operation of the setting device 3 having a transducer as described above will now be described in more detail. The negative pressure detected by the negative pressure sensor 1a is transduced into a voltage by the negative pressure-voltage transducer 2a and this voltage is applied to the characteristic converter 30 to be converted into a setting which is in accord with the amount of fuel injection corresponding to the negative pressure in the air intake manifold. The output voltages delivered from the throttle speed-voltage transducer 2b, throttle position-voltage transducer 2c and temperature-voltage transducer 2d and the output signal delivered from the revolution-voltage transducer 36 which converts the output voltage delivered from the reference position-voltage transducer 2f into a voltage proportional to the number of revolutions of the engine are applied to the adder 31 together with the output delivered from the characteristic converter 30. The output signal from the adder 31 is applied to the means 32 for setting the amount of fuel to be injected during normal driving conditions and an output signal for determining the amount of fuel to be injected during normal driving conditions appears at an output terminal 3a. The fuel injection interrupting signal generator 33 acts to interrupt the fuel supply in response to the output voltages delivered from the negative pressure-voltage transducer 2a and temperature-voltage transducer 2d when a high negative pressure exists in the warmed-up state of the engine, hence in the engine braking condition. The fuel increasing signal generator 34 generates a saw-tooth waveform in response to the output voltage delivered from the starting-voltage transducer 2e and this saw-tooth waveform is compared with the output voltage of the temperature-voltage transducer 2d so as to determine the extent of the increase in the amount of fuel supplied during starting. When the temperature of the engine is low, an increased amount of fuel is supplied for a long period of time, while when the engine is in its warmed-up state, a reduced amount of fuel is supplied for a short period of time.

The angular advance for the ignition signal is carried out in a manner as described below. The output from the negative pressure-voltage transducer 2a is applied to the characteristic converter 35 which delivers an output voltage proportional to the angular advance characteristic relative to the negative pressure. On the other hand, the output from the transducer 36 which converts the output from the reference position-voltage transducer 2f into a voltage proportional to the number of revolutions of the engine is applied to the character-

istic converter 37 which delivers an output voltage proportional to the angular advance characteristic relative to the revolution. The output voltages delivered from the characteristic converters 35 and 37 are applied to the adder 38 to be summed up therein so that an output signal proportional to the composite angular advance characteristic is delivered from the adder 38 to appear at the output terminal 3f.

FIGS. 3 and 4 are a block diagram and an electrical circuit diagram, respectively, of the saw-tooth wave generator 4. The structure and operation of the saw-tooth wave generator 4 will be described with reference to FIGS. 3, 4, 5a to 5d. Referring to FIG. 3, the combination of the timing sensor 1f and the reference position-voltage transducer 2f generates a signal synchronous with the rotation of the engine. The reference numerals 41, 42, 43, 44 and 45 designate a wave shaper, a saw-tooth wave generating means, an integrator, a differential amplifier and a setting means, respectively. The output voltage delivered from the reference position-voltage transducer 2f has a waveform as shown by V_G in FIG. 5a. This voltage waveform is applied to the wave shaper 41 to obtain a rectangular waveform as shown by V_s in FIG. 5b and this rectangular waveform is differentiated to obtain pulses as shown by V_d in FIG. 5c. The saw-tooth wave generating means 42 produces a saw-tooth waveform as shown by V_{sa} in FIG. 5d on the basis of the pulses obtained by the differentiation. That is, the saw-tooth waveform is reset in synchronism with the differentiated pulses.

The integrator 43 generates a d.c. voltage proportional to the area per unit time of the saw-tooth waveform V_{sa} . The differential amplifier 44 generates a voltage which is proportional to the difference between the d.c. voltage and a reference voltage applied from the setting means 45, and the output voltage delivered from the differential amplifier 44 is fed back to the saw-tooth wave generating means 42 so as to control the magnitude of the saw-tooth waveform to a constant value. The manner of control is such that the slope of the saw-tooth waveform is increased when the peak value of the saw-tooth waveform is smaller than the reference voltage applied from the setting means 45, while the slope of the saw-tooth waveform is decreased when the peak value of the saw-tooth waveform is larger than the reference voltage so that the area of the saw-tooth waveform is always in accord with the setting. By so controlling, the amplitude of the saw-tooth waveform can be maintained constant.

Referring to FIG. 4, the wave shaper 41 includes a Schmitt circuit for producing the rectangular waveform and a CR differentiation circuit for differentiating the rectangular waveform into the pulses. The saw-tooth wave generating means 42 includes a transistor 420 which conducts and is reset in response to the differentiated pulses, a transistor 421 whose collector current corresponds to the slope of the saw-tooth waveform, a capacitor 422 across which the saw-tooth waveform appears, and an emitter follower transistor 423. The integrator 43 includes a CR smoothing circuit. The differential amplifier 44 is one well known in the art, and the setting means 45 includes a potentiometer. The output from the differential amplifier 44 is applied to the base of the transistor 421 so as to maintain constant the area per unit time of the saw-tooth waveform, thereby maintaining the amplitude of the saw-tooth waveform always constant.

The fuel injection signal generator 5 controls the duration of fuel injection thereby determining the amount of injected fuel. The structure and operation of the fuel injection signal generator 5 will be described with reference to FIGS. 6 and 7 which are a block diagram and an electrical circuit diagram, respectively, of the generator 5. Voltage waveforms appearing in the generator 5 are shown in FIGS. 8a and 8b. Referring to FIG. 6, the fuel injection signal generator 5 includes a saw-tooth wave generator 51 for generating a saw-tooth waveform voltage V_{sb} as shown in FIG. 8a having a fixed time constant and a rectangular wave generator 52 which compares the saw-tooth waveform voltage V_{sb} with a reference voltage V_s for generating a rectangular waveform voltage V_i as shown in FIG. 8b. Referring to FIGS. 8a and 8b, the rectangular waveform V_i falls at time t_1 at which the saw-tooth waveform V_{sb} intersects the reference voltage V_s .

Referring to FIG. 7, the saw-tooth wave generator 51 is composed of a resistor 51a, a capacitor 51b and a resetting transistor 53. The rectangular wave generator 52 is composed of an emitter follower transistor 54, a resistor 55 for the transistor 54, a comparator 56, an amplifying transistor 57 and a load resistor 58 for the transistor 57. In response to the application of a fuel injection starting synchronizing signal to the base 53a of the transistor 53, the capacitor 51b discharges through the transistor 53. The transistor 53 is immediately cut off and the capacitor 51b is charged through the resistor 51a. As a result, a saw-tooth waveform V_{sb} as shown in FIG. 8a appears across the capacitor 51b to be derived through the transistor 54 and the resistor 55. The saw-tooth waveform V_{sb} is applied to one input terminal 56b of the comparator 56, while the output signal appearing at the output terminal 3a of the fuel injection amount setting means 32 in the setting device 3 is applied to the other terminal 56a of the comparator 56, which therefore compares these two inputs to generate a rectangular waveform output V_i as shown in FIG. 8b. More precisely, the fuel injection timing instruction signal delivered from the fuel injection amount setting means 32 in the setting device 3 is applied to one input terminal 56a of the comparator 56 and this signal has a voltage level shown by V_s in FIG. 8a. On the other hand, the saw-tooth waveform V_{sb} of a fixed time constant is applied to the other input terminal 56b of the comparator 56. As a result, the rectangular waveform V_i appearing at the output terminal 56c of the comparator 56 falls at time t_1 at which the reference voltage V_s intersects the saw-tooth waveform V_{sb} , and rises at time $t=0$ or a resetting point of the saw-tooth waveform V_{sb} . In so far as the saw-tooth wave voltage V_{sb} varies linearly with the lapse of time, the time interval between $t=0$ and $t=t_1$ is directly proportional to the reference voltage V_s . This rectangular waveform is then amplified by the transistor 57 to appear as a fuel injection timing signal at the output terminal 5a. According to the rectangular waveform shown in FIG. 8b, the fuel injection is started at time $t=t_0$ and is ceased at time $t=t_1$. When these two instructions are separately required, the rectangular waveform may be differentiated. The negative pulse V_d occurring at an angular position θ_1 of rotation of the crankshaft shown in FIG. 5c, that is, the pulse synchronous with the saw-tooth waveform appearing at the output terminal 4a of the saw-tooth wave generator 4 is preferably utilized as the fuel injection starting signal to be applied

to the base 53a of the transistor 53 unless especially specified.

A circuit arrangement as shown in FIG. 15 based on the same idea as that generally used in determining the ignition timing may be employed in order to obtain a suitable correlation between the engine valve opening timing and the fuel injection starting timing. Referring to FIG. 15, an output voltage delivered from a potentiometer 501 for setting the fuel injection timing and the saw-tooth waveform appearing at the output terminal 4a of the saw-tooth wave generator 4 are applied to a comparator 502 to produce a rectangular waveform. The reference numerals 503, 504, 505, 506, 507 and 508 designate an amplifying transistor, a load resistor for the transistor 503, a capacitor and a resistor constituting a differentiator, a differentiated pulse amplifying transistor, and a load resistor for the transistor 507, respectively. The output voltage of the potentiometer 501 and the saw-tooth waveform are compared in the comparator 502 which generates a rectangular waveform which is in synchronism with the angular position θ_1 of rotation of the crankshaft and rises and falls at two points at which the level of the output voltage of the potentiometer 501 is in accord with the voltage level of the saw-tooth waveform. The point other than the point corresponding to the angular position θ_1 of rotation of the crankshaft represents a fixed angular position of rotation of the engine crankshaft so long as the magnitude of the saw-tooth waveform remains unvaried. The rectangular waveform thus obtained is amplified by the transistor 503 and is then differentiated by the differentiator composed of the capacitor 505 and the resistor 506 to appear as a pulse at the collector of the transistor 507 or output terminal 509. This pulse occurs at the point other than the point corresponding to the angular position θ_1 of rotation of the crankshaft. This pulse is applied to the base 53a of the transistor 53 as the fuel injection starting signal.

The structure and operation of the ignition signal generator 6 will be described with reference to FIGS. 9 and 10 which are a block diagram and an electrical circuit diagram, respectively, of the generator 6. Referring to FIG. 9, a rectangular wave generator 60 generates a rectangular waveform in response to the application thereto of the saw-tooth waveform appearing at the output terminal 4a of the saw-tooth waveform generator 4. An integrator 61 generates a voltage proportional to the on-off ratio of the rectangular waveform and is composed of a CR smoothing circuit. The output from the integrator 61 and the angular advance setting output appearing at the output terminal 3f of the adder 38 in the setting device 3 are applied to a differential amplifier 62 which detects the difference between these two inputs and generates an output which is proportional to the difference therebetween. The output from the differential amplifier 62 is fed back to the input of the rectangular wave generator 60 so that the rectangular waveform generated by the generator 60 has an on-off ratio conforming to the output signal delivered from the adder 38. The output from the rectangular wave generator 60 is applied to a differentiator 63 in which the signal is differentiated to appear as an ignition pulse at the output terminal 6a. Voltage waveforms appearing at various parts of the ignition signal generator 6 are shown in FIGS. 11a, 11b and 11c in which the horizontal axis represents the angular position of the rotation of the crankshaft. Ignition takes

place at the angular positions θ_1 , θ_2 and θ_3 of the rotation of the crankshaft. The output from the saw-tooth wave generator 4 has a waveform as shown by V_{SA} in FIG. 11a, the output from the rectangular wave generator 60 has a waveform as shown by V_R in FIG. 11b, and the output delivered from the differentiator 63 has a waveform as shown by V_P in FIG. 11c. The differentiated pulse V_P is used as the ignition signal.

Referring to FIG. 10, the rectangular wave generator 60 is composed of a comparator 600, an amplifying transistor 601 and a load resistor 602 for the transistor 601. When applied with the saw-tooth waveform from the saw-tooth wave generator 4 and the d.c. output level from the differential amplifier 62, the comparator 600 delivers a rectangular waveform output having an on-off ratio corresponding to the d.c. level of the output from the differential amplifier 62 and this rectangular waveform output is amplified by the transistor 601. The output from the transistor 601 is integrated by an integrator composed of a resistor 610 and a capacitor 611, and the output from the integrator is applied to one of the input terminals of the differential amplifier 62. The differentiator 63 is composed of a resistor 630 and a capacitor 631 and differentiates the rectangular waveform output from the comparator 600 to produce the ignition signal V_P . The ignition signal V_P is supplied to the ignition circuit associated with each cylinder.

The structure and operation of the fuel injection signal distributor 7 will be described with reference to FIGS. 12 and 13 which are a block diagram and an electrical circuit diagram, respectively, of the distributor 7. Referring first to FIG. 12, a staircase waveform generator 701 generates a staircase waveform in response to the application of the fuel injection starting signal V_{IO} and is connected to a voltage divider 702. A fuel injection interrupting means 703 acts to interrupt the fuel injection in response to the fuel injection signal appearing at the output terminal 5a of the fuel injection signal generator 5. Discriminating means 7021, 7022, 7023 and 7024 discriminate the signal supplied from the voltage divider 702 so as to select the fuel injection signal to be directed to the respective fuel injection valves 801, 802, 803 and 804 in a fuel injection device (FIG. 13) associated with the cylinders. The staircase waveform generator 701 is reset in response to the application of the output voltage V_{IV} of the specific cylinder-voltage transducer 2g. When the first fuel injection starting signal V_{IO} is applied to the staircase wave generator 701, it generates a voltage corresponding to the first stair level of the staircase waveform. In response to the application of the second fuel injection starting signal V_{IO} , the generator 701 generates a voltage corresponding to the second stair level of the staircase waveform. In this manner, voltages corresponding to the third and fourth stair levels of the staircase waveform are successively generated. Thereafter, the staircase wave generator 701 is reset again in response to the application of the next synchronizing signal supplied from the specific cylinder-voltage transducer 2g. The staircase waveform voltage generated by the staircase wave generator 701 is applied to the voltage divider 702 by which the voltage is divided into four equal voltages so as to be applied to the respective discriminating means 7021, 7022, 7023 and 7024. In response to the application of the distributed voltages, the discriminating means 7021, 7022, 7023 and 7024 energize the respective fuel injection valves 801, 802,

803 and 804 successively to urge them into the open position. Thus, fuel injection is started. In the meantime, the fuel injection interrupting means 703 is actuated in response to the output signal delivered from the fuel injection signal generator 5 and generates a signal for closing the now opened fuel injection valve after a predetermined period of time thereby completing the injection of fuel into the cylinder.

Voltage waveforms appearing at various parts of the fuel injection signal distributor 7 are shown in FIGS. 14a through 14h. FIG. 14a shows the voltage waveform of the synchronizing signal. FIG. 14b shows the voltage waveform of the timing signal. FIG. 14c shows the staircase voltage waveform appearing at the output terminal of the staircase wave generator 701. FIG. 14d shows the voltage waveform of the output signal delivered from the fuel injection interrupting means 703. FIGS. 14e, 14f, 14g and 14h show the voltage waveforms of the fuel injection timing signal applied to the respective fuel injection valves 801, 802, 803 and 804.

Referring to FIG. 13, the staircase wave generator 701 includes an input terminal 701a for the synchronizing signal applied from the fuel injection signal generator 5, a transistor 701c, a base bias resistor 701b for the transistor 701c, a collector resistor 701d for the transistor 701c, a capacitor 701e, diodes 701f, 701g, 701h and 701i, a capacitor 701j, a transistor 701k, an emitter resistor 701l for the transistor 701k, a capacitor 701m connected across the emitter resistor 701l, a resistor 701n, an input terminal 701p for the timing signal applied from the specific cylinder-voltage transducer 2g, a transistor 701q making a switching operation in response to the timing signal, and an output terminal 701r.

The voltage divider 702 operating in response to the signal applied from the staircase wave generator 701 includes voltage dividing resistors 702a, 702b, 702c and 702d, transistors 702e, 702f, 702g and 702h, and diodes 702i, 702j, 702k, 702l, 702m and 702n. The fuel injection interrupting means 703 applying the signal for interrupting the injection of fuel includes an input terminal 703a, a resistor 703b, a transistor 703c, diodes 703d, 703e, 703f and 703g, and a collector resistor 703h for the transistor 703c. The fuel injection valves 801, 802, 803 and 804 in the fuel injection device 800 are disposed on the suction conduit near the suction valves for injecting a suitable amount of fuel at a suitable timing and are provided with respective driving coils 801a, 802a, 803a and 804a. The reference numeral 704 designates a power supply terminal.

The operation of the fuel injection signal distributor 7 having the structure described above will be described in more detail with reference to FIGS. 13 and 14a through 14h. The synchronizing signal having a voltage waveform as shown in FIG. 14a is applied to the input terminal 701a of the staircase wave generator 701, and the timing signal having a voltage waveform as shown in FIG. 14b is applied to the input terminal 701p, while at the same time, the fuel injection interrupting signal having a voltage waveform as shown in FIG. 14d is applied to the input terminal 703a of the fuel injection interrupting means 703. At time t_0 , the transistor 701q is urged to conduct from its previous cut-off state in response to the timing signal (FIG. 14b) applied to the input terminal 701p, and the diodes 701f and 701i conduct. Therefore, the capacitors 701e, 701j and 701m having been charged prior to time t_0

discharge and no voltage appears across the capacitors 701e, 701j and 701m. At time t_1 , the transistor 701q is cut off again due to the disappearance of the timing signal and the diodes 701f and 701i are cut off again. In the meantime, the transistor 701c is urged to cut off from its previous conducting state in response to the synchronizing signal applied to the input terminal 701a, and the capacitors 701e and 701j are charged through the resistor 701d and the diode 701h. Suppose that the time constant of the charge-discharge circuit including the capacitor 701j, the capacitor 701e and the resistor 701d is selected to be smaller than the pulse width of the synchronizing signal, that is, the period of time between time t_1 and time t_2 , and C_1 , C_2 , V_{in} , e_n and e_r are the capacitance of the capacitor 701e, the capacitance of the capacitor 701j, the power supply voltage, the voltage across the capacitor 701j, and the voltage across the capacitor 701m, respectively. Then, the following equation can be obtained:

$$e_n = (V_{in} + e_r - e_n) [C_1 / (C_1 + C_2)]$$

In FIG. 13, the transistor 701k operates as an emitter follower and therefore e_r is equal to e_n . At time t_2 , the transistor 701c conducts and the capacitor 701e is charged in the reverse direction through the diode 701g by the voltage e_r across the capacitor 701m. At time t_4 , the transistor 701c is cut off again and the capacitors 701e and 701j are charged through the diode 701h again in the manner similar to that described above with the result that a voltage of $e_n + e_n = 2e_n$ appears across the capacitor 701m. At times t_5 , t_7 , t_8 , t_{10} and t_{11} , an operation similar to that described above is repeated with the result that the voltage appearing across the capacitor 701m, hence the output voltage appearing at the output terminal 701r has a staircase waveform in the period of from time t_0 to time t_{13} as shown in FIG. 14c. At time t_{13} , a second pulse of the timing signal shown in FIG. 14b is applied to the base of the transistor 701q through the input terminal 701p and the transistor 701q is urged to conduct from its previous cut-off state. As a result, the diodes 701f and 701i conduct again and the voltage across the capacitor 701m disappears, while simultaneously, the voltage across the capacitor 701e also disappears. At time t_{14} and succeeding times, an operation similar to that occurred from time t_1 to time t_{13} is repeated so that the voltage across the capacitor 701m is increased in the form of a staircase waveform and disappears at time t_{28} again. The time constant of the combination consisting of the capacitor 701m and the resistor 701l is selected to be sufficiently large compared with the repetition period of the synchronizing signal shown in FIG. 14a.

It will be understood that an output voltage of staircase waveform as shown in FIG. 14c appears at the output terminal 701r by the above operation. At time t_0 , all of the transistors 702e, 702f, 702g and 702h are in the cut-off state. Then, when the output voltage appearing at the output terminal 701r is increased at time t_1 to the level of the first stair, that is, to the level of e_n , the output voltage is divided by the dividing resistors 702a, 702b, 702c and 702d to be applied to the bases of the respective transistors 702e, 702f, 702g and 702h. The resistances of the dividing resistors 702a, 702b, 702c and 702d are so selected that the transistor 702h conducts solely while the remaining transistors 702e, 702f and 702g remain in their cut-off state in this case. Thus, at time t_1 , the transistor 702h conducts to

energize the driving coil 804a for the fuel injection valve 804 connected to the collector of the transistor 702h so that the fuel injection valve 804 starts injection of fuel into the associated cylinder. At time t_3 , the fuel injection interrupting signal shown in FIG. 14d is applied to the input terminal 703a to urge the transistor 703c to conduct from its previous cut-off state. As a result, the signal voltage having been applied to the base of the transistor 702h is grounded through the diode 703g and the transistor 703c so that the transistor 702h is urged to the cut-off state again and the injection of fuel by the fuel injection valve 804 is ceased at time t_3 . At time t_4 , the fuel injection interrupting signal disappears and the transistor 703c is cut off again, while at the same time, the output voltage appearing at the output terminal 701r is increased to the level of the second stair, that is, to the level of $2e_n$. Since the resistances of the dividing resistors 702a, 702b, 702c and 702d are so selected that the transistor 702g conducts solely in this case while the remaining transistors 702h, 702f and 702e remain in their cut-off state, the transistor 702g energizes the driving coil 803a for the fuel injection valve 803 connected to the collector of the transistor 702g so that the fuel injection valve 803 starts to inject fuel into the associated cylinder. The conduction of the transistor 702g is not followed by the simultaneous conduction of transistor 702h because the base of transistor 702h is grounded through the diode 702l in response to the conduction of transistor 702g. That is to say, the transistor 702h conducts only when the output voltage appearing at the output terminal 701r is at the level of e_n and no pulse of the fuel injection interrupting signal shown in FIG. 14d is applied to the input terminal 703a. Accordingly, the fuel injection valve 804 injects fuel during a period of from time t_1 to t_3 and during a period of from time t_{14} to t_{16} in the next cycle as shown in FIG. 14e.

In response to the application of a pulse of the fuel injection interrupting signal to the input terminal 703a at time t_6 , the transistor 703c is urged to conduct again from its previous cut-off state and the diode 703f conducts to urge the transistor 702g to cut off again thereby ending the fuel injection by the fuel injection valve 803. Thus, the fuel injection valve 803 injects fuel during a period of from time t_4 to t_6 and during a period of from time t_{17} to t_{19} in the next cycle as shown in FIG. 14f. At time t_7 , the fuel injection interrupting signal having been applied to the input terminal 703a disappears as shown in FIG. 14d, and the transistor 703c is cut off again. At the same time, the fuel injection valve 802 starts to inject fuel into the associated cylinder because the resistances of the dividing resistors 702a, 702b, 702c and 702d connected to the output terminal 701r are so selected that the transistor 702f conducts solely when the output voltage appearing at the output terminal 701r attains the level of the third stair, that is, the level of $3e_n$. In this case, the transistors 702g and 702h are prevented from conducting and the fuel injection valves 803 and 804 do not inject fuel since the bases of these transistors 702g and 702h are grounded through the diodes 702j and 702m and the transistor 702f. At time t_8 , a pulse of the fuel injection interrupting signal shown in FIG. 14d is applied to the input terminal 703a to urge the transistor 703c to conduct so that the diode 703e conducts and the transistor 702f is cut off, thereby ending the fuel injection by the fuel injection valve 802. The fuel injection valve

802 injects fuel during a period of from time t_7 to t_9 and during a period of from time t_{20} to time t_{22} in the next cycle as shown in FIG. 14g. At time t_{10} , the fuel injection interrupting signal having been applied to the input terminal 703a disappears as shown in FIG. 14d and the transistor 703c is cut off. At the same time, the fuel injection valve 801 starts to inject fuel into the associated cylinder because the resistances of the dividing resistors 702a, 702b, 702c and 702d are so selected that the transistor 702e conducts only when the output voltage appearing at the output terminal 701r attains the level of the fourth stair, that is, the level of $4e_n$. The remaining transistors 702f, 702g and 702h are kept in their cut-off state due to the fact that their bases are grounded through diodes 702i, 702k and 702n and the transistor 702e. At time t_{12} , a pulse of the fuel injection interrupting signal as shown in FIG. 14d is applied to the input terminal 703a to urge the transistor 703c to conduct and the base of the transistor 702e is grounded through the diode 703d to end the fuel injection by the fuel injection valve 801. The fuel injection valve 801 injects fuel during a period of from time t_{10} to time t_{12} and during a period of from time t_{23} to time t_{25} in the next cycle as shown in FIG. 14h.

The structure and operation of the ignition signal distributor 10 will be described with reference to FIGS. 16 and 17 which are a block diagram and an electrical circuit diagram, respectively, of the distributor 10. Referring to FIG. 16, the synchronous sensor 1g is connected to the specific cylinder-voltage transducer 2g which delivers an output voltage or synchronizing signal V_{2g} having a waveform as shown in FIG. 18b. A wave shaper 110 applies wave shaping to the synchronizing signal V_{2g} . A signal generator 120 generates a signal specifying the first cylinder. A first cylinder ignition signal generator 130a identifies the first cylinder specifying signal and generates a first cylinder ignition signal. Similar signal generators 130b, 130c and 130d generate a second cylinder ignition signal, a third cylinder ignition signal and a fourth cylinder ignition signal, respectively. A wave shaper 150 applies wave shaping to the timing signal applied from the output terminal 6a of the ignition signal generator 6.

The synchronizing signal and timing signal subjected to wave shaping in the respective wave shapers 110 and 150 are applied to the first cylinder specifying signal generator 120 which applies its output signal to the first cylinder ignition signal generator 130a. Upon receiving the signal from the first cylinder specifying signal generator 120, the first cylinder ignition signal generator 130a generates a first cylinder ignition signal, and at the same time, informs the second cylinder ignition signal generator 130b that the next ignition should take place in the second cylinder. In other words, the second cylinder completes the preparation for ignition in response to the operation of the first cylinder. When, subsequently, a pulse is applied to the second cylinder ignition signal generator 130b from the wave shaper 150, the second cylinder ignition signal generator 130b generates a second cylinder ignition signal. At the same time, the third cylinder completes preparation for ignition and the first cylinder ignition signal generator 130a is restored to its original non-operative state. It will be seen that the circuit has the feature of a ring counter. Similarly, the third and fourth cylinder ignition signal generators 130c and 130d are sequentially operated. The fourth cylinder ignition signal generator 130d is re-

stored to its original non-operative state in response to the application of a pulse to the first cylinder ignition signal generator 130a.

Referring to FIG. 17, the wave shaper 110 is constituted by an input resistor 111 and a comparator 112. The first cylinder specifying signal generator 120 is constituted by a resistor 121, a silicon controlled rectifier 122 for specifying the first cylinder, a gate input resistor 123 for the silicon controlled rectifier 122, a transistor 124 for turning off the silicon controlled rectifier 122, and an input resistor 125 for the transistor 124. The first cylinder ignition signal generator 130a is constituted by a capacitor 131, a silicon controlled rectifier 135a, a gate input resistor 133a for the silicon controlled rectifier 135a, a load resistor 134a for the silicon controlled rectifier 135a, a transistor 136a for turning off the silicon controlled rectifier 135a, a capacitor 139a and a resistor 140a constituting a differentiator, a transistor 141a for polarity inversion, and a load resistor 142a for the transistor 141a. The structure of the second, third and fourth cylinder ignition signal generators 130b, 130c and 130d is similar to that of the first cylinder ignition signal generator 130a, and therefore, is not shown herein.

In FIGS. 18a through 18k, the horizontal axis represents the angular position θ of rotation of the crankshaft. FIG. 18a shows the pulses of the ignition signal V_{6a} applied to the base of the transistors 151 and 124. FIG. 18b shows the voltage waveform of the output delivered from the specific cylinder-voltage transducer 2g. FIG. 18c shows the waveform of the voltage V_{1a} appearing at the junction point of the resistor 121 and the anode of the silicon controlled rectifier 122. FIG. 18d shows the voltage waveform of the signal V_a appearing at the anode of the silicon controlled rectifier 135a for supply to the first cylinder for igniting the same. FIG. 18e shows the pulses of the first cylinder ignition signal V_{1a} . FIG. 18f shows the voltage waveform of the signal V_b appearing at the anode of the silicon controlled rectifier 135b for supplying to the second cylinder for igniting the same. FIG. 18g shows the pulses of the second cylinder ignition signal V_{2a} . FIG. 18h shows the voltage waveform of the signal V_c appearing at the anode of the silicon controlled rectifier 135c for supply to the third cylinder for igniting the same. FIG. 18i shows the pulses of the third cylinder ignition signal V_{3a} . FIG. 18j shows the voltage waveform of the signal V_d appearing at the anode of the silicon controlled rectifier 135d for supply to the fourth cylinder for igniting the same. FIG. 18k shows the pulses of the fourth cylinder ignition signal V_{4a} .

Referring to FIG. 17 again, when the cylinder specifying synchronizing signal is applied to the comparator 112, the comparator 112 produces a rectangular waveform which is applied to the gate of the silicon controlled rectifier 122 to urge the same to conduct. The transistor 124 is normally in the conducting state, and therefore, current flows through the resistor 121, silicon controlled rectifier 122 and transistor 124 resulting in a reduction of the potential at the junction point 121a of the resistor 121 and the anode of the silicon controlled rectifier 122. The transistor 151 conducts and the transistor 124 is cut off in response to the application of a pulse of the ignition signal from the output terminal 6a of the ignition signal generator 6 to the base of the transistor 151. As a result, no current flows through the silicon controlled rectifier 122 and the po-

tential at the junction point 121a increases abruptly. This results in the conduction of the silicon controlled rectifier 135a and in the cut-off of the transistor 141a through the capacitor 139a. However, the transistor 141a conducts again after a period of time which is determined depending on the time constant of the combination consisting of the capacitor 139a and the resistor 140a, and a positive pulse as shown by V_{1a} in FIG. 18e appears at the collector of the transistor 141a. The positive pulse V_{1a} is used as the first cylinder ignition signal. The voltage at the anode of the silicon controlled rectifier 135a is reduced due to the conduction of the silicon controlled rectifier 135a, and the capacitor 131b discharging through the resistor 132b, silicon controlled rectifier 135a and resistor 133b. When, subsequently, a pulse of the ignition signal for igniting the second cylinder is applied from the ignition signal generator 6, the transistor 151 is cut off and the raised collector voltage charges the capacitor 131b through the diode 138. As a result, a positive voltage is applied to the gate of the silicon controlled rectifier 135b which, therefore, conducts. At the same time, the capacitor 136a discharges through the silicon controlled rectifiers 135b and 135a thereby to cut off the silicon controlled rectifier 135a. Further, due to the fact that the voltage at the anode of the silicon controlled rectifier 135b is reduced, anode the silicon controlled rectifier 135c conducts in response to the next pulse of the ignition signal. In this manner, the first, second, third and fourth cylinder ignition signals V_{1a} , V_{2a} , V_{3a} and V_{4a} can be produced.

The entire circuit diagram of the system according to the present invention is shown in FIGS. 19a and 19b. In FIG. 19a, the reference numeral 11 designates a power supply circuit having a positive lead D, a grounded lead E and a negative lead B for the supply of power to the components described above. The input to the power supply circuit 11 is supplied from a battery 12 mounted on the vehicle. The ignition device 9 is of the capacitor ignition type comprised of silicon control rectifiers 901, 902, 903 and 904, ignition coils 905, 906, 907 and 908, ignition plugs 909, 910, 911 and 912, and a common discharging capacitor 913.

The operation of the system will be described with reference to FIGS. 19a and 19b. The detector for the negative pressure in the intake manifold is composed of the negative pressure sensor 1a and the negative pressure-voltage transducer 2a. The negative pressure sensor 1a is connected to the air intake manifold of the engine so that a diaphragm incorporated in the sensor 1a is moved depending on the negative pressure in the air intake manifold and a differential transformer is actuated in response to the movement of the diaphragm. The signal thus produced is supplied to the characteristic converter 30 to be subjected to conversion and amplification therein so that the output from the characteristic converter 30 represents the required amount of fuel corresponding to the negative pressure in the air intake manifold. A part of the output of the transducer 2a is applied to the characteristic converter 35 so that the latter generates a d.c. voltage which is in accord with the angular advance corresponding to the negative pressure in the air intake manifold. The operation of the characteristic converter 30 and characteristic converter 35 is such that current flows only through a resistor when the input voltage is low, but the current flows through a Zener diode when the input voltage is in-

creased to a certain level so as to thereby obtain an output voltage characteristic which shows a break point with the increase in the negative pressure in the air intake manifold. The angular advance for ignition relative to the negative pressure is such that the angular advance is large during a high negative pressure in the air intake manifold, while the amount of injected fuel relative to the negative pressure is such that the amount of injected fuel is small at a high negative pressure in the air intake manifold. Thus, the polarities are selected to meet the above conditions. The timing sensor 1f comprises a generator rotating in synchronism with the engine and is connected to the reference position-voltage transducer 2f which delivers an output signal synchronous with the rotation of the engine. This output signal is applied to the revolution-voltage transducer 36 which detects the number of revolutions of the engine and also to the saw-tooth wave generator 4 which detects the reference position of the crankshaft. The output from the reference position-voltage transducer 2f has a waveform as shown by V_G in FIG. 5a and the reference angular position of rotation of the crankshaft so detected is designated by $\theta_1, \theta_2, \dots$. The signal voltage delivered from the reference position-voltage transducer 2f is subjected to wave shaping by the Schmitt circuit in the revolution-voltage transducer 36 to appear as a rectangular waveform which is then differentiated by the differentiator so that a pulse appears at the reference angular position of rotation of the crankshaft. This pulse is utilized to produce a saw-tooth waveform which is reset at the reference angular position of rotation of the crankshaft. The revolution-voltage transducer 36 is provided therein with a saw-tooth wave generator which generates another saw-tooth waveform of a fixed time constant which is reset by the differentiated pulse. This saw-tooth waveform is utilized to produce a rectangular waveform which rises and falls at a predetermined level of the saw-tooth waveform and this rectangular waveform is integrated to detect the number of revolutions of the engine. More precisely, the rectangular waveform of a fixed period is integrated in the revolution-voltage transducer 36 to produce a voltage which varies linearly with the number of revolutions of the engine thereby to detect the number of revolutions of the engine. The signal voltage proportional to the number of revolutions of the engine is applied through the characteristic converter 37 to the adder 38 together with the signal voltages applied from the characteristic converter 35 and temperature-voltage transducer 2d so that a voltage representative of the composite angular advance characteristic is delivered from the adder 38 to be applied to the ignition signal generator 6. The temperature sensor 1d is connected to the temperature-voltage transducer 2d comprises a thermistor T_n submerged in the engine cooling water or engine oil so as to detect the temperature on the basis of a variation in the resistance of the thermistor T_n which is dependant on the temperature. More precisely, a resistor whose resistance does not vary depending on the temperature is connected in series with the thermistor T_n , and a constant voltage is applied across the series circuit. The voltage applied across the thermistor T_n varies due to a variation in the resistance of the thermistor T_n and this voltage is detected to determine the temperature of the engine. The voltage representative of the temperature of the engine is applied to the adders 31 and 38. The throttle position sen-

sor 1c connected to the throttle position-voltage transducer 2c delivers a signal indicative of the position or opening of the throttle valve. The throttle position-voltage transducer 2c operates when the throttle valve opening exceeds a predetermined value so as to increase the amount of injected fuel thereby to switch over the fuel consumption from the economical fuel-air ratio to the high output fuel-air ratio. The starting-voltage transducer 2e acts to increase the amount of injected fuel in response to the detection of the starting of the engine by the starting sensor 1e and applies its output signal to the adder 31. The throttle speed sensor 1b connected to the throttle speed-voltage transducer 2b comprises a generator connected to the throttle valve so that the throttle speed-voltage transducer 2b generates an output voltage when the throttle valve is abruptly urged to its open position and this output is applied to the adder 31 for increasing the amount of injected fuel.

What is claimed is:

1. A control system for internal combustion engines comprising:

sensor means including at least a negative pressure sensor for detecting the negative pressure in the air intake manifold of the engine, a temperature sensor for detecting the temperature of the engine and a timing sensor for detecting predetermined rotating angular positions of the engine crankshaft;

transducer means including at least a first transducer connected to said negative pressure sensor for generating an output voltage proportional to the negative pressure, a second transducer connected to said temperature detector for generating an output voltage proportional to the temperature of the engine, and a third transducer connected to said timing sensor for generating output pulses indicative of said predetermined rotating angular positions of said engine crankshaft;

a setting device including a first converter means connected to at least said first and second transducer for producing a first voltage signal from at least the output voltages of said first and second transducers, said first voltage signal being indicative of an amount of the fuel to be injected into the engine and varying as a function of at least said negative pressure and said temperature of the engine, a fourth transducer connected to said third transducer for generating an output voltage proportional to the number of the output pulses of said third transducer which is proportional to the number of revolutions of the engine, and a second converter connected to said first and fourth transducers for producing a second voltage signal from the output voltages of said first and fourth transducers, said second voltage signal being indicative of an angular value to be advanced for ignition under the condition of said negative pressure and said number of revolutions of the engine;

a saw-tooth wave generator connected to said third transducer for generating a train of saw-tooth voltages each synchronized with the output pulses of said third transducer, said saw-tooth voltages having trailing ends indicative of said rotating angular positions of the engine crankshaft and peak amplitudes of a predetermined constant value independent of engine speed;

injection means electrically connected to said first converter and said saw-tooth generator for supplying each cylinder of the engine with a fuel whose amount is proportional to the value of said first voltage signal of said first converter and whose timing is determined by said saw-tooth voltages of said saw-tooth wave generator; and

ignition means connected to said saw-tooth wave generator and said second converter for generating ignition signals whose timing is determined by said saw-tooth voltages from said saw-tooth generator and said second voltage signal of said second converter, and for operating ignition of the cylinders of the engine in accordance with said ignition signals.

2. A control system according to claim 1, wherein said sensor means further comprises a synchronous sensor for detecting a specific rotating angular position corresponding to a specific one of said predetermined rotating angular positions of the engine crankshaft; and said transducer means further comprises a fifth transducer connected in circuit with said synchronous sensor for generating an output signal representative of said specific rotating angular position; and wherein

said ignition means comprises

an ignition signal generator connected in circuit with said second converter and said saw-tooth wave generator for producing output signals by comparing said saw-tooth voltages of said saw-tooth wave generator with said second voltage signal of said second converter,

a distributor connected in circuit with said fifth transducer and said ignition signal generator for distributing said output signals of said ignition signal generator to the cylinders of the engine in a predetermined order thereof, with correspondency determined with reference to said output signals of said fifth transducer, and

an ignition device connected in circuit with said distributor for effecting ignition of the cylinders of the engine in accordance with said ignition signals distributed from said distributor.

3. A control system according to claim 1, wherein said sensor means further comprises a throttle speed sensor for detecting the speed of movement of a throttle valve for the engine, a throttle position sensor for detecting the position of said throttle valve, and a starting sensor for detecting the starting of the engine;

said transducer means further comprises sixth, seventh, and eighth transducers connected in circuit with said throttle speed sensor, said throttle position sensor and said starting sensor, respectively for producing voltage signals representative of the speed of the movement of said throttle valve, the position of said throttle valve and the starting of the engine, respectively;

said setting device further comprises a fuel increasing signal generator connected in circuit with said second and eighth transducers for producing an output signal for increasing the amount of fuel supply at the starting of the engine when the temperature

of the engine is below a predetermined value, a fuel injection interrupting signal generator connected in circuit with said first and second transducers for producing an output signal when the temperature of the engine is higher than a predetermined value and the negative pressure in the air intake manifold is more negative than a predetermined value corresponding to the idling state of the engine, said first converter being further connected in circuit with said fourth, sixth and seventh transducers and said fuel increasing signal generator for producing said first voltage signal modified in accordance with the output signals of the connected transducers and generator thereby controlling the amount of fuel supply, and a fuel injection amount setting means connected in circuit with said first converter and said fuel interrupting signal generator for canceling said first voltage signal of said first converter at the presence of said output signal of said fuel injection interrupting signal thereby interrupting the fuel injection.

4. A control system according to claim 1 wherein said sensor means further comprises a synchronous sensor for detecting a specific one of said predetermined rotating angular positions of the engine crankshaft; and said transducer means further comprises a fifth transducer connected in circuit with said synchronous sensor for generating an output signal representative of said specific rotating angular position; and wherein

said injection means comprises;

a fuel injection signal generator connected in circuit with said first converter means and said saw-tooth wave generator for generating other saw-tooth voltages synchronized with said trailing ends of said first-mentioned saw-tooth voltages, the amplitudes of said other saw-tooth voltages being of a predetermined constant value and for producing rectangular pulses by comparing said first voltage signal of said first converter means with said other saw-tooth waves,

a distributor connected in circuit with said fuel injection signal generator, said saw-tooth wave generator and said fifth transducer for generating a staircase voltage, the voltage level of which is reset to a predetermined initial value upon occurrence of the output signal of said fifth transducer and increases stepwisely upon each occurrence of the leading ends of said first-mentioned saw-tooth voltages, and for generating fuel injection signals for the respective cylinders of the engine, said fuel injection signals beginning when said staircase voltage reaches the respective stepwisely increased levels thereof and ending in synchronism with the trailing ends of said rectangular pulses; and

a fuel injection device connected in circuit with said distributor for supplying each cylinder of the engine with fuel during the time that the respective one of said fuel injection signals is applied thereto.

* * * * *