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Scofield

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[54] **SYNCHRONIZING MEANS FOR SEQUENTIAL FUEL INJECTION**

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[73] Assignee: **International Harvester Company,** Chicago, Ill.

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[52] **U.S. Cl.... 123/32 EA,** 123/119 R, 123/146.5 A
[51] **Int. Cl.** **F02b 3/00**
[58] **Field of Search**........ 123/32 EA, 119 R, 146 E, 123/146 B, 146 AC

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Assistant Examiner—Ronald B. Cox
Attorney, Agent, or Firm—Frederick J. Krubel; Floyd B. Harman

[57] **ABSTRACT**

Synchronizing means for sequential fuel injection wherein valve actuator means are energized in response to signals from sequencing and timer circuits. Triggering signals are applied to the sequencing circuit, including an indexing pulse developed in predetermined phase relation to each and every power stroke of the engine and a reset pulse in predetermined phase relation to the power stroke of a predetermined one of the engine cylinders. The sequencing circuit includes a digital counter which is indexed by the index pulses and which is reset by the reset pulses. In one embodiment, an index pulse generator is connected to ignition pulse generating means of the engine, preferably in circuit with an ignition coil primary, and a reset pulse generator is connected to one output of the distributor. In another embodiment, the index and reset pulses are generated inductively in response to rotation of engine parts.

5 Claims, 6 Drawing Figures

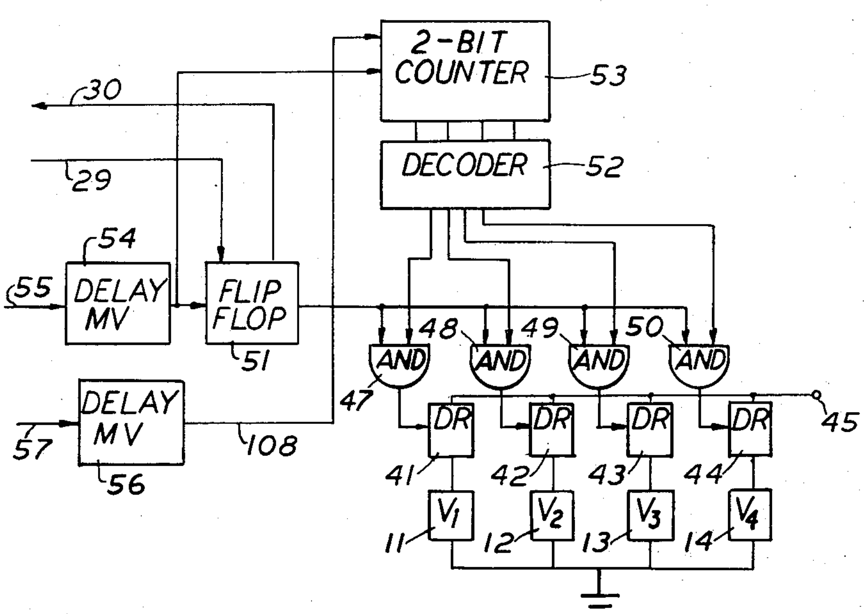
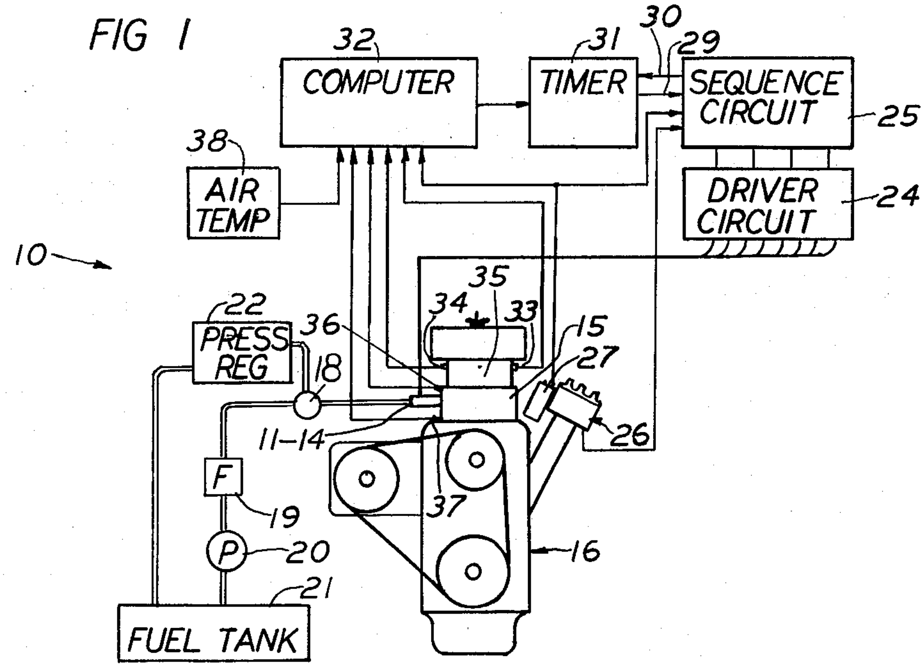


FIG 1


COMPUTER
32
TIMER
31
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29
SEQUENCE CIRCUIT
25
DRIVER CIRCUIT
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38
AIR TEMP
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22
PRESS REG
36
18
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34
33
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27
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11-14
37
F
19
P
20
21
FUEL TANK
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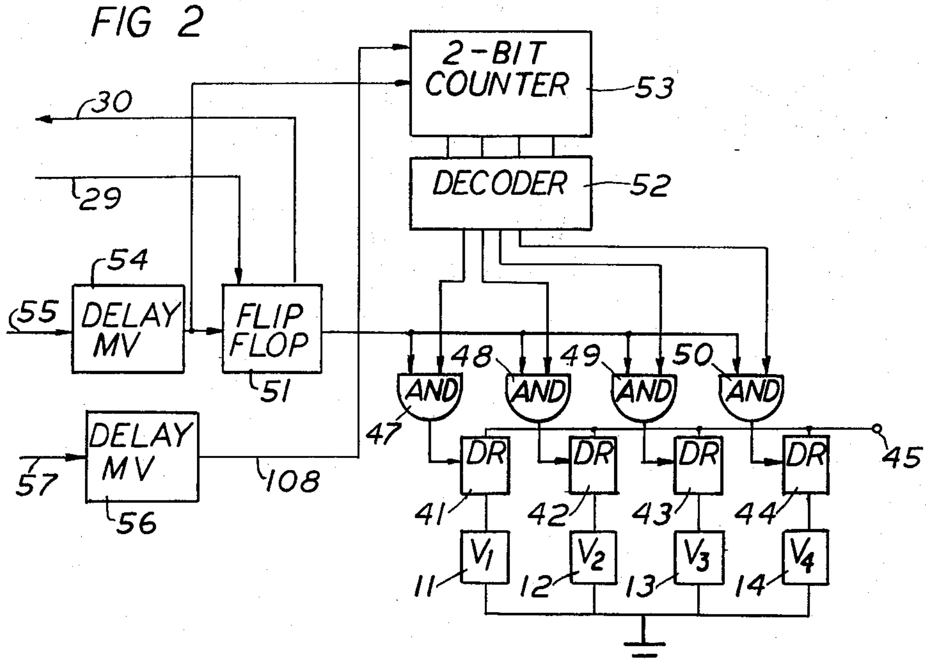
FIG 2


2-BIT COUNTER
53
DECODER
52
30
29
54
DELAY MV
55
FLIP FLOP
51
DELAY MV
57
56
108
AND
47
48
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V1
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V3
V4
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FIG 4

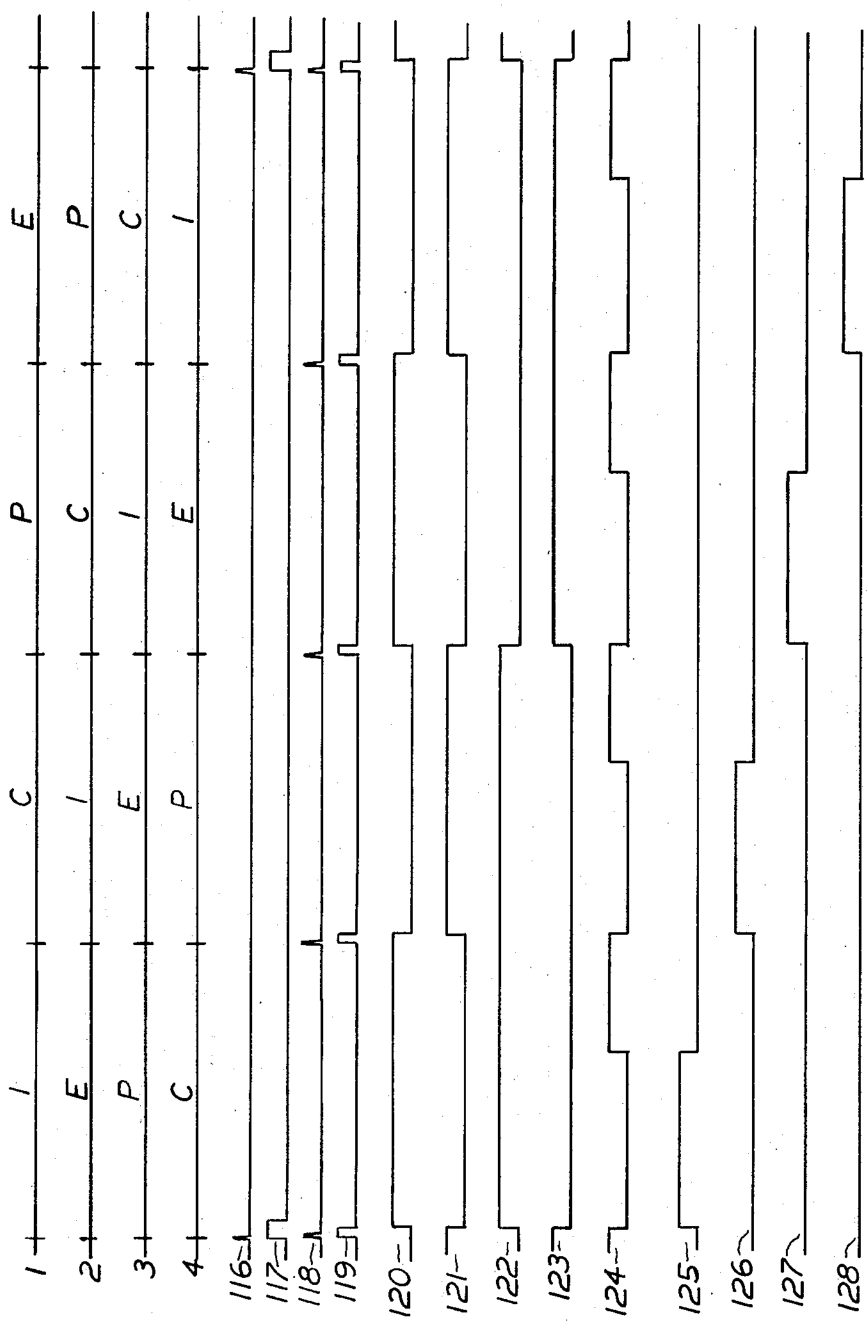

FIG 5

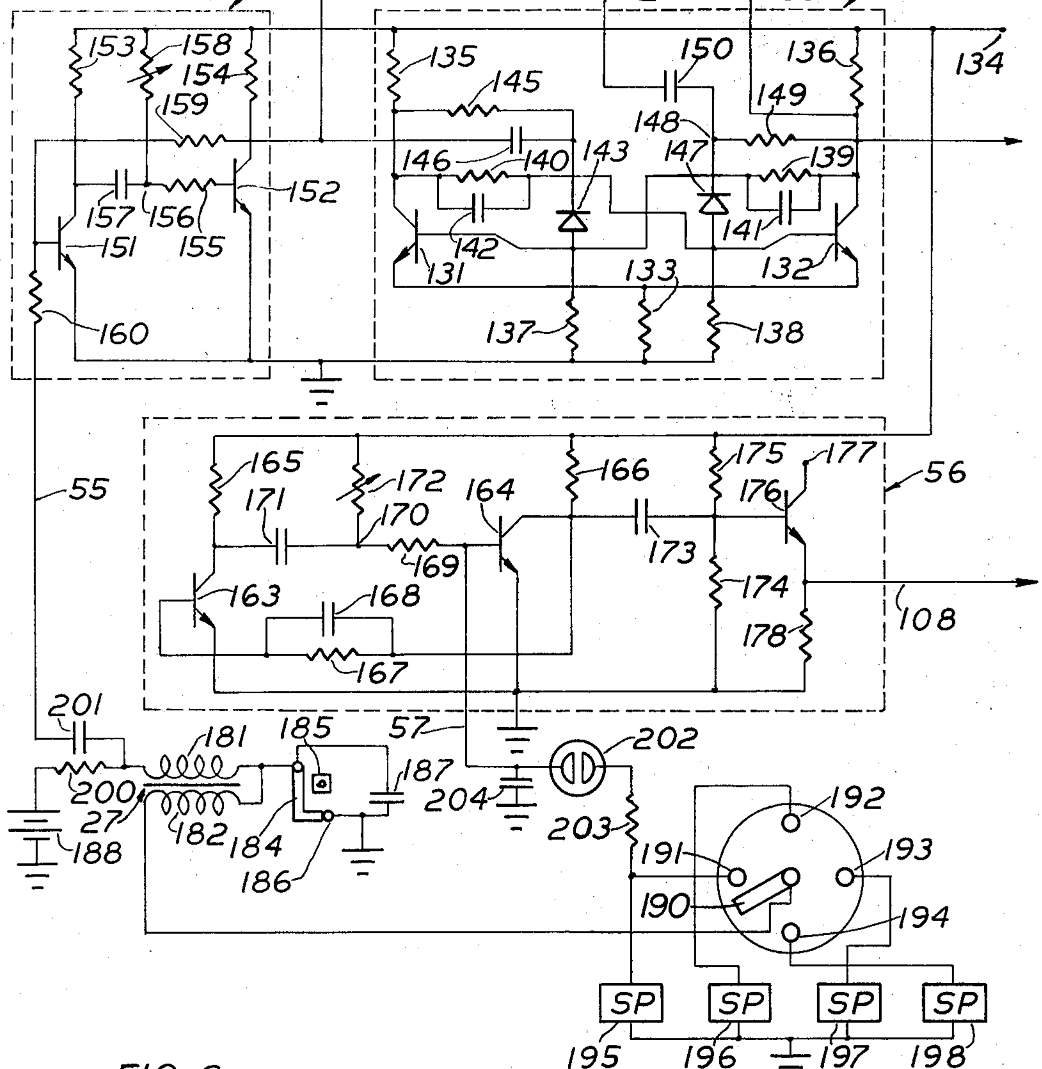
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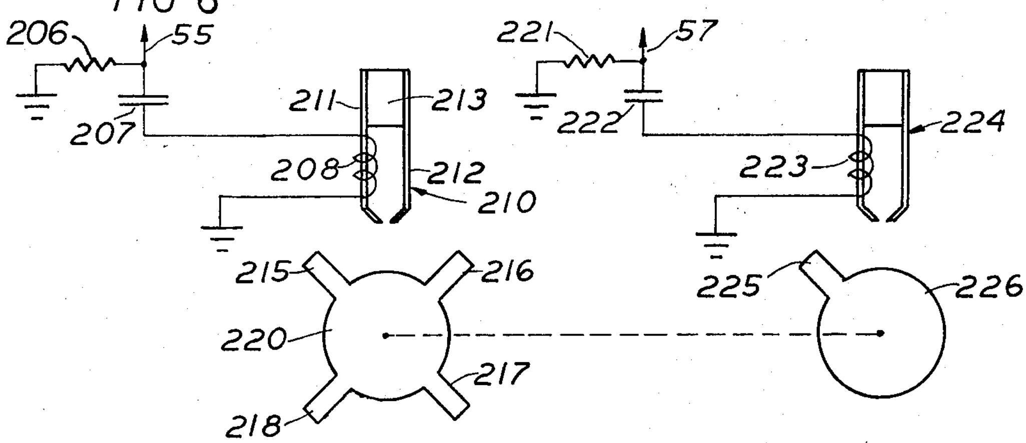
FIG 6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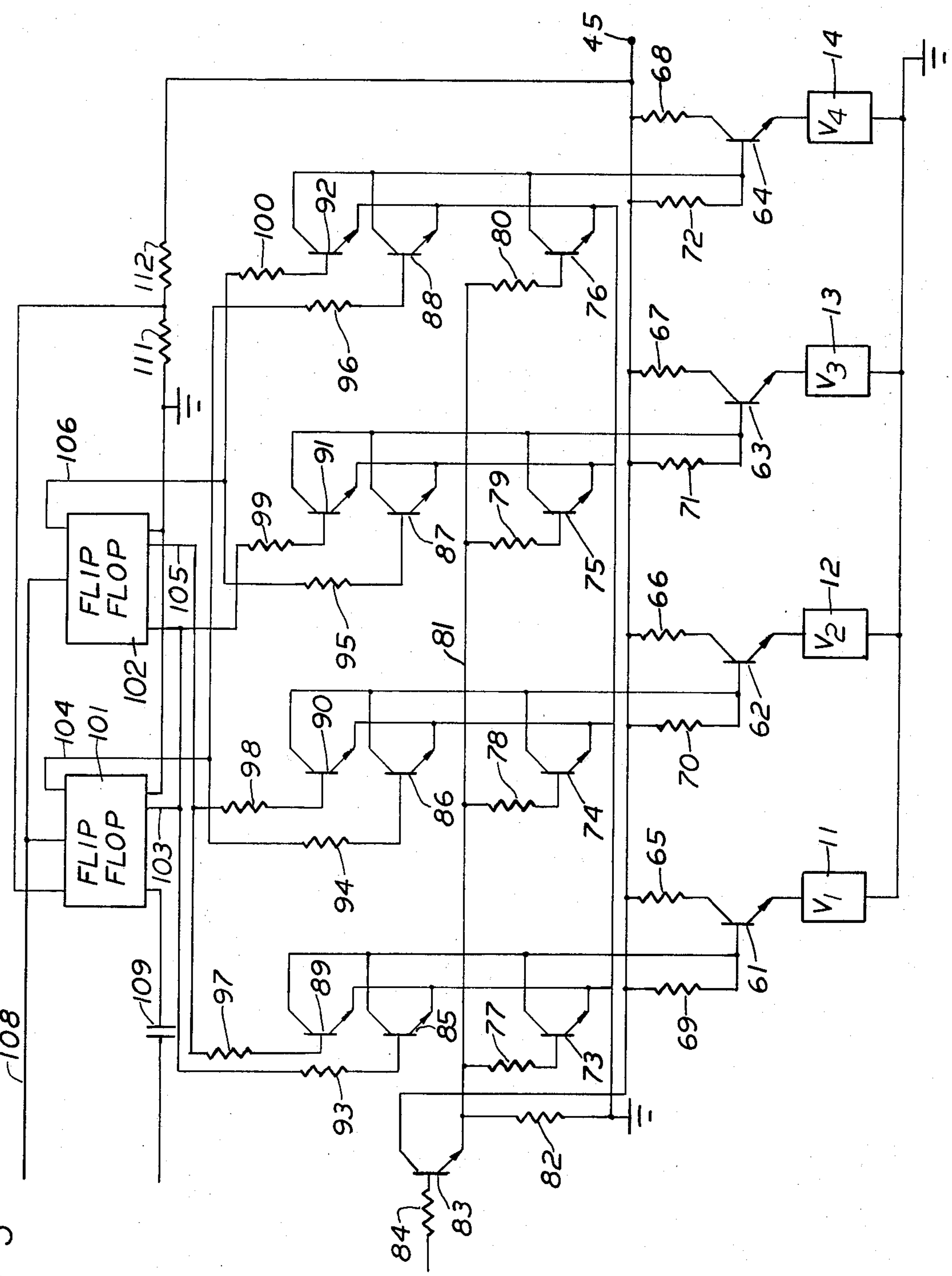

FIG 3

SYNCHRONIZING MEANS FOR SEQUENTIAL FUEL INJECTION

This invention relates to synchronizing means for sequential fuel injection and more particularly to synchronizing means which permit highly accurate control while being economically manufacturable and very durable and reliable.

BACKGROUND OF THE INVENTION

Sequential fuel injection systems have heretofore been proposed using one electrically operated valve for each cylinder to allow flow of a controlled amount of fuel during each intake stroke, with the amount of fuel being controlled by controlling the duration of electrical pulses applied through distributor means to allocate the application of the pulses to the injector valves in accordance with the firing order of the invention. Such systems have not been entirely satisfactory with respect to construction, operation and reliability. For example, the distributor means have generally required the use of rotating contacts having sliding engagement with commutator segments and/or mechanically operated switches operated from an engine part for transmitting the pulses or developing control signals.

SUMMARY OF THE INVENTION

This invention was evolved with the general object of overcoming the disadvantages of prior art systems and of providing a system using electronic circuitry for controlling the sequential energization of injector valves and in which the operation of the electronic circuitry is synchronized with the operation of the engine in a highly accurate and reliable manner.

Another object of the invention is to provide a synchronizing arrangement for sequential fuel injection using components which are rugged and durable while being economically manufacturable.

In a system according to this invention, injector valve actuators are controlled from timing signals and from control signals from a sequencing circuit to which triggering signals are applied from triggering means including index pulse means for supplying an index pulse in predetermined phase relation to each and every power stroke of the engine and including reset pulse means for supplying reset pulses in predetermined phase relation to the power stroke of a predetermined one of the engine cylinders. Through the application of such index and reset pulses, the operation of the sequencing circuitry is reliably synchronized with the operation of the engine and is accurately controlled, to insure that the fuel is injected into the correct engine cylinder and in proper phase relation to the intake stroke of the cylinder.

In one preferred embodiment, the indexed pulse means is coupled to the ignition pulse generating means of the engine to develop an index pulse in response to each ignition pulse and the reset pulse means is arranged for coupling to distributor means of the engine ignition system to develop a reset pulse in response to each ignition pulse applied to the spark plug of a predetermined one of the engine cylinders. With this arrangement, the ignition system of the engine performs a dual function and the number of components required is minimized. No addition of switching contacts or the like is required and a high degree of reliability is obtained.

In another embodiment, the index and reset pulse means respond to pulses from pulse generating means coupled to the engine, separate from the ignition system. Preferably, and in accordance with a specific feature, such pulse generator means generate pulses from magnetic field changes in a manner such that no contacts are required and insuring high reliability.

Additional very important features of the invention relate to the combination of the index and reset pulse means with sequencing means including digital counter means arranged to count or be indexed by the index pulses and to be reset to a predetermined condition by each reset pulse. With this combination, the required control signals can be generated electronically with no switching contacts or the like. As claimed in a related application of Bruce A. Scofield, Ser. No. 265,047, filed June 21, 1972, now U.S. Pat. No. 3,820,198, such electronically generated control signals, together with electronically generated timing signals, can be applied through gate means to transistor driver stages for the injector valve actuators, the use of the digital counter means being also highly advantageous in conjunction with such electronic switching circuitry.

Further features relate to electronic circuitry associated with the synchronizing means and operative to generate the index and reset pulses in a uniform, accurate and reliable manner.

This invention contemplates other objects, advantages and features, which will become more fully apparent from the following detailed description taken in conjunction with the accompanying drawings.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic diagram of a sequential fuel injection system for a four cylinder engine, incorporating switching circuitry according to the invention;

FIG. **2** is a block diagram of sequence and driver circuits of the system of FIG. **1**;

FIG. **3** is a circuit diagram of counter, decoder, gating and driver circuitry shown in block form in FIG. **2**;

FIG. **4** is a wave form diagram for explanation of the circuitry of FIGS. **2** and **3**;

FIG. **5** shows the circuits of delay multivibrators and a flip-flop, shown in block form in FIG. **2**, and also shows schematically means for applying triggering signals, from the engine ignition system; and

FIG. **6** shows schematically a modified means of applying triggering signals.

Reference numeral **10** generally designates a sequential fuel injection system designed for a four cylinder engine, incorporating synchronizing means and associated circuitry constructed in accordance with the principles of the invention. An individual solenoid-operated injection nozzle or valve is provided for each cylinder of an engine and each valve is opened once during every revolution of the engine cam shaft, or once during every other revolution of the crank shaft, in the case of a four cycle engine. In the system **10**, designed for a four-cylinder engine, there are four injection valves, **11–14**, FIG. **2**, which may be mounted on an intake manifold **15** of an engine **16** in the manner as shown diagrammatically in FIG. **1**. As also shown in FIG. **1**, the injection valves are connected to a header **18** which is connected through a filter **19** to the outlet of a pump **20** having an inlet connected to a fuel tank **21**. A pressure regulator **22** is provided between the header 18 in the fuel tank 21 to maintain the pressure in the header at a substantially constant value which may be on the order of 40 PSI, by way of example.

The injection valves 11–14 are connected to a driver circuit 24 controlled from a sequence circuit 25. In accordance with the invention, the sequence circuit 25 receives control or reset and triggering or index signals from a distributor 26 and an ignition coil 27 of the engine and controls the time intervals in which the valves 11–14 may be energized, to synchronize the injection of fuel in relation to the intake strokes of the respective cylinders. The sequence circuit 25 is also connected through lines 29 and 30 to a timer 31 which is controlled from a computer 32.

Computer 32 controls the timer 31 and through the sequence and driver circuits 25 and 24, the time duration of each opening of each injection valve is controlled, the control being a function of the prevailing operating conditions at the time of injection. In the illustrated arrangement, the computer 32 receives pulses from the ignition coil 27 to develop a speed signal and is connected to switches 33 and 34 mounted on a throttle 35 of the engine 16, switch 33 being operated when the throttle is closed and switch 34 being operated when the throttle is wide open. Computer 32 is also connected to a sensor 36 which senses intake manifold absolute pressure, to a sensor 37 which senses coolant temperature and to a sensor 38 which senses air temperature, as diagrammatically illustrated. The computer 32 may also contain circuitry for sensing acceleration and also the rate of change of intake manifold absolute pressure. In response to such sensed operating conditions, the computer 32 may develop an analog voltage output which controls the duration of a pulse generated by timer 31 and applied to the sequence circuit through line 29, the beginning of each pulse being determined by a triggering signal applied through line 30. It should be understood that the timer 31 and computer 32 are not, by themselves, part of the present invention, and, so far as concerns the synchronizing means and associated circuitry of this invention, any suitable means could be employed to generate a timing signal or pulse of controllable duration. By way of example, the duration of the timing signal or pulse may typically be on the order of from 2 to 12 milliseconds.

Referring now to FIG. 2, the solenoids of the injection valves 11–14 are connected between ground and outputs of four driver stages 41–44 connected to a power supply terminal 45 to which battery voltage of on the order of twelve volts may be supplied. Inputs of the driver stages 41–44 are connected to the outputs of four AND gates 47–50 having inputs connected together into the output of a flip-flop 51 and having additional inputs connected through a decoder 52 to outputs of a two-bit counter 53. Inputs of the flip-flop 51 and of the counter 53 are connected to the output of a delay monostable multivibrator 54 having an input connected through a line 55 to the ignition coil 27. An additional input of the counter 53 is connected to the output of a second monostable delay multivibrator 56 having an input connected through a line 57 to the distributor 26.

In the general operation of the system, index signals responsive to ignition pulses are applied through the delay multivibrator 54 to the counter 53 to advance the count thereof and also to the flip-flop 51 which is then placed in a set condition, a signal being then applied through line 30 to the timer 31 to initiate operation thereof. Timer 31 then generates a pulse of controlled length at the termination of which a signal on line 29 resets the flip-flop 51. When the flip-flop 51 is set, a signal is applied through one of the AND gates 47–50, depending upon the condition of the counter 52, to one of the driver stages 41–44, to energize one of the injection valves 11–14 for a time interval corresponding to the timing pulse applied from the timer 31. The reset signal applied from the distributor 26 through the delay multivibrator 56 to the counter 53 is for the purpose of correlating the operation of the counter 53 to the firing sequence of the engine.

Although the details of the circuits of the driver stages 41–44, gates 47–50, decoder 52 and counter 53 are not essential to an understanding of the synchronizing means and associated circuitry of this invention, the circuits and their operation are illustrated and described in detail to facilitate understanding of the synchronizing operation and an understanding of the advantages obtained from the combination of synchronizing means and circuitry with switching circuitry in a full injection system.

Referring to FIG. 3, the driver stages 41–44 include power transistors 61–64 having emitters connected to the injection valves 11–14 and having collectors connected through resistors 65–68 to the power supply terminal 45. The bases of the transistors 61–64 are connected through resistors 69–72 to the power supply terminal 45 and to the collectors of transistors 73–76 the emitters of which are connected to ground and the bases of which are connected through resistors 77–80 to a line 81 which is connected through a resistor 82 to ground and which is also connected to an emitter of a transistor 83 the collector of which is connected to the power supply terminal 45 and the base of which is connected through a resistor 84 to the output of the flip-flop 51. The bases of the transistors 61–64 are additionally connected to the collectors of transistors 85–88 and also to the collectors of transistors 89–92.

The bases of the driver transistors 61–64 are also connected to the collectors of transistors 85–88 and to the collectors of transistors 89–92, the emitters of the transistors 85–92 being connected to ground.

The bases of transistors 85–92 are connected through resistors 93–100 to outputs of two flip-flops 101 and 102, together forming the counter 53. A reset output of flip-flop 101, on line 103, is connected to resistors 93 and 99 and also to an input line of flip-flop 102. A set output of flip-flop 101, on line 104, is connected to resistors 94 and 96. A reset output of flip-flop 102, on line 105, is connected to resistors 97 and 98. A set output of flip-flop 102, on line 106, is connected to resistors 99 and 100. A set input of both flip-flops 101 and 102 is connected through a line 108 to the output of the delay multivibrator 56. A triggering input of flip-flop 101 is connected through a capacitor 109 to the output of the delay multivibrator 54. Power supply terminals for both flip-flops 101 and 102 are connected to the junction between two resistors 111 and 112, connected between ground and the power supply terminal 45.

FIG. 4 graphically illustrates the operation of the circuitry of FIG. 3. The top four representations, numbered: "1," "2," "3" and "4" indicate the intake, compression, power and exhaust strokes for the engine cylinders corresponding to injection valves 11–14. It is noted that these numbers do not correspond directly to the conventional numbering of engine cylinders from front to rear. With an engine having a 1, 3, 4, 2 firing order, the numbers 1, 2, 3 and 4 in FIG. 4 may respectively correspond to the numbers 3, 4, 2 and 1 cylinders, numbered from front to rear in the engine.

Wave form **116** indicates the signal applied from the distributor **26** through the line **57** to the input of delay multivibrator **56.** The signal is in the form of an ignition pulse applied to the front cylinder, corresponding to the injection valve **13**, being approximately coincident with the start of the power stroke of that cylinder which is the number 3 cylinder using the desigation of FIG. **4.** Wave form **117** indicates the signal developed at the output of the delay multivibrator **56** which is applied through the line **108** to the set inputs of both flip-flops **101** and **102.** The signal is in the form of a short pulse having a trailing negative-going edge delayed by certain time interval after the triggering pulse applied from the distributor. When the trailing negative-going edge is applied to the set inputs of the flip-flops **101** and **102,** it insures that they will be placed in a set condition, if not already in that condition.

Wave form **118** is that of the signal applied through line **55** to the delay multivibrator **54** from the ignition coil **27,** this signal being in the form of an ignition pulse developed at a time approximately coincident with the start of every power stroke.

Wave form **119** is that of the signal developed at the output of the delay multivibrator **54** which is applied through the capacitor **109** to the triggering signal input to the flip-flop **101.** This signal was in the form of a series of pulses having negative-going trailing edges delayed by short time interval after the applied ignition pulses. Such trailing edges cause the flip-flop **101** to change its state from one state to the other.

Wave form **120** is that of the set output line **104** of the flip-flop **101** which is caused to go "high" by the first illustrated pulse wave form **119,** "low" by the second, again "high" by the third, again "low" by the fourth and again "high" by the fifth. It is noted that the trailing edge of the pulse of wave form **117** occurs after the trailing edge of the first illustrated pulse of wave form **119** and since flip-flop **101** is already in a set condition, the pulses of wave form **117** have no effect. However, if during starting conditions, for example, the flip-flops **101** and **102** were not in set conditions when the first pulse of wave form **117** is applied, the first pulse would then operate to insure placing both flip-flops in a set condition at this point of the operation.

Wave form **121** is that of a signal at the reset output line **103** of the flip-flop **101** while wave forms **122** and **123** are of the signals at the set and reset output lines **106** and **105** of the flip-flop **102.** It will be noted that the flip-flop **102** is shifted from one state to the other in response to negative-going portions of the signal applied thereto from the reset line **103** of the flip-flop **101,** indicated by wave form **121.**

Wave form **124** is that of the signal at the output of the flip-flop **51** which is shifted "low" by the negative-going trailing edges of the pulses from delay multivibrator **54** (wave form **119**) and which is shifted "high" by a signal applied from timer **31** through line **29,** it being noted that the operation of the timer **31** is initiated when the flip-flop **51** is shifted "low," by a signal applied through line **30.**

Wave forms **125–128** are those of the signals applied to the injection valves **11, 12, 13** and **14,** which are in the form of positive pulses during the respective intake strokes of the cylinders with which valves **11–14** are associated. It is noted that during the first 180° of engine rotation, the signals applied from the reset output lines **103** and **105** of the flip-flops **101** and **102,** wave forms **121** and **123,** are "low." Such signals are applied through the resistors **93** and **97** to the bases of transistors **85** and **89** which are cut off. The timing signal, wave form **124,** is also "low" during part of the first 180° of engine rotation and this signal is applied through the transistor **83,** operative as an emitter-follower, to the line **81** and from line **81** through the resistor **77** to the base of transistor **73,** which is thus also cut off. With all three transistors **73, 85** and **89** cut off, the potential of the base of the transistor **61** rises toward the potential of the power supply terminal **45,** being limited only by the flow of base-emitter current through the resistor **69,** and the driver transistor **61** conducts heavily through the injection valve **11,** so long as the timing signal, wave form **124,** is "low."

During the first 180° of engine rotation, "high" signals are applied to the bases of transistors **86, 87** and **88,** and also **92,** which are rendered conductive to place the potentials of the bases of the driver transistors **62, 63** and **64** at values close to ground potential. The driver transistors **62, 63** and **64** are thus non-conductive, and no signal is applied to the injection valves **12, 13** and **14.**

During the next 180° of engine rotation, the signals applied to the bases of transistors **86** and **90** are both low, and the driver transistor **62** is rendered conductive for the duration of the timing signal from flip-flop **51** (wave form **124**). At this time, the inputs to transistors **85, 87** and **88** are "high" preventing conduction of the transistors **61, 63** and **64.**

In a similar fashion, the driver transistors **63** and **64** are rendered conductive during the third and fourth 180° intervals of engine rotation, for time intervals equal to the duration of the timing signal from flip-flop **51.** It is noted that the wave forms **125–128,** as illustrated, are rectangular pulses but in actual operation, the wave forms are distorted due to the inductance of the solenoid actuators and due to inertial effects. Because of such inductance and inertial effects the actual opening of the injection valve is delayed to take place after the leading edge of the applied pulse and likewise, the actual closing of the valve may be delayed. However, the actual time of opening of each injection valve and thereby the amount of fuel injected are proportional to the duration of the timing pulse, to within close limits of accuracy.

It is also noted that each injection valve may be opened throughout nearly 180° of crankshaft rotation which is important in that the required instantaneous rate of flow through each injection valve or nozzle, during the time it is opened, under maximum total flow of conditions, is reduced since the valve is open for a longer time interval. The requirements as to design and construction of the valve are not nearly as stringent as they would be if the valve had to be opened for short periods of time with a correspondingly higher required instantaneous rate of flow. Also, variations in opening and closing times of the valves, as well as variations in the accuracy of generation of the timing signals, have a reduced effect on overall accuracy. By way of example, the system may be designed for a 6 millisecond maximum pulse length each 180° crank rotation, for operation and up to 5,000 RPM.

It is noted that FIG. 2 illustrates the functional operations performed whereas FIG. 3 illustrates the implementation of such functions in an actual circuit. In FIG. 2, the functions of the decoder 52, illustrated in block form, is to produce a number of outputs in sequence, the number being equal to the number of engine cylinders, and the function of the illustrated AND gates 47–50 is to combine such outputs of the decoder 52 with the output of the timing flip-flop 51. In the actual circuit of FIG. 3, these functions are implemented by using three input NOR gates for each of the driver transistors 61–64. For example, transistors 73, 86 and 89 and associated circuit elements form a three input NOR gate for the driver transistor 61, requiring three "low" inputs to produce a "high" output at the base of driver transistor 61. In a strict sense, there is no AND gate as such in that there is no individual circuit in which all inputs must have the same value to make the output equal to any of the inputs. However, in a broader sense, the functional operations are nevertheless performed, in that the transistors 85 and 89 perform a decoding function, allowing the collectors thereof to go toward "high" only when the flip-flops 101 and 102 are in prescribed states, and through the common connection of the collectors of transistors 85, 89 with the collector of the transistor 73, an AND function is performed in that the decoding function must be performed and the timing flip-flop 51 must be in a certain state in order to make the output have a certain value. It will be understood that other types of logic circuit elements might be used to implement the prescribed functions and that reference herein to AND and OR gates is intended in a functional sense and not as limiting the invention to particular circuits for implementation of the prescribed functions.

Referring to FIG. 5, the flip-flop 51 comprises a pair of transistors 131 and 132 having emitters connected together into a resistor 133 to ground and having collectors connected to a power supply terminal 134 through resistors 135 and 136. The bases of transistors 131 and 132 are connected through resistors 137 and 138 and through resistors 139 and 140 to the collectors of the transistors 132 and 131, respectively, capacitors 141 and 142 being connected in parallel with the resistors 139 and 140. The base of transistor 131 is additionally connected through a diode 143 to a circuit point 144 which is connected to a resistor 145 to the collector of the transistor 131 and which is connected through a capacitor 146 to the output of the delay multivibrator 54. Similarly, the base of the transistor 132 is additionally connected through diode 147 to a circuit point 148 which is connected through a resistor 149 to the collector of the transistor 132 and which is connected through a coupling capacitor 150 to the line 29 from the timer 31.

In operation, the transistor 131 is normally conductive while the transistor 132 is cut off. When a negative-going signal is applied from the output of the delay multivibrator 54, through the coupling capacitor 146 and the diode 143, the transistor 131 is rendered non-conductive while the transistor 132 is rendered conductive, developing a negative-going signal at the collector thereof applied through the line 30 to the timer 31 to initiate operation thereof. After a certain time interval, depending upon the control signals applied to the timer 31, a negative-going signal is applied from the timer through the line 29, capacitor 150 and diode 147 to the base of the transistor 132, rendering the transistor 132 non-conductive and the transistor 131 conductive, thus restoring the initial condition. The collector of the transistor 132 is connected to the AND gates 47–50 (through resistor 84 to the base of the transistor 83, in the circuit of FIG. 3) to apply a drive pulse to the appropriate injector valve, depending upon the condition of the sequencing circuitry, including flip-flops 101 and 102.

The delay multivibrator 54 comprises a pair of transistors 151 and 152 having emitters connected to ground and having collectors connected through resistors 153 and 154 to the power supply terminal 134. The base of the transistor 152 is connected through a resistor 155 to a circuit point 156 which is connected through a capacitor 157 to the collector of the transistor 151 and which is connected through an adjustable resistor 158 to the power supply terminal 134. The base of the transistor 151 is connected through a resistor 159 to the collector of the transistor 152 and is also connected through a resistor 160 and through the line 55 to the ignition system.

In operation of the delay multivibrator 54, the transistor 151 is normally non-conductive while the transistor 152 is normally conductive. When a positive pulse is applied through line 55 and the resistor 160 to the base of the transistor 151, the transistor 151 conducts, cutting off the transistor 152 through the connection of the collector of transistor 151 through capacitor 157 and resistor 155 to the base of the transistor 152. The charge of the capacitor 157 is then gradually changed through current flow through the adjustable resistor 158 and after a certain time interval, depending upon a position of adjustment of the resistor 158, the transistor 152 again conducts, cutting off the transistor 151. Thus a positive pulse of predetermined duration is developed at the collector of the transistor 152, which is applied to the flip-flop 51 and also through the capacitor 109 to the flip-flop 101, the negative-going or trailing edge of the pulse being effective to trigger the flip-flop 51 and also to trigger the flip-flop 101.

The delay multivibrator 56 comprises a pair of transistors 163 and 164 having emitters connected to ground and having collectors connected through resistors 165 and 166 to the power supply terminal 134. The base of the transistor 163 is connected through a resistor 167, in parallel with a capacitor 168, to the collector of the transistor 164. The base of the transistor 164 is connected through the line 57 to the ignition circuit and is also connected through a resistor 169 to a circuit point 170 which is connected through a capacitor 171 to the collector of the transistor 163 and through an adjustable resistor 172 to the power supply terminal 134. This circuit operates in a manner similar to the circuit of the delay multivibrator 54, the transistor 163 being normally non-conducting and the transistor 164 being normally conducting. When a negative pulse is applied to the base of the transistor 164 through the line 57, transistor 164 is cut off and transistor 163 becomes conducting and remains conducting until the charge of capacitor 171 is changed through current flow through the resistor 172 to an extent sufficient to render the transistor 164 again conducting whereupon the transistor 163 is cut off.

Thus a positive pulse of predetermined duration, determined by the adjustment of the resistor **172**, is developed at the collector of the transistor **164**. This pulse is applied through a capacitor **173** to a circuit point which is connected through a resistor **174** to ground, through a resistor **175** to the power supply terminal **134** and directly to the base of a transistor **176**. The collector of the transistor **176** is connected to a power supply terminal **177** while the emitter thereof is connected to the line **108** and through a resistor **178** to ground. Transistor **176** operates as an emitter-follower, developing a positive pulse on the line **108**, the negative-going or trailing edge of the pulse being effective to reset the flip-flops **101** and **102**.

In the circuit arrangement of FIG. **5**, the triggering signals for developing the index and reset pulses are developed from the engine ignition system which may be of conventional construction as diagrammatically illustrated, including the ignition coil **27** having primary and secondary windings **181** and **182**. The primary winding **181** is connected between the positive terminal of a battery **183** and a movable breaker contact **184** which is actuated by a four lobe cam **185** driven from the cam shaft of the engine, the contact **184** being periodically moved out of engagement with a grounded contact **186** to interrupt current flow through the primary **181** and to induce a high voltage in the secondary winding **182**. Capacitor **187** is connected between contacts **184** and **186**.

The ignition system further includes the distributor **26** comprising a rotating contact **190** sequentially engaged with contacts **191–194** which are respectively connected to spark plugs **195–198**. Contact **190** is connected to one end of the secondary winding **182** the other end of which is connected to one end of the primary winding **181** and to the contact **184**, connected through the capacitor **187** to ground.

In the arrangement of FIG. **5**, the triggering pulses for the multivibrator **54** are developed by inserting a resistor **200** between the positive terminal **188** and of the primary winding **181** which is connected through a coupling capacitor **201** to the line **55**. When the breaker contacts **184, 186** are opened, a voltage pulse is developed at the junction between resistor **200** and the primary winding **181** which is applied through the coupling capacitor **201**, line **55** and resistor **160** to the transistor **151** to trigger the transistor **151** into conduction.

To develop the triggering pulses on the line **57**, it is connected through a neon lamp **202** and a resistor **203** to the distributor contact **191** for a predetermined one of the engine cylinders. Resistor **203** may have a relatively high value, **6** megohms, for example, and a capacitor **204** may preferably be connected between line **57** and ground. When a high voltage pulse is applied to the distributor contact **191**, the neon lamp **202** conducts and discharges the capacitor **204** to trigger the transistor **164** to a non-conductive state and to initiate development of a pulse on the output line **108** the negative-going or trailing edge of which resets the flip-flops **101** and **102** to a predetermined state in a manner as described above.

FIG. **6** illustrates a modified arrangement for developing the triggering pulses. In this arrangement, line **55** is connected through a resistor **206** to ground and through a capacitor **207** to one end of a coil **208** of a pick-up unit **210** may comprise a pair of pole pieces **211** and **212** with a small permanent magnet **213** therebetween. The ends of the pole pieces **211** and **212** are spaced a short distance apart and are in proximity to the annular path of movement of the outer ends of four teeth **215–218** of magnetic material, carried by a rotor **220** which may be driven from the cam shaft of the engine. As each of the teeth **215–218** pass in proximity to the ends of the pole pieces **211** and **212**, the magnetic flux linking the coil **208** is abruptly increased and then decreased, generating positive and negative pulses, the positive pulses being effective to trigger the transistor **151** into conduction.

The line **57** in FIG. **6** is connected through a resistor **221** to ground and through a capacitor **222** to a coil **223** of a pick-up unit **224**, the other end of coil **223** being grounded. Pick-up unit **224** may be substantially identical to the unit **210** and is in proximity to the path of movement of a single tooth **225** of a second rotor **226**, also driven from the cam shaft of the engine.

It will be noted that neither the arrangement of FIG. **5** nor the arrangement of FIG. **6** requires any contacts for developing the triggering signals, other than those which may already be present in the ignition system. The arrangement of FIG. **5** is particularly advantageous in that it requires comparatively simple and inexpensive circuit connections to the ignition system. The arrangement of FIG. **6** is advantageous in permitting additional flexibility as to the time of generation of the triggering pulses. The pick-up units **210** and **224** may be adjustable, with respect to their angular positions. It will be understood that modifications and variations may be effected without departing from the spirit and scope of the novel concepts of this invention.

What is claimed is:

1. A fuel injection control system for an engine including a plurality of cylinders and fuel injection valve means associated with each cylinder for injection of fuel for flow into each cylinder during the intake stroke thereof, electrically energizable actuator means for each of said fuel injector valve means, spark plug means for each cylinder, ignition pulse generating means for generating an ignition pulse in predetermined phase relation to each and every power stroke of the engine, and distributor means for applying said ignition pulses to said spark plug means in sequence, said control system comprising: a sequencing circuit for supplying sequencing signals in synchronized relation to intake strokes of the engine, timer means for supplying timing signals, means responsive to said sequencing and timing signals for energizing said actuator means, said sequencing circuit having a plurality of stable states respectively corresponding to said actuator means and being arranged to be indexed from one state to another in a predetermined order and to develop in each of said states a sequencing signal for control of the corresponding actuator means in response to a timing signal from said timer means, index pulse means for supplying to said sequencing circuit an index pulse in predetermined phase to each and every power stroke of the engine to index said sequencing circuit from one state to another, and reset pulse means for supplying to said sequencing circuit a reset pulse in predetermined phase relation to the power stroke of a predetermined one of the engine cylinders to reset said sequencing circuit to a predetermined initial state, said index pulse means being arranged for coupling to said ignition pulse generating means to develop and index in response to each ignition pulse, and said reset pulse means being arranged for coupling to said distributor means to develop a reset pulse in response to each ignition pulse applied to the spark plug means for said predetermined one of the engine cylinders, said index pulse means comprising a first monostable multivibrator, said reset pulse means comprising a second monostable multivibrator, said first and second multivibrators being triggered in response to ignition pulses from said ignition pulse generating means and said distributor means.

2. In a system as defined in claim **1,** said sequencing circuit comprising digital counter means, means for applying said index pulses from said index pulse means to said digital counter means to advance the count thereof in response to each index pulse, and means for applying said reset pulses to said counter means to insure reset of said counter means to a predetermined condition in response to each reset pulse.

3. In a system as defined in claim **1,** at least one of said multivibrators being operative as a delay circuit such as to provide a phase-displaced relation between each reset pulse and the corresponding index pulse.

4. In a system as defined in claim **1,** wherein the ignition pulse generating means comprises an ignition coil having primary and secondary winding means, and means providing a connection from said primary winding means to a voltage source and arranged for periodically breaking said connection to develop a high voltage ignition pulse in said scondary winding means, said index pulse means including resistance means in series with said primary winding means.

5. In a system as defined in claim **1,** said reset pulse means comprising ionizable discharge means, and a high resistance connection from said discharge means to said distributor means.

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