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[72] Inventors Iseji Kamazuka
Kariya-shi;
Kunio Endo, Anjo-shi, both of Japan
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[73] Assignee Toyota Jidosha Kogyo Kabushiki Kaisha
Toyota-shi, Japan
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[54] **FUEL INJECTION SYNCHRONIZING SYSTEM**
6 Claims, 4 Drawing Figs.

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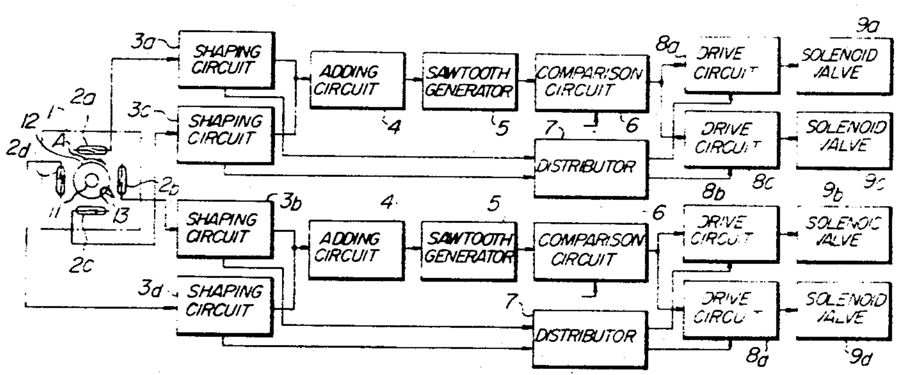
Primary Examiner—Laurence M. Goodridge
Attorney—Cushman, Darby & Cushman

ABSTRACT: In a fuel injection control apparatus for use with a multicylinder fuel injection-type engine, which gives each fuel injection nozzle-operating solenoid valve an exciting pulse of a duration to satisfy the engine requirement, a fuel injection synchronizing system by which a pulse signal synchronous with the cycle of the engine is produced and the exciting pulse is distributed to each cylinder.



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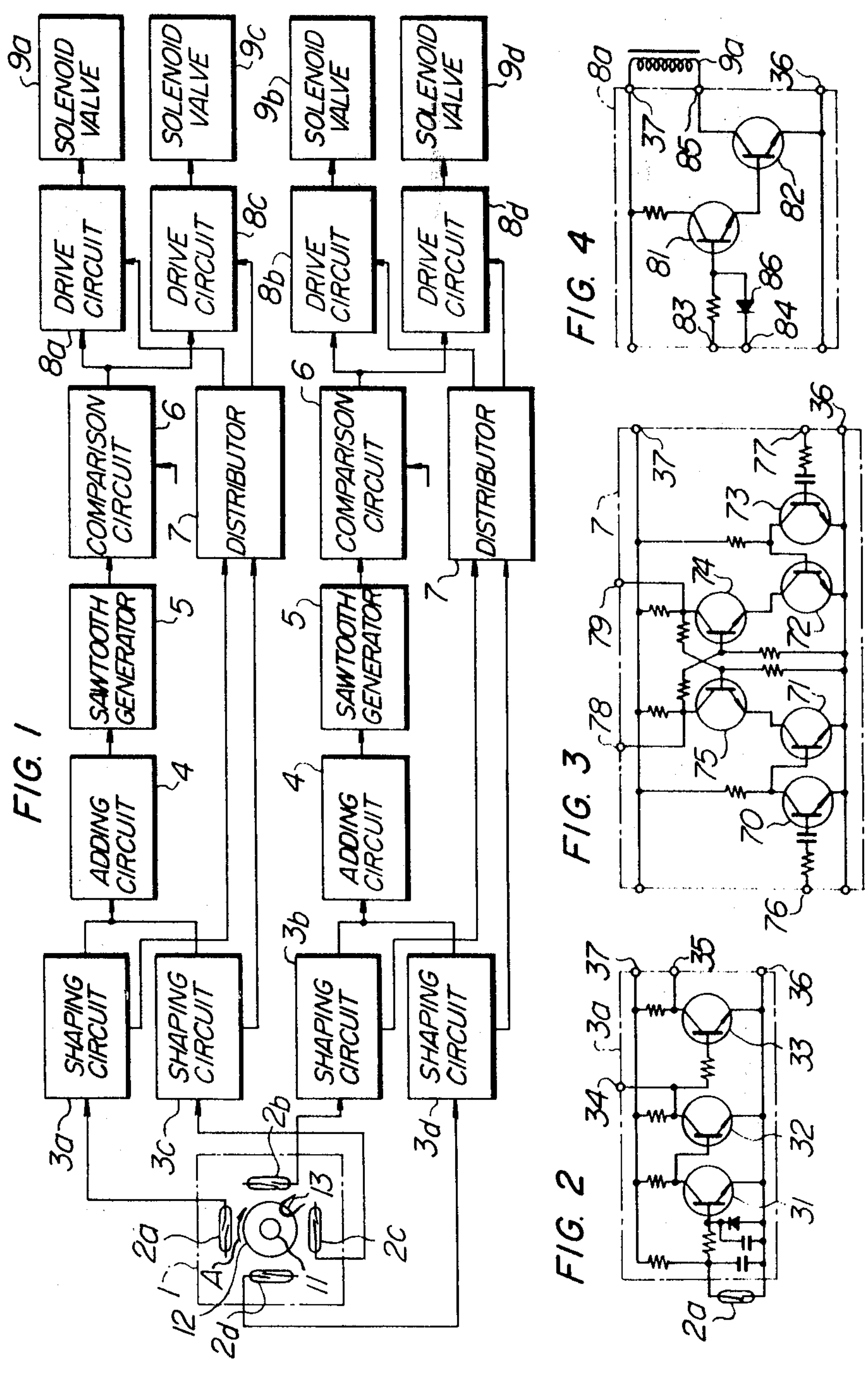

INVENTORS

Iseji Kamazuka
Kunio Endo
BY Cushman, Darby & Cushman
ATTORNEYS

FUEL INJECTION SYNCHRONIZING SYSTEM

The present invention relates to a fuel injection control apparatus adapted for use with fuel injection-type internal combustion engines having at least two cylinders, by which the quantity of fuel injected into the cylinders, and the sequence and timing of fuel injection are properly controlled by electrical means. The invention particularly relates to an electrical synchronizing system for properly controlling the timing of operation of the fuel injection control apparatus described above.

A conventional apparatus used in fuel injection-type internal combustion engines for controlling the fuel injection synchronously with the cylinder stroke, is so designed that the fuel injection sequence is controlled by a distributor which is provided separately from the ignition distributor.

However, such a distributor used in the conventional apparatus performs its function mechanically and, therefore, has the fatal drawback that wear of the sliding contacts results in unsatisfactory electrical connection which in turn results in unsatisfactory operation of the engine.

It is, therefore, an object of the present invention to provide a fuel injection synchronizing system which obviates the aforesaid drawback of the conventional one and in which use is made of a sliding engagement-free electric circuit as a distributor, whereby the quantity of fuel injected, and the sequence and synchronization of the fuel injection are controlled accurately and smoothly, without being hampered by the drawback of the conventional distributor.

In order to attain the object of the invention set forth above, the fuel injection synchronizing system of this invention produces a pulse signal synchronous with the cycle of each piston and distributes an exciting pulse of proper duration and timing to each cylinder using an electrical circuit that permits easy and accurate control over both the timing and the duration without requiring cam operated switches using sliding mechanical contacts. The exemplary embodiment comprises opening and closing elements provided in a number equal to the number of the cylinders and which are opened and closed in synchronized relation to the rotation of an engine together with waveform-shaping circuits respectively connected with the opening and closing elements and each shaping circuit being adapted to generate a shaped pulse corresponding to the operation of the associated opening and closing element. In addition, the system includes a circuit for combining the output pulses of each pair of said waveform-shaping circuits, the combined pulses to be given to a circuit which generates said an exciting pulse in response thereto. The exciting pulse is then distributed to the proper cylinder by a bistable circuit adapted to generate two outputs alternately one at a time upon receiving the pulses from the two waveform-shaping circuits and gate means for receiving one of the outputs of said bistable circuit and said exciting pulse and passing the latter only when an output is present from the bistable circuit.

Other features and the merits of the present invention will be more apparent from the following detailed description when taken in conjunction with the accompanying drawings, in which:

FIG. 1 is a block diagram briefly showing the construction of a fuel injection control apparatus to which the present invention relates;

FIG 2 is an electric connection diagram showing one form of the waveform-shaping circuit in the apparatus of this invention;

FIG. 3 is an electric connection diagram showing one form of the distribution circuit in the apparatus of this invention;

FIG. 4 is an electric connection diagram showing one form of the solenoid valve-operating circuit in the apparatus of this invention; and

FIG. 5 is a waveform chart illustrating some of the waveforms which occur in the elements shown in other figures.

Referring first to FIG. 1, there is shown a fuel injection control apparatus according to the present invention which is adapted for use in a four-cylinder, fuel injection-type internal combustion engine. In FIG. 1, reference numeral 1 designates a pulse generator for fuel injection; *2a*, *2b*, *2c* and *2d* sealed contacts, one for each cylinder; and *3a*, *3b*, *3c* and *3d* shaping circuits for shaping the waveforms of pulse signals produced on opening and closing of said respective sealed contacts *2a*, *2b*, *2c* and *2d*.

The shaping circuits *3a* and *3c* are connected with an adding circuit 4 by which the output pulses of said respective shaping circuits are combined, whereas the shaping circuits *3b* and *3d* are connected with another adding circuit 4 by which the output pulses of said respective shaping circuits are combined. That is, the adding circuit 4 is effectively an OR gate which combines plural input pulse trains in the sense that a single output pulse train is produced having a pulse each time either input has a pulse to result in a composite output pulse train as will be apparent to those in the art. A sawtooth generator 5 is connected with each of the adding circuits 4 to be triggered by the summed or composite pulse signal from its respectively associated adding circuit. Each sawtooth generator 5 generates a sawtooth or ramp-shaped signal voltage output with the beginning of each individual ramp being triggered by an input pulse as will be apparent to those in the art. Each of the sawtooth generators 5 is connected to one input of a comparison circuit 6 which generates a signal having a pulse width corresponding to the fuel injection time upon comparing the sawtooth wave signal voltage from the respectively associated sawtooth generator 5 with another input voltage obtained from suitable means by which the operating condition of the engine, such as the negative pressure in the suction manifold to the respective cylinders is converted into a direct-current voltage for input to comparison circuits 6. Comparison circuit 6 is of the conventional type that changes its state or output signal whenever a first input (i.e. the voltage input on said one input) becomes less than a second input (i.e. the sawtooth voltage on said another input) or vice versa as will be apparent to those in the art.

Reference numeral 7 designates distributors by which the output signals of the respective comparison circuits 6, i.e. fuel injection pulse signals, are impressed on selected ones of the four solenoid valve drive circuits *8a*, *8b*, *8c* and *8d*, one for each cylinder, in sequence. The distributors 7 are actuated by the output pulses of the shaping circuits *3a*, *3c* and the shaping circuits *3b*, *3d* respectively, so that the order of impressing the fuel injection pulses from the comparison circuits 6 on the solenoid valve drive circuits *8a*, *8b*, *8c* and *8d* may be determined.

Solenoid valves *9a*, *9b*, *9c* and *9d* operate the fuel injection nozzles provided near the intake valves of the respective cylinders, in response to the signals from the associated solenoid valve drive circuits *8a*, *8b*, *8c* and *8d* impressed thereon.

The control circuit constructed as described above is arranged in two functional lines each handling injection pulses for two cylinders that are not fired in direct succession, in consideration of the possible overlap of the engine cylinder driving strokes and in accordance with the maximum fuel injection time, in such a manner that the solenoid valves *9a* and *9c* are controlled by the pulse signals from the sealed contacts *2a* and *2c* of the pulse generator 1 in the first or upper line as shown in FIG. 1, while the solenoid valves *9b* and *9d* are controlled by the pulse signals from the sealed contacts *2b* and *2d* of the pulse generator 1 in the second or lower line as shown in FIG. 1. These two lines of control circuit are identical with each other in both function and construction. In the embodiment shown, the pulse generator 1 for fuel injection is provided adjacent to an ignition distributor which is not apparent in the drawings, and a drive shaft 11 of said pulse generator 1 is integral with a drive shaft of said ignition distributor. The drive shaft 11 has a rotary member 12 mounted thereon for concurrent rotation therewith. The rotary member 12 is provided with a substantially horseshoe-shaped permanent magnet 13 as shown, and the sealed contacts *2a*, *2b*, *2c* and *2d* are arranged adjacent to the outer periphery of the rotary member

12 in substantially equally spaced relation to each other, so that said sealed contacts 2a, 2b, 2c and 2d may be closed under the influence of the magnetic flux of said permanent magnet 13.

With such an arrangement, it will be seen that pulse signals are produced sequentially, one from each of the sealed contacts 2a, 2b, 2c and 2d on every revolution of the rotary member 12. The pulse generator 1 of the construction described above may be converted into a contactless pulse generator by replacing the sealed contacts 2a, 2b, 2c and 2d with magnetic semiconductors respectively as will be appreciated by those in the art.

The pulse signals from the sealed contacts 2a, 2b, 2c and 2d are each shaped into an ideal rectangular pulse by the respective shaping circuits 3a, 3b, 3c and 3d. These shaping circuits have the same construction, so that the practical construction of the shaping circuit 3a only is shown in FIG. 2. As shown in FIG. 2, the shaping circuit 3a comprises transistors 31, 32 and 33 which form an amplifier circuit for suitably amplifying and shaping the pulse signal from the sealed contact 2a, output terminals 34 and 35, a common terminal 36 and a power source terminal 37. The output terminal 35 is connected with the input terminal of the pulse adding circuit 4, together with the output terminal of the shaping circuit 3c. The output terminal 34 of the shaping circuit 3a and the output terminal of the shaping circuit 3c are connected with the input terminal of the distributor 7 respectively. The practical construction of the distributor 7 is shown in FIG. 3. The distributor 7 in the first line is provided successively to the shaping circuits 3a and 3c, and comprises transistors 70, 71, 72, 73, 74 and 75. The arrangement is such that the distributor 7 emits an output signal on lines 78 or 79 upon receipt of the pulse signal from the shaping circuits 3a and 3c respectively, and in response to said signal from the distributor 7 a fuel injection pulse signal, that is, an output signal of the comparison circuit 6, is impressed on the one of the solenoid valves 9a and 9c, which is then to be operated, to energize the same. An input terminal 76 of the distributor 7 is connected with the output terminal 34 of the shaping circuit 3a and an input terminal 77 thereof with the output terminal of the shaping circuit 3c.

Output terminals 78 and 79 of the distributor 7 are connected with the input terminals of the solenoid valve drive circuits 8a and 8c respectively. The practical construction of the solenoid valve drive circuit 8a is shown in FIG. 4. As shown, the solenoid valve drive circuit 8a comprises and 81 and 82 which form an amplifier circuit for amplifying the fuel injection pulse signal, that is, the output signal of the comparison circuit 6. An input terminal 83 of the solenoid valve drive circuit 8a is connected with the output terminal of the comparison circuit 6 and an input terminal 84 thereof with the output terminal 78 of the distributor 7. An output terminal 85 of the solenoid valve drive circuit 8a is connected with the solenoid valve 9a, together with the power source terminal 37. The constructions of the solenoid valve drive circuits 8b, 8c and 8d are identical with that of the solenoid valve drive circuit 8a shown in FIG. 4. An input terminal of the solenoid valve drive circuit 8c is connected with the output terminal 79 of the distributor 7. The construction of the control circuit in the second line is similar to that of the control circuit in the first line described above.

The apparatus of the present invention having a construction as described above operates in the following manner: Namely, when the rotary member 12 in the pulse generator 1 is rotated in the direction of arrow A, the sealed contacts 2a, 2b, 2c and 2d are opened and closed, respectively generating pulse signals. The pulse signals generated by the opening and closing operation of the sealed contacts 2a and 2c are each shaped into a rectangular pulse (as shown in FIG. 5 at times *a* and *b* respectively) through the associated shaping circuits 3a and 3c, impressed on the adding circuit 4 to be summed thereby (as shown on line *c* in FIG. 5) and then impressed on one input of the sawtooth generator 5 to trigger it in synchronism with the composite output of adder 4.

Upon receiving the composed pulse from the adding circuit 4, the sawtooth generator 5 generates a sawtooth wave synchronous with said composed pulse (as shown on line *d* in FIG. 5 as waveform B) and said sawtooth wave is impressed on the comparison circuit 6. On the other hand, the negative pressure in the intake manifold is converted into a direct-current voltage (as shown on line *d* in FIG. 5 as waveform C) by suitable means not shown and the voltage thus obtained is also impressed on the comparison circuit 6. In the comparison circuit 6, both signals impressed thereon are compared with each other and as a result a fuel injection pulse (as shown on line *e* of FIG. 5) of a pulse width, corresponding to the desired fuel injection time (which time is a function of the instantaneous value of waveform C as will be apparent to those in the art), is generated by said comparison circuit. Whether the fuel injection pulse should be impressed on the solenoid valve drive circuit 8a or 8b is determined by the distributor 7. For instance, when the sealed contact 2a is opened from its closed position, the potential at the output terminal 34 of the shaping circuit 3a rises sharply, so that the transistor 70 in the distributor 7 is momentarily energized and, therefore, the transistors 71 and 75 are deenergized and the transistors 72 and 74 are energized to cause an output on line 78 as shown on line *f* of FIG. 5 until the bistable distributor 7 is presented with an input on terminal 77 corresponding to the closing of contact 2c. The output on line 79 is shown at line *g* of FIG. 5.

The fuel injection pulse impressed on the input terminal 83 of the solenoid valve drive circuit 8a is amplified and impressed on the solenoid valve 9a when a distributor input is present on line 84 to provide output driving pulses as shown on line *h* of FIG. 5. These driving pulses energize the solenoid valve 9a and thus fuel is injected through the associated fuel injection nozzle. In this case, the fuel injection pulse is not impressed on the solenoid valve drive circuit 8c, since the transistors 72 and 74 of the distributor 7 are in the energized state and the fuel injection pulse impressed on driver 8c is thus shunted through a diode corresponding to diode 86, terminal 84 and transistors 72 and 74 as will be apparent to those in the art. The time at which the distributor 7 changes outputs is synchronous with the rise of the fuel injection pulse. On the other hand, when the sealed contact 2c is opened from its closed position, an operation reverse to that described above takes place. Namely, the transistors 71 and 75 are energized and the transistors 72 and 74 are deenergized, so that the base of the transistor 81 of the solenoid valve drive circuit 8a is grounded through a diode 86. Consequently, the fuel injection pulse is impressed on the solenoid valve drive circuit 8c only (as shown by line *i* of FIG. 5) and then on the solenoid valve 9c after having been amplified. Thus, fuel is injected through the associated fuel injection nozzle. The circuits associated with the sealed contacts 2b and 2d in the second line of control circuit operate in the same manner as described above with reference to the first line of control circuit. Thus, it will be understood that the solenoid valves 9a, 9b, 9c and 9d are actuated in synchronized relation to the opening and closing operation of the intake valves for the respective cylinders not shown, i.e. the operating strokes of the cylinders, in accordance with the sequence of opening and closing operation of the sealed contacts 2a, 2b, 2c and 2d of the pulse generator 1 and thereby the fuel injection is properly controlled even if an overlap occurs between the time periods of operating strokes on immediately successively fired cylinders. That is, if there is an overlap between injection times in cylinders associated with valves 9a and 9b (as may be the case at higher r.p.m.) the circuits will still function properly since sequentially actuated valves 9a and 9b are actuated by different functional lines, i.e. the top and bottom line as shown in FIG. 1.

As stated previously, the permanent magnet 13 used for causing the opening and closing operation of the sealed contacts 2a, 2b, 2c and 2d in the above-described embodiment, has a horseshoe shape. The selection of such shape is for the purpose of ensuring the positive opening and closing operation of the respective sealed contacts, and of providing for the use of a small permanent magnet for the permanent magnet **13** and small contacts for the sealed contacts **2a**, **2b**, **2c** and **2d** as a result of the opening and closing operation being thus ensured.

Although in the embodiment described and illustrated herein use is preferably made of the permanent magnet **13** and a number of sealed contacts **2a**, **2b**, **2c** and **2d** corresponding to the number of cylinders, as the opening and closing elements for obtaining pulse signals corresponding to the engine r.p.m. and the fuel injection times, it will be obvious that such pulse signals can similarly be obtained and used with the basic circuit arrangement of this invention by operatively connecting a cam, having a single notch therein, to a shaft which is driven at a rate proportional to the rate of rotation of the crankshaft and by arranging a number of breaker points equal to the number of cylinders along the periphery of said cam in substantially equally spaced relation to each other so as to be opened and closed by said cam, as in the mechanical switch which intermittently breaks the primary circuit of the ignition coils.

As described above, according to the present invention it is possible to determine electrically the sequence of fuel injection, without involving a mechanical sliding engagement, to completely eliminate a number of troubles caused by unsatisfactory electrical contact which can be attributed to the sliding engagement, and hence to provide a durable fuel injection control apparatus. Further, according to the present invention, as described herein, a plurality of shaping circuits are arranged in a number of lines as determined according to the maximum fuel injection time and each shaping circuit in each line of control circuit is provided with a pulse adding circuit, a sawtooth generator, etc. Therefore, in case of a four-cylinder fuel injection-type internal combustion engine for example, the fuel injection for each cylinder can be controlled positively and accurately in synchronized relation to the opening and closing time of the associated intake valve, even when an overlap occurs between the operating strokes of the respective cylinders upon rising of the engine r.p.m.

We claim:

1. A synchronized fuel injection system for producing and distributing fuel injection exciting pulses which are synchronous with the operation of the cylinders of an internal combustion engine and which have a time duration that is automatically varied by a DC parameter signal representing at least one engine-operating parameter, said system comprising:

first and second switching means, each such means corresponding to a particular cylinder of said engine,

means for sequentially and repetitively operating said switching means in synchronism with the operation of said engine,

an adding circuit means for providing a composite sum output of uniform pulses, each representing the actuation of either one of said switching means,

sawtooth generator means electrically connected to said adding circuit means for producing a sawtooth shaped waveform synchronous with said composite sum output,

comparing means electrically connected to said sawtooth generator means for comparing said sawtooth waveform with said DC parameter signal and for providing a timed output pulse in synchronism with said sawtooth waveform and having a time duration that is a predetermined function of said DC parameter signal,

bistable distributor means for providing first and second outputs corresponding to the actuation of said first and second switching means respectively,

first drive means electrically connected to said comparing means and to said distributor means for providing a first fuel injection valve exciting pulse when both said timed output pulse and said first output are present thereby providing a timed fuel injection signal for the cylinder corresponding to said first switching means, and

second drive means electrically connected to said comparing means and to said distributor means for providing a second fuel injection valve exciting pulse when both said timed output pulse and said second output are present thereby providing a timed fuel injection signal for the cylinder corresponding to said second switching means.

2. A fuel injection synchronizing system as defined in claim **1**, in which said opening and closing elements include a cam rotated synchronously with the rotation of the engine and breaker points provided each for every cylinder above the path of rotation of said cam and opened and closed by said cam.

3. A synchronized fuel injection system as in claim **1** further comprising:

first and second pulse shaping means electrically connected to said first and second switching means respectively for providing uniformly shaped pulses in response to actuation of the respectively associated switching means.

4. A synchronized fuel injection system wherein:

one set of elements as recited in claim **1** comprise a first functional line of control apparatus for controlling fuel injection in first and third cylinders, and

another like set of elements comprise a second functional line of control apparatus for controlling fuel injection in second and fourth cylinders,

whereby, when the first, second, third and fourth cylinders are sequentially fired in that order, proper overall fuel injection control is maintained even though time overlaps occur at higher engine r.p.m. since only alternately fired cylinders are controlled by a single functional line of control apparatus.

5. A synchronized fuel injection system as in claim **4** further comprising:

pulse-shaping means electrically connected to each switching means for providing uniformly shaped pulses in response to the actuation of its associated switching means.

6. A synchronized fuel injection system as in claim **1** wherein:

said means for sequentially and repetitively operating comprises a permanent magnet mounted for rotation synchronously with the rotation of said engine, and

each of said switching means comprise sealed magnetic contacts corresponding to one engine cylinder and mounted adjacent the path of revolution of said permanent magnet whereby said switching means are sequentially and repetitively operated in synchronism with the rotation of said engine.