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Neuman

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[54] **INTERNAL COMBUSTION ENGINE COORDINATED DUAL ACTION INDUCTIVE DISCHARGE SPARK IGNITION SYSTEM**

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[73] Assignee: **General Motors Corporation,** Detroit, Mich.

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[52] **U.S. Cl.** ..... **123/148 E;** 315/222; 315/227

[51] **Int. Cl.**[2] **F02P 3/02**

[58] **Field of Search** ..... 123/148 E; 315/209 R, 219, 315/222, 223, 226, 227

[56] **References Cited**

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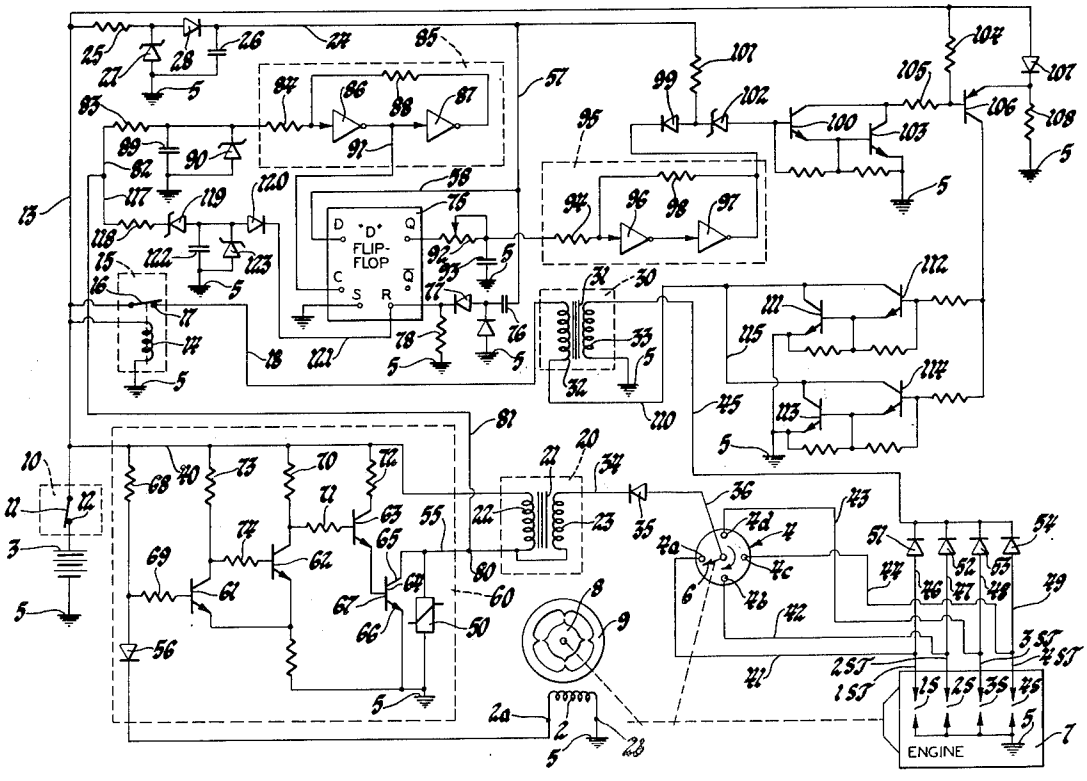
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[57] **ABSTRACT**

A coordinated dual action inductive discharge spark ignition system for use in an internal combustion engine composed of a first inductive discharge circuit effective to produce a high arc-creating voltage and a second inductive discharge circuit operated in slaved relationship to the first circuit effective to produce a high arc current. The system accommodates itself to the rapid change from very high resistance across the sparking electrodes immediately prior to ignition arc creation to the very low effective resistance after the arc is struck by shifting automatically from the high voltage system as the source of arcing current to the high current system. The ignition coil of the high current system is designed with a comparatively small number of low resistance secondary turns so that the internal resistance of the high current system is low when viewed from the arcing terminals and is very much less than that of the high voltage system. In an operative embodiment of the invention, such resistance was of the order of 0.5 percent of that of the high voltage system. In the preferred form of the invention, the systems are further coordinated in that voltage pulses on the negative terminal of the primary winding of the high voltage ignition coil at the times current flow is initiated therein and at the time the arc strikes trigger the current flow and current interruption events in the primary winding of the high current ignition coil so that the high current system is actuated a predetermined time after the high voltage system strikes the arc and before the arc current unduly diminishes. The systems coact so that each provides current to the single pair of arcing electrodes through energizing connections that include at least one rectifier that isolates the high voltage secondary from the high current system. In modifications of the present invention only the high voltage secondary is connected through the engine ignition distributor.

13 Claims, 4 Drawing Figures



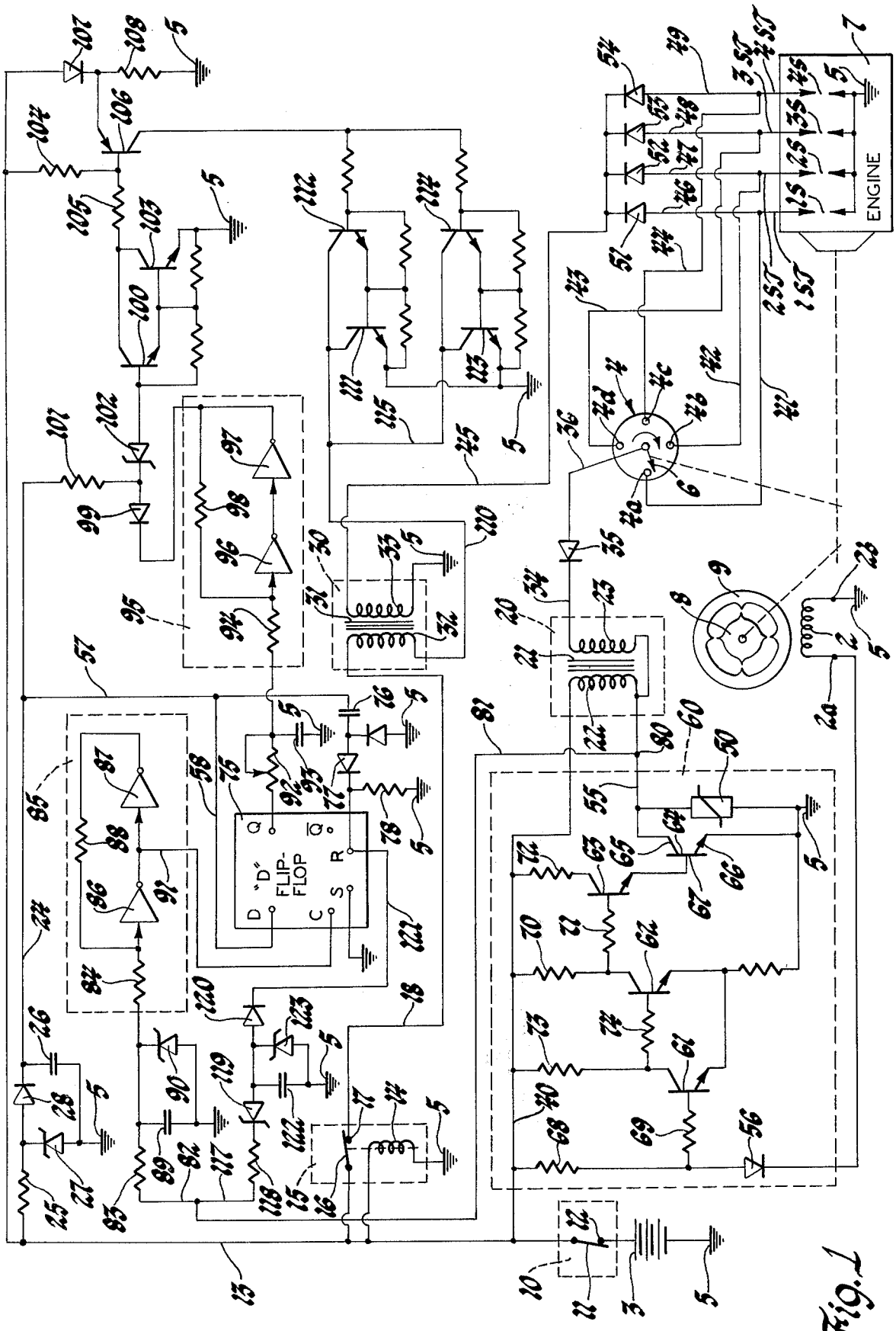


Fig. 1

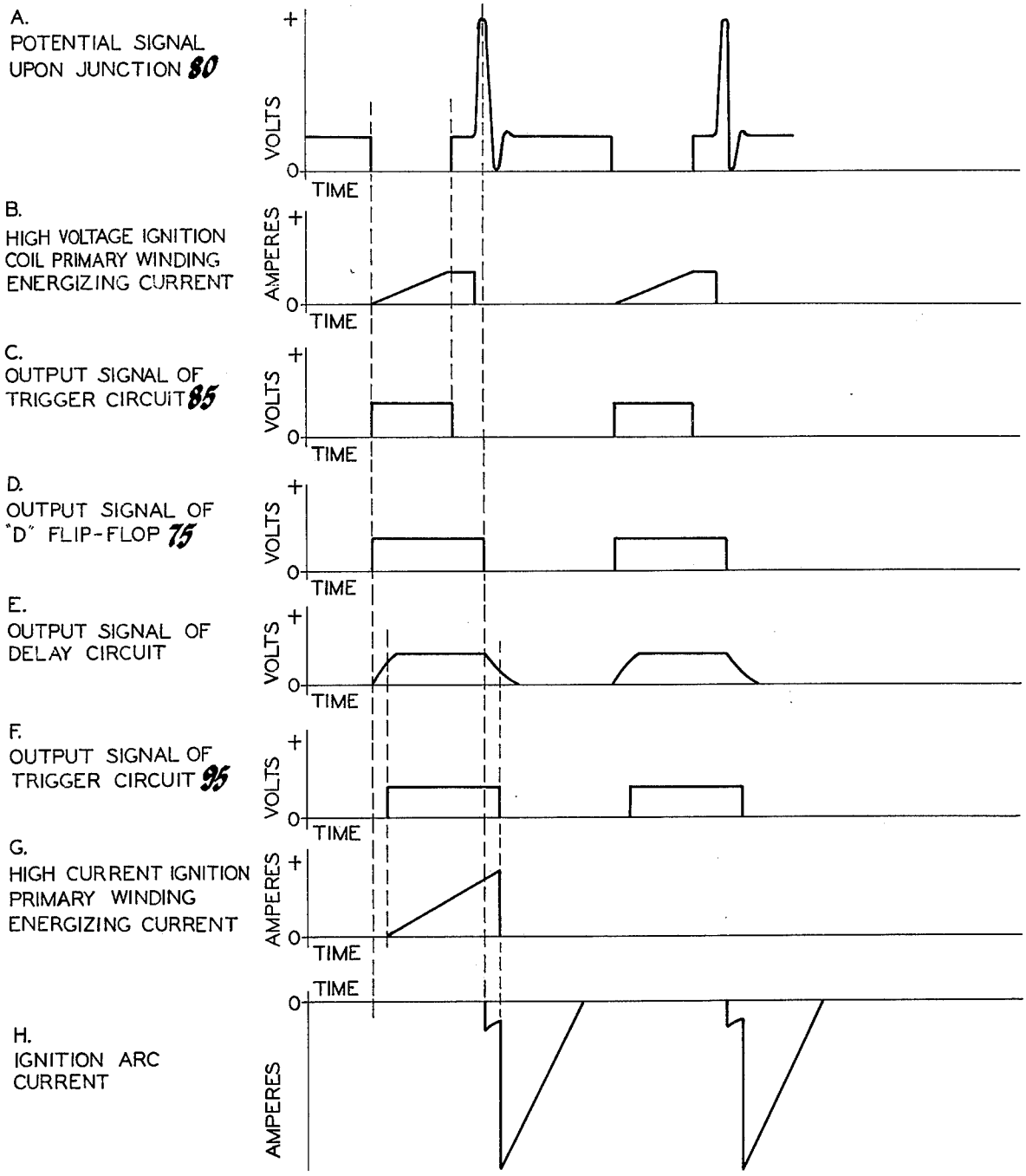

A.
POTENTIAL SIGNAL
UPON JUNCTION 80
+
VOLTS
0
TIME
B.
HIGH VOLTAGE IGNITION
COIL PRIMARY WINDING
ENERGIZING CURRENT
+
AMPERES
0
TIME
C.
OUTPUT SIGNAL OF
TRIGGER CIRCUIT 85
+
VOLTS
0
TIME
D.
OUTPUT SIGNAL OF
"D" FLIP-FLOP 75
+
VOLTS
0
TIME
E.
OUTPUT SIGNAL OF
DELAY CIRCUIT
+
VOLTS
0
TIME
F.
OUTPUT SIGNAL OF
TRIGGER CIRCUIT 95
+
VOLTS
0
TIME
G.
HIGH CURRENT IGNITION
PRIMARY WINDING
ENERGIZING CURRENT
+
AMPERES
0
TIME
TIME
0
H.
IGNITION ARC
CURRENT
AMPERES

Fig. 2

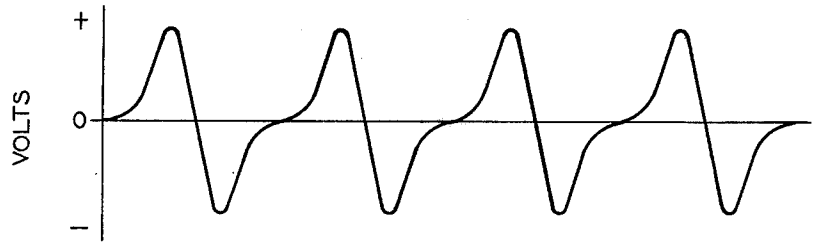


Fig. 3

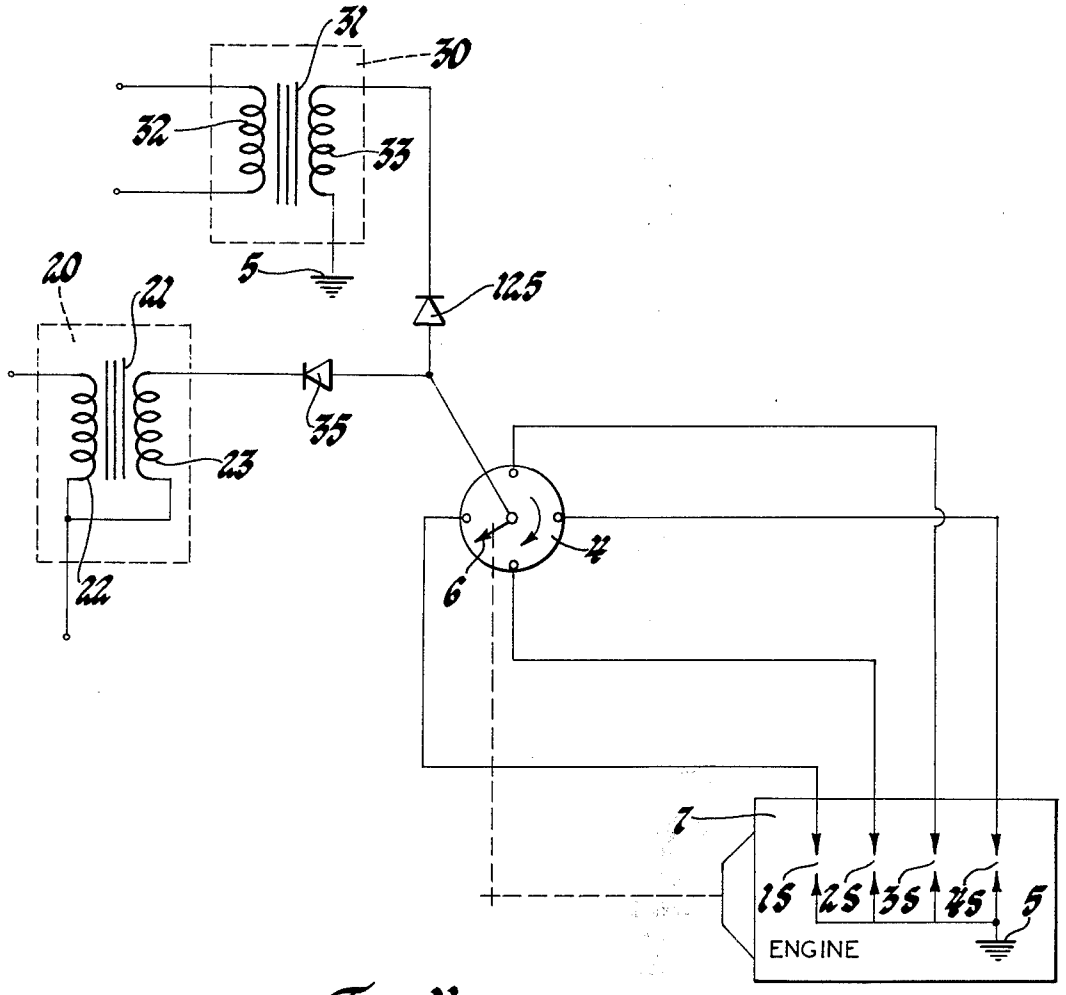


Fig. 4

INTERNAL COMBUSTION ENGINE COORDINATED DUAL ACTION INDUCTIVE DISCHARGE SPARK IGNITION SYSTEM

This invention is directed to an internal combustion engine ignition system and, more specifically, to an efficient internal combustion engine ignition system which produces both a high ignition potential for initiating each ignition arc and a high current through the ignition arc previously initiated.

In the inductive discharge type ignition systems for spark ignition engines, the primary winding of an ignition coil is connected to a source of voltage through current interrupting mechanism that operates in synchronism with the engine to create and then, each time a spark plug is to be fired, to interrupt the primary current. The resulting induced high voltage in the secondary is applied, usually through an ignition distributor, to the spark plugs in sequence so as to create successive fuel igniting arcs on the respective spark plugs. The operation of this type system requires that the ignition coil be so designed that an arc-creating voltage is generated on each primary current interruption. However, once the arc is created, the current and power delivered to the arcing contacts is limited by the essentially high impedance current source required to generate the arc-creating voltage.

The operation of an internal combustion engine of the spark ignition type requires that the combustion-initiating arc be of sufficient intensity and duration to provide positive ignition. In the case of low fuel to air mixtures, the required intensity and duration is relatively great because of the inherent difficulty of establishing ignition of such mixtures. The present invention provides such an effective combustion-initiating arc by providing separate ignition arc sources which accommodate the differing requirements of initiating and sustaining the arc, coupled with elements which serve to coordinate and time the action of the separate arc sources so as to provide, overall, a positively and reliably created arc and a high energy prolonged arcing period after the arc is created. Therefore, an improved inductive discharge type ignition system in accordance with the principles of the present invnetion characterized by effective operation to strike and maintain an arc, which makes it possible, in a reliable, efficient, and practical ignition system, to provide effective engine operation and good "drivability" while operating under relatively low fuel to air mixtures, is desirable.

It is, therefore, a general object of this invention to provide an improved internal combustion engine ignition system.

It is an additional object of this invention to provide an improved internal combustion engine ignition system of the inductive discharge type which produces both a high ignition potential of sufficient magnitude to strike an ignition arc followed by a coordinated high ignition current flow through an ignition arc previously struck.

It is an additional object of the present invention to provide an improved inductive discharge type ignition system that operates effectively to strike the ignition arc across the spark plug electrodes and yet efficiently maintains the arc under high energy conditions for a period thereafter, the unit being so coordinated that each of these actions occurs in proper timed relationship to the other and without prejudice to the other.

It is another object of the present invention to provide an improved inductive discharge type ignition system that operates effectively to strike the ignition arc across the spark plug electrodes via one circuit configuration characterized by high internal resistance and producing a high arc striking voltage and yet efficiently maintains the arc under high energy conditions for a period thereafter via a second circuit configuration characterized by low internal resistance, and wherein the two circuits are coordinated as to time in such fashion that effective ignition is obtained under adverse conditions.

It is another object of the present invention to provide an improved inductive discharge type ignition system that operates effectively to strike the ignition arc across the spark plug electrodes via one circuit configuration characterized by high internal resistance and yet efficiently maintains the arc under high energy conditions for a period thereafter via a second circuit configuration characterized by low internal resistance, and wherein at least the low current circuit is connected to the spark plug via a rectifier that permits the high internal resistance system to operate without loading from the low internal resistance system.

Yet another object of the present invention is to provide an ignition system of the foregoing type wherein current flow from the low internal resistance circuit configuration is applied to the spark plug without passing through an ignition distributor.

Still another object of the present invention is to provide a coordinated inductive discharge ignition system wherein an inductive discharge system having an ignition coil with a primary winding produces a high arc-creating voltage and the resulting voltage events at the primary winding serve to initiate and then interrupt the primary winding current of a low resistance high current ignition coil to produce a sustained high energy arc after the high voltage system has created the arc.

Further, it is an object of the present invention to provide a system achieving the above object wherein voltage conditions in the primary winding of the high voltage ignition coil at the instant of arc strike trigger initiation of the high current arc.

Further, it is another object of this invention to provide an ignition system having a slave system operated in timed sequence to a high voltage master system wherein the high voltage spike reflected back into the primary winding of the master system ignition coil at the instant an ignition arc is struck triggers circuitry to interrupt the energizing circuit of the slave system ignition coil primary winding.

Further objects and advantages of the present invention include achieving an inductive discharge ignition system that is simple, effective, and suitable for usage in mass production, and yet accommodates itself to both the requirements of the engine before the ignition arc is struck and the requirements of high efficiency and high arc energy after the arc is struck.

In accordance with this invention, a coordinated dual action inductive discharge type internal combustion engine ignition system is provided wherein a high ignition potential of sufficient magnitude to strike an ignition arc is induced in the secondary winding of a high voltage ignition coil in timed relationship with an associated internal combustion engine and a high ignition current is induced in the secondary winding of a high current ignition coil upon each striking of an ignition

arc to provide a high current flow through an ignition arc previously struck.

Briefly, in the novel coordinated dual action inductive discharge ignition system of this invention, the ignition arc is struck by a high voltage system, including a high turns ratio ignition coil which has the primary winding energizing current interrupted when the arc is to be initiated, and an ignition distributor which connects the proper spark plug to the secondary winding for such to create the arc. The current supply to the arc is thereafter shifted to a high current system, including a relatively low turns ratio ignition coil, which has its primary winding interrupted in slaved relationship to the interruption of the primary current of the high voltage system, and at a short time after the arc is struck. One or more rectifiers connect the respective secondary windings to the spark plugs, so that at least the high current secondary is isolated from the high voltage secondary at the instant of arc strike. The result is conjoint action of the two systems in such fashion that sufficient voltage to positively and effectively strike the ignition arc is first created and while the arc is still ignited the high current system takes over to maintain the arc in a highly energized condition. It has been found that with this arrangement it is possible to effectively and reliably ignite lean or otherwise difficult to ignite fuel/air mixtures and to achieve smooth and drivable engine operation.

For a better understanding of the present invention, together with additional objects, advantages and features thereof, reference is made to the following description and accompanying drawing in which:

FIG. **1** is a circuit diagram of the internal combustion engine ignition system of this invention;

FIG. **2** is a set of curves useful in understanding the circuitry of FIG. **1**;

FIG. **3** is a curve illustrating the wave form produced by a magnetic type distributor which may be used with the circuitry of FIG. **1**; and

FIG. **4** is a fragmentary view of an alternate embodiment of the circuit of FIG. **1**.

As point of reference or ground potential is the same point electrically throughout the system, it has been represented in the drawing by the accepted schematic symbol and referenced by the numeral **5**.

In FIG. **1** of the drawing, the high voltage-high current internal combustion engine ignition system of this invention is set forth in schematic form in combination with a source of direct current potential, which may be a conventional automotive type storage battery **3**, and an ignition distributor **4** having a movable electrical contact **6**, rotated in timed relationship with an associated internal combustion engine **7**, through which ignition spark energy is directed to the spark plugs of the engine individually, in a manner well known in the automotive art.

The internal combustion engine with which the high voltage-high current ignition system of this invention may be used is set forth in block form, is referenced by the numeral **7** and is illustrated as having four spark plugs **1S, 2S, 3S** and **4S**, each having an arc gap, as is well known in the automotive art. It is to be specifically understood, however, that the ignition system of this invention may be used with internal combustion engines having more or less cylinders or with rotary type engines.

To supply operating potential to the system, movable contact **11** of an electrical switch **10** may be closed to stationary contact **12** to supply battery potential across lead **13** and point of reference or ground potential **5**. Movable contact **11** and stationary contact **12** may be a pair of normally open electrical contacts included in a conventional automotive ignition switch of a type well known in the automotive art. For purposes of this specification, it will be assumed that movable contact **11** is closed to electrical contact with stationary contact **12**, as shown in FIG. **1**.

While movable contact **11** of switch **10** is closed to stationary contact **12**, operating coil **14** of electrical relay **15** is energized across battery **3**. While operating coil **14** is energized, movable contact **16** is closed to electrical engagement with stationary contact **17**. Battery **3** potential, therefore, is present across lead **18** and point of reference or ground potential **5**.

To supply a substantially constant direct current potential free of ripples and noise across lead **24** and point of reference or ground potential **5**, battery potential may be filtered by resistors **25** and capacitor **26** and regulated to a selected maximum value by a Zener diode **27**, which clips off negative polarity spikes and positive polarity spikes greater than a selected maximum voltage. Diode **28** prevents filter capacitor **26** from discharging through battery **3** with any momentary drop of battery potential.

The high voltage ignition coil **20** has a magnetic core **21**, a primary winding **22** which, during the build-up of the flow of energizing current therethrough, produces a magnetic flux in core **21** and a secondary winding **23**. With none of the engine spark plugs fired, an ignition spark potential of sufficient magnitude to initiate an ignition arc or spark across the arc gap of each of the spark plugs **1S, 2S, 3S** and **4S** is induced by induction coil action in secondary winding **23** upon the interruption of the flow of energizing current through primary winding **22**, in a manner well known in the automotive art. In one practical application of the high voltage-high current internal combustion engine ignition system of this invention, a high voltage ignition coil having a primary winding of 30 turns, a secondary winding of 3,000 turns and a magnetic core having a cross-sectional area of 0.625 square inch with a 0.029 inch air gap was employed. The primary winding energizing current at the time of interruption was 30 amperes. The direct current resistance of the secondary winding was 710 ohms.

The high current ignition coil **30** has a magnetic core **31**, a primary winding **32** which, during the build-up of the flow of an energizing current therethrough, produces a magnetic flux in core **31** and a secondary winding **33**. Upon striking of an ignition arc across the arc gap of any of the engine spark plugs, an ignition current is induced in secondary winding **33** upon the interruption of the flow of energizing current through primary winding **32**, in a manner well known in the automotive art. In one practical application of the high voltage-high current internal combustion engine ignition system of this invention, a high current ignition coil having a primary winding of 10 turns and a secondary winding of **135** turns and a magnetic core having a cross-sectional area of 2½ square inches with a 0.042 inch air gap was employed. The primary winding energizing current at the time of interruption was **90** amperes. The direct current resistance of the secondary winding was 4½ ohms.

The spark plug terminals are represented in the drawing by dots and are referenced, respectively, **1ST, 2ST,**

3ST, and 4ST. One terminal end of high voltage ignition coil secondary winding 23 is connected through lead 34, isolating diode 35 and lead 36 to the movable electrical contact 6 of distributor 4. Output terminal 4*a* of distributor 4 is connected to spark plug 1S through lead 41 and terminal 1ST, output terminal 4*b* is connected to spark plug 2S through lead 42 and terminal 2ST, output terminal 4*c* is connected to spark plug 4S through lead 44 and terminal 4ST and output terminal 4*d* is connected to spark plug 3S through lead 43 and terminal 3ST. One terminal end of high current ignition coil secondary winding 33 is connected through lead 45, respective diodes 51, 52, 53 and 54 and respective leads 46, 47, 48, and 49 to spark plugs 1S, 2S, 3S and 4S. Leads 34, 36, 41, 42, 43 and 44 may be of conventional ignition spark plug cable well known in the art. As high current ignition coil secondary winding 33 provides a high current to the ignition spark, leads 45, 46, 47, 48 and 49 should be of a material of high electrical conductivity, such as copper or aluminum.

Isolating diode 35 isolates the high voltage ignition coil secondary winding 23 from the high current ignition coil secondary winding 33. Without isolating diode 35, high current ignition coil secondary winding 33 would have a parallel path to point of reference or ground potential 5 through the arc and through the high voltage ignition coil secondary winding 23. Diodes 51, 52, 53 and 54 isolate the high current ignition coil secondary winding 33 from the high ignition spark potential induced in high voltage ignition coil secondary winding 23 and also direct current produced in the high current ignition coil secondary winding 23 to the fired spark plug in a manner to be latter explained. In view of the fact that diodes 51, 52, 53 and 54 are exposed to the high ignition potential induced in high voltage ignition coil secondary winding 23 in an inverse polarity relationship, it is necessary that these diodes have a PIV rating greater than the high ignition potentials to which they may be subjected. With an engine having spark plugs in good operating condition, the spark plugs will fire with ignition potentials of 12 to 14 KV, however, in the event a spark plug should not fire, the high ignition potential will rise to a much higher value. In a practical application of the ignition circuit of this invention, the diodes corresponding to diodes 51, 52, 53 and 54 had a PIV rating of 30 kilovolts. Diodes of this type are commercially available items and are marketed by Semtech Corporation of Newbury Park, California and are identified as type SDHD15KM. Normally, the distributed capacitance of the ignition system will prevent the high ignition potential from exceeding approximately 30 KV. The primary and secondary potential relationship in an ignition coil is represented by the formula, $E_p = (E_s/TR)$ where E_p is the primary winding potential, E_s is the high ignition potential induced in the secondary winding, and TR is the secondary to primary winding turns ratio (N_s/N_p). As the high ignition potential E_s induced in the secondary winding increases, a corresponding increase in primary winding potential E_p is reflected back into the primary winding of a value equal to the high ignition potential E_s divided by the ignition coil turns ratio and that if provision is made for limiting the value of the primary winding potential E_p to a maximum value, the high ignition potential E_s will be limited to a maximum value equal to the maximum value of the primary winding potential E_p multiplied by the turns ratio. To protect diodes 51, 52, 53 and 54 in the event of worst case conditions, a metal oxide varistor 50 may be connected across one terminal end of high voltage ignition coil primary winding 22 and point of reference or ground potential 5. The metal oxide varistor is a commercially available item marketed by the General Electric Company and is a semiconductor device which is normally not conductive but will break down and conduct with applied voltages thereacross exceeding the voltage rating of the device. Therefore, with diodes corresponding to diodes 51, 52, 53 and 54 having a PIV rating of 30 kilovolts and an ignition coil having a secondary to primary winding turns ratio of 100, to prevent the high ignition potential induced in high voltage ignition coil secondary winding 23 from exceeding the PIV rating of these diodes, the high voltage ignition coil primary winding potential should be limited to a maximum value of 300 volts. Therefore, metal oxide varistor 50 should have a 300 volt rating. In other ignition systems having high voltage ignition coil secondary to primary winding turns ratio different than 100, the metal oxide varistor should have a voltage rating which will clamp the high voltage ignition coil primary winding voltage at a value which will prevent the high ignition potential induced in the secondary winding thereof from rising to a value greater than the PIV rating of the diodes corresponding to diodes 51, 52, 53 and 54.

To interrupt and complete the high voltage ignition coil primary winding energizing circuit in timed relationship with engine 7, the current carrying elements of an electrical switching device which are operable to the electrical circuit open and closed conditions, are connected in series therein. Without intention or inference of a limitation thereto, this electrical switching device may be a type NPN switching transistor 64 included in an electronic ignition system 60. The current carrying elements of switching transistor 64, collector electrode 65 and emitter electrode 66, are operable to the electrical circuit open and closed conditons in response to electrical signals applied to the control electrode, base electrode 67, and are connected in series in the high voltage ignition coil primary winding energizing circuit. The high voltage ignition coil primary winding energizing circuit may be traced from the positive polarity terminal of battery 3, through the closed contacts of electrical switch 10, lead 40, primary winding 22 of high voltage ignition coil 20, lead 55, the collector-emitter electrodes of switching transistor 64 and point of reference or ground potential 5 to the negative polarity of battery 3. The collector-emiter electrodes of switching transistor 64 are operated to the electrical circuit open condition at the time each spark plug of engine 7 is to be fired in response to each one of a series of ignition signals produced in timed relationship with engine 7.

The series of ignition signals may be produced in timed relationship with engine 7 by any one of the several conventional magnetic distributors well known in the automotive art. One example of a magnetic distributor well known in the automotive art suitable for use with the high voltage-high current ignition system circuit of this invention is of the variable reluctance type disclosed and described in U.S. Pat. No. 3,254,247, Falge, which issued May 31, 1966 and is assigned to the same assignee as is the present invention. In the interest of reducing drawing complexity, the variable reluctance type ignition distributor disclosed and described in U.S. Pat. No. 3,254,247 is set forth in schematic form in the drawing. A rotor member 8 is rotated in timed relationship with the engine by the engine in a

manner well known in the automotive art within the bore of pole piece 9. Equally spaced about the outer periphery of rotor 8 and about the bore of pole piece 9 are a series of projections equal in number to the number of cylinders of the engine with which the distributor and ignition system are being used. Pole piece 9 may be made up of a stack of a number of laminations of magnetic material secured in stacked relationship by rivets or bolts or other fastening methods and the magnetic flux may be provided by a permanent magnet, not shown, which may be secured to the lower face surface thereof. As each projection of rotor 8 approaches a projection on pole piece 9, the reluctance of the magnetic circuit between rotor 8 and pole piece 9 decreases and as each projection on rotor 8 moves away from the projection on pole piece 9, the reluctance of the magnetic circuit between rotor 8 and pole piece 9 increases. Consequently, the magnetic field produced by the permanent magnet increases and decreases as each projection on rotor 8 approaches and passes a projection on pole piece 9, a condition which induces a alternating current potential in pickup coil 2, which is magnetically coupled to pole piece 9, of a wave form as shown in FIG. 3.

During each positive polarity excursion of the series of ignition signals induced in pickup coil 2, terminal 2*a* thereof is of a positive polarity with respect to terminal end 2*b*, consequently, diode 56 is reverse biased. While diode 56 is reverse biased, base-emitter drive current is supplied to NPN transistor 61 through resistors 68 and 69. While base-emitter drive current is supplied to transistor 61, this device conducts through the collector-emitter electrodes thereof to divert base-emitter drive current from NPN transistor 62, consequently, transistor 62 does not conduct. While transistor 62 is not conductive, base-emitter drive current is supplied to NPN transistor 63 through resistors 70 and 71, consequently, transistor 63 conducts through the collector-emitter electrodes. While transistor 63 conducts through the collector-emitter electrodes, base-emitter drive current is supplied to NPN switching transistor 64 through resistor 72 and the collector-emitter electrodes of transistor 63. While base-emitter drive current is supplied to switching transistor 64, this device conducts through the collector-emitter electrodes to complete the high voltage ignition coil primary winding energizing circuit previously described. During the next negative polarity excursion of the series of ignition signals induced in pickup coil 2, terminal end 2*a* thereof is of a negative polarity with respect to terminal end 2*b*, consequently, diode 56 is forward biased. At the moment diode 56 becomes forward biased at the beginning of each negative polarity excursion of the ignition signals, the base-emitter drive current is diverted from transistor 61 to extinguish this device. With transistor 61 not conducting, base-emitter drive current is supplied to transistor 62 through resistors 73 and 74, consequently, transistor 62 conducts through the collector-emitter electrodes. Conducting transistor 62 diverts base-emitter drive current from transistor 63, consequently, transistor 63 extinguishes. When transistor 63 extinguishes, base-emitter drive current is no longer supplied to switching transistor 64, consequently, switching transistor 64 extinguishes to interrupt the high voltage ignition coil primary winding energizing circuit. Upon each interruption of the high voltage ignition coil primary winding energizing circuit, an ignition spark potential of a sufficiently high value to initiate an ignition arc across the arc gap of the spark plug to which it is directed is induced in secondary winding 23. This high ignition potential is directed to the next spark plug of engine 7 to be fired through the movable contact 4 of distributor 6, in a manner well known in the automotive art.

In a practical application of the high voltage-high current internal combustion engine ignition system of this invention the electronic ignition systems disclosed and described in detail in U.S. Pat. No. 3,605,713, LeMasters et al, which issued Sept. 20, 1971, and in U.S. patent application, Ser. No. 390,882, Richards et al, filed Aug. 23, 1973, both of which are assigned to the same assignee as is this invention, were employed.

The remainder of the circuitry of the high voltage-high current internal combustion engine ignition system operates in response to logic signals. In accordance with logic terminology well known in the art, throughout this specification, logic signals will be referred to as being in the "high" or logic 1 state or in the "low" or logic 0 state. For purposes of this specification and without intenion or inference of a limitation thereto, the "high" or logic 1 signals will be considered to be of the positive polarity potential and the "low" or logic 0 signals will be considered to be of zero or ground potential.

One of the commercially available logic circuit elements used with the high voltage-high current ignition system of this invention is a type "D" flip-flop circuit referenced by the numeral 75. The type "D" flip-flop circuit is a well known logic circuit element which the "Set" condition produces a logic 1 signal upon the "Q" output terminal and a logic 0 signal upon the "Q" output terminal; in the "Reset" condition produces a logic 0 signal upon the "$\overline{Q}$" output terminal and a logic 1 signal upon the "$\overline{Q}$" output terminal and transfers the logic signal present upon the "D" input terminal to the "Q" output terminal upon the application of a logic 1 clock signal to the "C" clock input terminal. The filtered and regulated positive polarity potential appearing upon lead 24 is applied through leads 57 and 58 as a logic 1 signal to the "D" input terminal of type "D" flip-flop circuit 75 and is applied through coupling capacitor 76 and diode 77 across resistor 78. The potential appearing across resistor 78 is applied as a logic 1 reset signal to the "R"reset terminal of type "D" flip-flop circuit 75 to reset this device upon the closure of movable contact 11 of electrical switch 10 to stationary contact 12. In the "Reset" condition, a logic 0 signal is present upon the "Q" output terminal of type "D" flip-flop circuit 75.

Assuming that switching transistor 64 of the electronic ignition system circuit 60 is not conducting, a logic 1 signal is present upon junction 80 and is applied through leads 81 and 82 and current limiting resistor 83 to the input terminal of a trigger circuit 85. Without intention or inference of a limitation thereto, trigger circuit 85 may be comprised of two conventional commercially available inverter circuit elements 86 and 87. As is well known in the electronics art, inverter circuits invert the logic signal to the input terminal thereof and produce the opposite logic signal upon the output circuit thereof. The output of inverter circuit 87 is fed back to the input circuit of inverter circuit 86 through a feedback resistor 88 to introduce a hysteresis into the trigger circuit operation. The logic 1 signal appearing upon junction 80 is filtered by capacitor 89 and Zener diode 90 and is applied through input resistor 84 to the input terminal of inverter circuit 86. This logic 1 input

signal is inverted to a logic 0 signal upon the output terminal of inverter circuit **86** and is applied through lead **91** to the "C" clock input terminal of type "D" flip-flop circuit **75.** This logic 0 signal does not affect type "D" flip-flop circuit **75.**

Upon the operation of switching transistor **64** conductive through the collector-emitter electrodes thereof at the beginning of each positive polarity excursion of the ignition signals, FIG. **3,** the high voltage ignition coil primary winding energizing circuit, previously described, is completed therethrough. While switching transistor **64** is conductive, energizing current begins to flow and build up through the high voltage ignition coil primary winding energizing circuit, curve B of FIG. **2,** and the signal present upon junction **80** is a substantially zero or ground potential, curve A of FIG. **2.** This logic 0 signal is applied to the input circuit of trigger circuit **85** through a circuit previously described and is inverted by inverter circuit **86** to a logic 1 output control signal of trigger circuit **85,** curve C of FIG. **2.** That is, trigger circuit **85** is responsive to each completion of the high voltage ignition coil primary winding energizing circuit for producing a high current ignition coil primary winding energizing circuit logic 1 control signal. This logic 1 output control signal is applied to the "C" clock input terminal of type "D" flip-flop circuit **75** through lead **91.** As the "D" input terminal of type "D" flip-flop circiut **75** is connected to the regulated and filtered potential appearing across lead **24** and point of reference or ground potential **5** through leads **57** and **58,** a logic 1 signal is maintained upon the "D" input terminal. Consequently, the application of the logic 1 control signal to the "C" clock input terminal upon each completion of the high voltage ignition coil primary winding energizing circuit transfers the logic 1 signal present upon the "D" input terminal to the "Q" output terminal to place the type "D" flip-flop circuit **75** in the "Set" condition with a logic 1 signal upon the "Q" output terminal thereof, curve D of FIG. **2.** This logic 1 output signal is applied across a delay circuit comprised of variable resistor **92** and capacitor **93.** The output signal of this delay circuit, curve E of FIG. **2,** begins to increase in a positive polarity direction and is applied through input resistor **94** to another trigger circuit **95.** Without intention or inference of a limitation thereto, trigger circuit **95** also may be comprised of two conventional commercially available inverter circuit elements **96** and **97.** The output signal of inverter circuit element **97** is returned to the input terminal of inverter circuit element **96** through a feedback resistor **98** for the purpose of introducing a hysteresis into the operation of this trigger circuit. When the output signal of the delay circuit has increased in a positive direction to a sufficient magnitude to trigger inverter circuit element **96** of trigger circuit **95,** a logic 0 signal appears upon the output circuit thereof which is applied to the input terminal of inverter circuit element **97.** This logic 0 signal is inverted by inverter circuit element **97** to a logic 1 output signal of trigger circuit **95,** curve F of FIG. **2.** This logic 1 output signal produces a reverse bias upon the cathode electrode of diode **99.** With a reverse bias upon the cathode electrode of diode **99,** base drive current is supplied to NPN transistor **100** through resistor **101** and Zener diode **102.** Zener diode **102** is included in this circuit for the purpose of providing noise immunity. As the collector electrodes of NPN transistors **100** and **103** are connected to the positive polarity terminal of battery **3** through the closed contacts of switch **10,** lead **13** and resistors **104** and **105** and the emitter electrodes thereof are connected to the negative polarity terminal of battery **3** through point of reference or ground potential **5,** with base drive current supplied to transistor **100,** these two transistors **100** and **103** conduct through the collector-emitter electrodes. With transistors **100** and **103** conducting through the collector-emitter electrodes, a circuit is completed through which base drive current is supplied to PNP transistor **106** through a circuit which may be traced from the positive polarity terminal of battery **3,** through the closed contacts of switch **10,** lead **13,** diode **107,** the emitter-base electrodes of PNP transistor **106,** resistor **105,** the parallel combination of the collector-emitter electrodes PNP transistors **100** and **103** and point of reference or ground potential **5** to the negative polarity terminal of battery **3.** Diode **107** and resistor **108** are provided for the purpose of maintaining the base electrode of PNP transistor **106** at a voltage level above the emitter electrode thereof equal to the potential drop across diode **107** when transistor **106** is extinguished. While emitter-base drive current is supplied to PNP transistor **106,** this device conducts through the emitter-collector electrodes thereof to supply base drive current to parallel connected NPN transistor pairs **111** and **112, 113** and **114.** While base-emitter drive current is supplied to these NPN transistors, these devices conduct through the collector-emitter electrodes to complete the energizing circuit for the high current ignition coil primary winding which may be traced from the positive polarity terminal of battery **3,** through the closed contacts of switch **10,** lead **13,** the closed contacts of relay **15,** lead **18,** primary winding **32** of high current ignition coil **30,** lead **110,** the parallel combination of the collector-emitter electrodes of NPN transistor **111** and **112** and lead **115** and the parallel combination of the collector-emitter electrodes of NPN transistors **113** and **114** and point of reference or ground potential **5** to the negative polarity terminal of battery **3.** Relay **15** and transistor pairs **111** and **112** and **113** and **114** are employed to safely conduct the high energizing current flow through the high current ignition coil primary winding **32** which may be of the order of 80–100 amperes. It is to be specifically understood that the circuit of this invention is not to be limited to this specific arrangement as other circuit elements capable of adequately conducting this high current ignition coil primary winding energizing current may be employed without departing from the spirit of the invention.

The high voltage ignition coil primary winding energizing current increases in magnitude, curve B of FIG. **2,** until the next negative polarity excursion of the ignition signals, FIG. **3.** At the moment diode **56** becomes forward biased at the beginning of the next negative polarity excursion of the ignition signals, switching transistor **64** is extinguished in a manner previously explained to interrupt the high voltage ignition coil primary winding energizing circuit. With ignition systems which have a current limit feature for limiting high voltage ignition coil primary winding energizing current to a maximum value at which it levels, curve B of FIG. **2,** a logic 1 signal appears upon junction **80,** curve A of FIG. **2,** at the time the ignition system goes into current limit. Upon the interruption of the high voltage ignition coil primary winding energizing circuit, a high ignition potential is induced in secondary winding **23** of high voltage ignition coil **20.** With ignition systems which do

not have a current limit feature, the logic 1 signal would appear upon junction **80** upon the interruption of the high voltage ignition coil primary winding energizing circuit. The high ignition potential induced in secondary winding **23** of high voltage ignition coil **20** initiates an ignition arc across the arc gap of the spark plug of engine **7** to which it is directed through distributor **4** to produce an arc current, curve H of FIG. **2,** and the logic 1 signal upon junction **80** is applied to the input terminal of trigger circuit **85.** This logic 1 signal is inverted by inverter circuit element **86** to a logic 0 output signal of trigger circuit **85,** curve C of FIG. **2.** Upon the striking of the ignition arc, a high voltage transient potential is reflected back through primary winding **22** of high voltage ignition coil **20** and appears upon junction **80,** curve A of FIG **2.** This high voltage transient potential is applied through leads **81** and **117,** resistor **118,** Zener diode **119,** diode **120** and lead **121** to the "R" reset terminal of type "D" flip-flop circuit **75** to place this device in the "Reset" condition with a logic 0 signal present upon the output terminal thereof, curve D of FIG. **2.** Zener diode **119** prevents the resetting of type "D" flip-flop circuit **75** with potentials less than the high transient spike reflected into primary winding **22** upon the striking of an ignition arc, capacitor **122** acts as a filter capacitor and Zener diode **123** limits the signal passed through Zener diode **119** to a maximum value consistent with that which will not destroy type "D" flip-flop circuit **75.** When the output of type "D" flip-flop **75,** curve D of FIG. **2,** drops to a logic 0, the outut signal of the delay circuit, curve E of FIG. **2,** begins to fall in a negative direction toward zero until it is of a level recognized by trigger circuit **95** as a logic 0 signal. The purpose of the delay circuit is to insure that an ignition arc has been struck before the high current ignition coil primary winding energizing circuit is interrupted in a manner to be now explained. The delay period may be adjusted by adjusting variable resistor **92.** This logic 0 signal is then inverted by inverter circuit element **96** which produces a logic 1 signal upon the output terminal thereof. The logic 1 signal upon the output terminal of inverter element **96** is inverted by inverter element circuit **97** which produces a logic 0 output signal from trigger circuit **95,** curve F of FIG. **2.** The logic 0 output signal of trigger circuit **95** forward biases diode **99,** consequently, base drive current is diverted from transistor **100** of transistor pair **100** and **103** through diode **99** and the output device of inverter circuit element **97.** Upon the diversion of base drive current from transistor **100,** this device and, consequently, transistor **103** extinguish to interrupt the circuit through which emitter-base drive current is supplied to transistor **106.** Upon the interruption of the circuit through which emitter-base drive is supplied to transistor **106,** this device extinguishes to interrupt the circuit through which base-emitter drive current is supplied to transistor pairs **111** and **112** and **113** and **114.** Upon the interruption of the circuit through which base drive current is supplied to these transistor pairs, these devices extinguish to interrupt the high current ignition coil primary winding energizing circuit. Upon the interruption of the high current ignition coil primary winding energizing circuit, a high ignition current which is equal to the quotient of the primary winding current divided by the turns ratio of the high current ignition coil, is induced in secondary winding **33** and is directed to the spark plug of engine **7** across which an arc has been initiated through the corresponding one of the respective diodes **51, 52, 53** or **54.** In a practical application of the ignition circuit of this invention, the high current ignition coil secondary current was of the order of **6** amperes. At this time, the ignition arc current increases to a high value, curve H of FIG. **2,** of sufficient intensity to maintain the ignition arc and to provide complete combustion of the air-fuel mixture in the combustion chamber. It may be noted that the potential induced in high current ignition coil secondary winding **33** is of an insufficient magnitude to initiate an ignition arc.

As leads **45, 46, 47, 48** and **49** are of a material of high electrical conductivity such as cooper, there is substantially no resistance in the discharge circuit of the high current ignition coil secondary winding **33.** Consequently, the potential induced therein is dropped across the one of diodes **51, 52, 53** or **54** which is conductive and the ignition arc, The duration of the high current ignition arc, therefore, is a function of the inductance of the high current ignition coil secondary winding and initial secondary current divided by the sum of the diode and arc potential drops.

Upon the next positive polarity excursion of the ignition signals, FIG. **3,** the high voltage ignition coil primary winding energizing circuit is again completed by switching transistor **64** and the sequence of events just described is repeated. Consequently, the high voltage-high current internal combustion engine ignition system of this invention operates in response to ignition signals produced in timed relationship with the engine to initially produce a high ignition potential for striking an ignition arc and, after the ignition arc is struck, to produce a high ignition current which supplies more energy to the ignition arc.

It is to be specifically understood that the high voltage-high current internal combustion engine ignition system of this invention may be used with conventional breaker type contact ignition systems and is not limited to use with electronic ignition systems as set forth in the drawing.

An alternate embodiment of the circuit of this invention is set forth by the fragmentary view of FIG. **4.** In this view, it may be noted that diodes **51, 52, 53** and **54** are eliminated and the high current induced in the secondary winding **33** of high current ignition coil **30** is directed to the spark plug of the engine across which an arc has been initiated through isolating diode **125** and movable contact **6** of distributor **4.**

While a preferred embodiment of the present invention has been shown and described, it will be obvious to those skilled in the art that various modifications and substitutions may be made without departing from the spirit of the invention which is to be limited only within the scope of the appended claims.

What is claimed is:

1. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which an ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc energy comprising: a high voltage ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding an arc-striking potential upon interruption of predetermined primary winding energizing current; a high current ignition coil having a magnetic core and primary and secondary wind-

ings, the turns ratio and core size being such as to produce in said secondary winding a potential incapable of striking an arc upon interruption of a predetermined primary current but capable of delivering high arc current after the arc is struck, a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high current ignition coil; means for completing said high voltage ignition coil primary winding energizing circuit and for abruptly interrupting the same in timed relationship with said engine at the instant when the arc is to be struck; circuit means responsive to voltage at the primary winding of the high voltage ignition coil effective to initiate current flow in the primary of the high current ignition coil when voltage changes in one sense as current flow through the primary winding of the high voltage ignition coil starts and to interrupt current flow in the primary winding of the high current ignition coil when voltage changes in opposite sense occur in the primary winding of the high voltage ignition coil upon creation of the arc; and means including at least one rectifier connecting said high voltage ignition coil secondary winding and said high current ignition coil secondary winding to the ignition arc gap so that the high voltage ignition coil and the high current ignition coil primary winding energizing currents, when interrupted in sequence, create and maintain the arc without substantial interaction.

2. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which an ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc energy comprising: a high voltage ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding an arc-striking potential upon interruption of predetermined primary winding energizing current; a high current ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding a potential incapable of striking an arc upon interruption of a predetermined primary current but capable of delivery high arc current after the arc is struck; a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high current ignition coil; means for completing said high voltage ignition coil primary winding energizing circuit and for abruptly interrupting the same in timed relationship with said engine at the instant when the arc is to be struck; cirucit means responsive to the completion of said high voltage ignition coil primary winding energizing circuit effective to actuate the high current ignition coil primary winding in an energizing current build-up and responsive to voltage at the said primary winding when the arc is struck to abruptly interrupt the energizing current before extinction of the arc created by the high voltage circuit; and means including at least one rectifier connecting said high voltage ignition coil secondary winding and said high current ingnition coil secondary winding to the ignition arc gap so that the high voltage ignition coil and the high current ignition coil primary winding energizing currents, when interrupted in sequence, create and maintain the arc without substantial interaction.

3. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc energy comprising: a high voltage ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding an arc-striking potential upon interruption of predetermined primary winding energizing current; a high current ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding a potential incapable of striking an arc upon interruption of a predetermined primary current but capable of delivering high arc current after the arc is struck; a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high current ignition coil; means for completing said high voltage ignition coil primary winding energizing circuit and for abruptly interrupting the same in timed relationship with said engine at the instant when the arc is to be struck; circuit means responsive to the action of said last means effective to actuate the high current ignition coil primary winding in an energizing current build-up followed by abrupt energizing current interruption before extinction of the arc created by the high voltage circuit; means including at least one rectifier connecting said high voltage ignition coil secondary winding and said high current ignition coil secondary winding to the ignition arc gap so that the high voltage ignition coil and the high current ignition coil primary winding energizing currents, when interrupted in sequence, create and maintain the arc without substantial interaction.

4. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which an ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc energy comprising: a high voltage ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding an arc-striking potential upon interruption of predetermined primary winding energizing current; a high current ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding a potential incapable of striking an arc upon interruption of a predetermined primary current but capable of delivering prolonged arc-sustaining energy after the arc is struck; a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through

said primary winding of said high current ignition coil; means for completing said high voltage ignition coil primary winding energizing circuit and for abruptly interrupting the same in timed relationship with said engine at the instant when the arc is to be struck; circuit means responsive to the completion of said high voltage ignition coil primary winding energizing circuit effective to actuate the high current ignition coil primary winding in an energizing current build-up and to the striking of an ignition arc to abruptly interrupt said energizing current before extinction of the arc created by the high voltage circuit; and means including at least one rectifier connecting said high voltage ignition coil secondary winding and said high current ignition coil secondary winding to the ignition arc gap so that the high voltage ignition coil and the high current ignition coil primary winding energizing currents, when interrupted in sequence, create and maintain the arc without substantial interaction.

5. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which an ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc current comprising: a high voltage ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding an arc-striking potential upon interruption of predetermined primary winding energizing current; a high current ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding a potential incapable of striking an arc upon interruption of a predetermined primary current but capable of delivering prolonged arc-sustaining energy after the arc is struck; a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high current ignition coil; means for completing said high voltage ignition coil primary winding energizing circuit and for abruptly interrupting the same in timed relationship with said engine at the instant when the arc is to be struck; circuit means including a delay circuit responsive to the completion of said high voltage ignition coil primary winding energizing circuit effective to actuate the high current ignition coil primary winding in an energizing current build-up and to the striking of an ignition arc to abruptly interrupt said energizing current after a predetermined period of delay as determined by said delay circuit but before extinction of the arc created by the high voltage circuit; and means including at least one rectifier connecting said high voltage ignition coil secondary winding and said high current ignition coil secondary winding to the ignition arc gap so that the high voltage ignition coil and the high current ignition coil primary winding energizing currents, when interrupted in sequence, create and maintain the arc without substantial interaction.

6. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which an ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc energy comprising: a high voltage ignition coil having primary and secondary windings of the type in which a high ignition potential of sufficient magnitude to strike an ignition arc is induced in said secondary winding upon the interruption of the flow of energizing current through said primary winding; a high current ignition coil having primary and secondary windings of the type in which a high ignition current is induced in said secondary winding upon the interruption of the flow of energizing current through said primary winding; a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high current ignition coil; means for interrupting and completing said high voltage ignition coil primary winding energizing circuit in timed relationship with said engine; circuit means responsive to each completion of said high voltage ignition coil primary winding energizing circuit for producing a high current ignition coil primary winding energizing circuit control signal; and circuit means responsive to each of said high current ignition coil primary winding energizing circuit control signals for completing said high current ignition coil primary winding energizing circuit and responsive to each striking of an ignition arc for interrupting said high current ignition coil primary winding energizing circuit.

7. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which an ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc energy comprising: a high voltage ignition coil having primary and secondary windings of the type in which a high ignition potential of sufficient magnitude to strike an ignition arc is induced in said secondary winding upon the interruption of the flow of energizing current through said primary winding; a high current ignition coil having primary and secondary windings of the type in which a high ignition current is induced in said secondary winding upon the interruption of the flow of energizing current through said primary winding; a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high current ignition coil; means for interrupting and completing said high voltage ignition coil primary winding energizing circuit in timed relationship with said engine; circuit means responsive to each completion of said high voltage ignition coil primary winding energizing circuit for producing a high current ignition coil primary winding energizing circuit control signal; circuit means responsive to each of said high current ignition coil primary winding energizing circuit control signals for initiating and responsive to each striking of an ignition arc for terminating a high current ignition coil primary winding dwell signal; circuit means responsive to each of said dwell signals for completing said high current ignition coil primary winding energizing circuit for the duration thereof; and rectifier means for isolating said high voltage ignition coil secondary winding from said

high current ignition coil secondary winding.

8. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which an ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc energy comprising: a high voltage ignition coil having primary and secondary windings of the type in which a high ignition potential of sufficient magnitude to strike as ignition arc is induced in said secondary winding upon the interruption of the flow of energizing current through said primary winding; a high current ignition coil having primary and secondary windings of the type in which a high ignition current is induced in said secondary winding upon the interruption of the flow of energizing current through said primary winding; a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high current ignition coil; means for interrupting and completing said high voltage ignition coil primary winding energizing circuit in timed relationship with said engine; a trigger circuit responsive to each completion of said high voltage ignition coil primary winding energizing circuit for producing a high current ignition coil primary winding energizing circuit control signal; a flip-flop circuit responsive to each of said high current ignition coil primary winding energizing circuit control signals and to each striking of an ignition arc for producing an output signal of a duration equal to the time between each of said control signals and the next strike of an ignition arc; circuit means responsive to each of said output signals of said flip-flop circuit for producing a high current ignition coil primary winding energizing circuit dwell signal; transistor switch means responsive to each of said dwell signals for completing said high current ignition coil primary winding energizing circuit for the duration thereof; and retifier means for isolating said high voltage ignition coil secondary winding from said high current ignition coil secondary winding.

9. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which an ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc energy comprising: a high voltage ignition coil having primary and secondary windings of the type in which a high ignition potential of sufficient magnitude to strike an ignition arc is induced in said secondary winding upon the interruption of the flow of energizing current through said primary winding; a high current ignition coil having primary and secondary windings of the type in which a high ignition current is induced in said secondary winding upon the interruption of the flow of energizing current through said primary winding; a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high current ignition coil; means for interrupting and completing said high voltage ignition coil primary winding energizing circuit in timed relationship with said engine; a trigger circuit responsive to each completion of said high voltage ignition coil primary winding energizing circuit for producing a high current ignition coil primary winding energizing circuit control signal; a flip-flop circuit responsive to each of said high current ignition coil primary winding energizing circuit control signals and to each striking of an ignition arc for producing an output signal of a duration equal to the time between each one of said control signals and the next strike of an ignition arc; circuit means including a delay circuit responsive to each of said output signals of said flip-flop circuit for producing a high current ignition coil primary winding energizing circuit dwell signal which begins after the initiation of and terminates after the termination of each one of said output signals of said flip-flop circuit; transistor switch means responsive to each of said dwell signals for completing said high current ignition coil primary winding energizing circuit for the duration thereof; and rectifier means for isolating and high voltage ignition coil secondary winding from said high current ignition coil secondary winding.

10. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which an ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc energy comprising: a high voltage ignition coil having primary and secondary windings of the type in which a high ignition potential of sufficient magnitude to strike an ignition arc is induced in said secondary winding upon the interruption of the flow of energizing current through said primary winding; a high current ignition coil having primary and secondary windings of the type in which a high ignition current is induced in said secondary winding upon the interruption of the flow of energizing current through said primary winding; a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high current ignition coil; means for interrupting and completing said high voltage ignition coil primary winding energizing circuit in timed relationship with said engine; a first trigger circuit responsive to each completion of said high voltage ignition coil primary winding energizing circuit for producing a high current ignition coil primary winding energizing circuit control signal; a flip-flop circuit responsive to each of said high current ignition coil primary winding energizing circuit control signals and to each striking of an ignition arc for producing an output signal of a duration equal to the time between each of said control signals and the next strike of an ignition arc; a second trigger circuit responsive to said output signal of said flipflop circuit for producing a high current ignition coil primary winding energizing circuit dwell signal; a delay circuit connected between said flip-flop circuit and said second trigger circuit for delaying the initiation of said dwell signal until after the initiation of said output signal of said flip-flop circuit and delaying the termination of said dwell signal until after the termination of said output signal of said flip-flop circuit; transistor switch means responsive to each of said dwell signals for completing said high current ignition coil primary winding energizing circuit for the

duration thereof; and rectifier means for isolating said high voltage ignition coil secondary winding from said high current ignition coil secondary winding.

11. A dual action inductive discharge internal combustion engine ignition system for use with an engine having at least one combustion chamber and an ignition arc gap in communication therewith across which an ignition arc is struck to initiate combustion within the chamber and thereafter maintained efficiently at high arc energy comprising: a high voltage ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding an arc-striking potential upon interruption of predetermined primary winding energizing current; a high current ignition coil having a magnetic core and primary and secondary windings, the turns ratio and core size being such as to produce in said secondary winding a potential incapable of striking an arc upon interruption of a predetermined primary current but capable of delivering high arc current after the arc is struck, a high voltage ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high voltage ignition coil; a high current ignition coil primary winding energizing circuit through which energizing current flows through said primary winding of said high current ignition coil; means for completing said high voltage ignition coil primary winding energizing circuit and for abruptly interrupting the same in timed relationship with said engine at the instant when the arc is to be struck; circuit means responsive to the completion of said high voltage ignition coil primary winding energizing circuit effective to actuate the high current ignition coil primary winding in an energizing current build-up and to the striking of an ignition arc to abruptly interrupt said energizing current before extinction of the arc created by the high voltage circuit; an ignition distributor having a movable contact; means including at least one rectifier for connecting said high voltage ignition coil secondary winding to said movable contact of said distributor; and means for connecting said high current ignition coil secondary winding to the ignition arc gap so that the high voltage ignition coil and the high current ignition coil primary winding energizing currents, when interrupted in sequence, created and maintain the arc without substantial interaction.

12. In combination, an ignition system comprising a master inductive discharge ignition system including an ignition coil having a primary winding wherein energizing current flow is initiated and thereafter interrupted to establish an ignition arc, a slave inductive discharge ignition system having an energizing circuit and an actuating mechanism for said slave ignition system, said actuating mechanism including means responsive to voltage in one sense at said primary winding of said ignition coil to initiate current flow in said energizing circuit of said slave ignition system and to voltage in the opposite sense at said primary winding of said ignition coil at the instant an ignition arc is struck to interrupt current flow in said energizing circuit of said slave ignition system.

13. In combination, an ignition system comprising a master inductive discharge ignition system including an ignition coil having a primary winding wherein energizing current flow is initiated and thereafter interrupted to establish an ignition arc, a slave inductive discharge ignition system having an energizing circuit and an actuating mechanism for said slave ignition system, said actuating mechanism including means responsive to voltage in one sense at said primary winding of said ignition coil to initiate current flow in said energizing circuit of said slave ignition system and responsive to the high voltage spike in the opposite sense reflected back into said primary winding of said ignition coil at the instant an ignition arc is struck to interrupt current flow in said energizing circuit of said slave ignition system.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 3,919,993

DATED : November 18, 1975

INVENTOR(S) : John G. Neuman

It is certified that error appears in the above-identified patent and that said Letters Patent are hereby corrected as shown below:

Col. 1, line 45, "invnetion" should read -- invention --.
Col. 4, line 20, "resistors" should read -- resistor --.
Col. 6, line 1, "tons," should read -- tions, --;
line 38, "conditons" should read -- conditions --;
line 49, "emiter" should read -- emitter --.
Col. 7, line 21, after "induces" change "a" to -- an --.
Col. 8, line 30, after "which" insert -- in --;
line 32, " "Q" " should read -- "$\overline{Q}$" --;
line 34, " "$\overline{Q}$" " should read -- "Q" --;
line 60, after "signal" insert -- applied --.
Col. 9, line 28, "circiut" should read -- circuit --.
Col. 12, line 13, "cooper" should read -- copper --.
Col. 13, line 48, "delivery" should read -- delivering --;
line 59, "cirucit" should read -- circuit --.
Col. 14, line 38, after "circuit;" insert -- and --.
Col. 17, line 11, after "strike" change "as" to -- an --.
Col. 18, line 20, after "isolating" change "and" to -- said --;
line 58, "flipflop" should read -- flip-flop --.
Col. 20, line 7, "created" should read -- create --.

Signed and Sealed this

second Day of *March 1976*

[SEAL]

Attest:

RUTH C. MASON
Attesting Officer

C. MARSHALL DANN
Commissioner of Patents and Trademarks