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Schweitzer et al.

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[54] **CONTROLLED VARIABLE SPARK CAPACITOR DISCHARGE IGNITION SYSTEM**

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[52] **U.S. Cl....123/148 E,** 315/209 CD, 315/209 SC, 315/209 T, 315/212, 315/223

[51] **Int. Cl.** **H01t 15/02,** F02p 3/06, F02p 5/04

[58] **Field of Search**..315/209, 223, 209 CD, 209 SC, 315/209 T, 212, 223; 328/58; 123/148, 148 E

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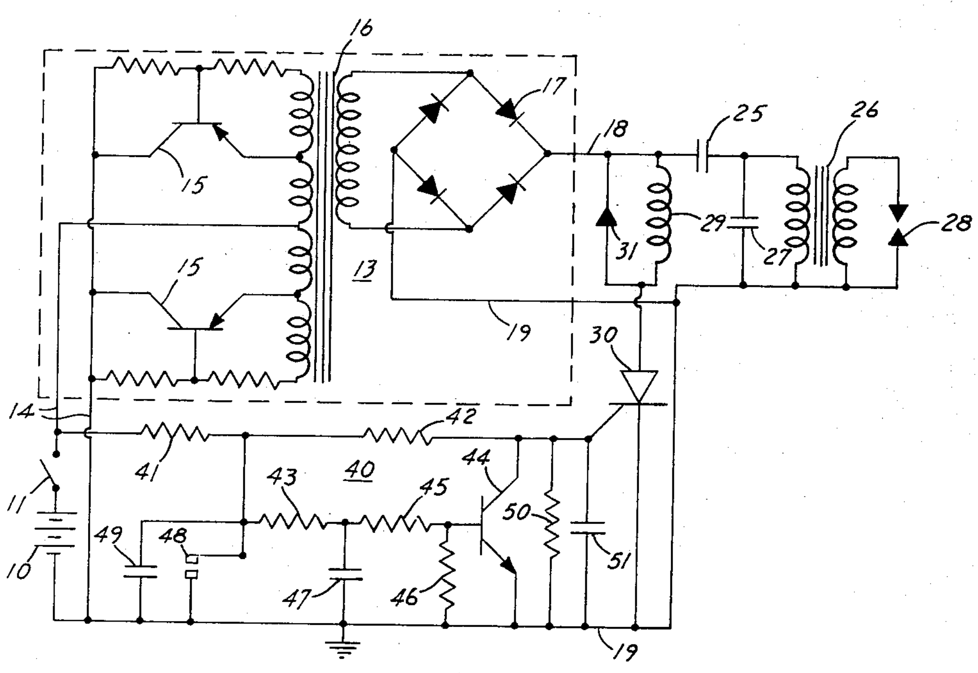
[57] **ABSTRACT**

A capacitor discharge type ignition system is arranged to deliver pulses of energy to the distributor of an engine, thereby to generate ignition sparks. A control circuit is provided for controlling the duration of the energy pulses, and hence the duration of ignition sparks, as a function of selected operating conditions of the ignition system and its associated engine, such as, supply voltage level, operating temperature and engine speed.

16 Claims, 5 Drawing Figures



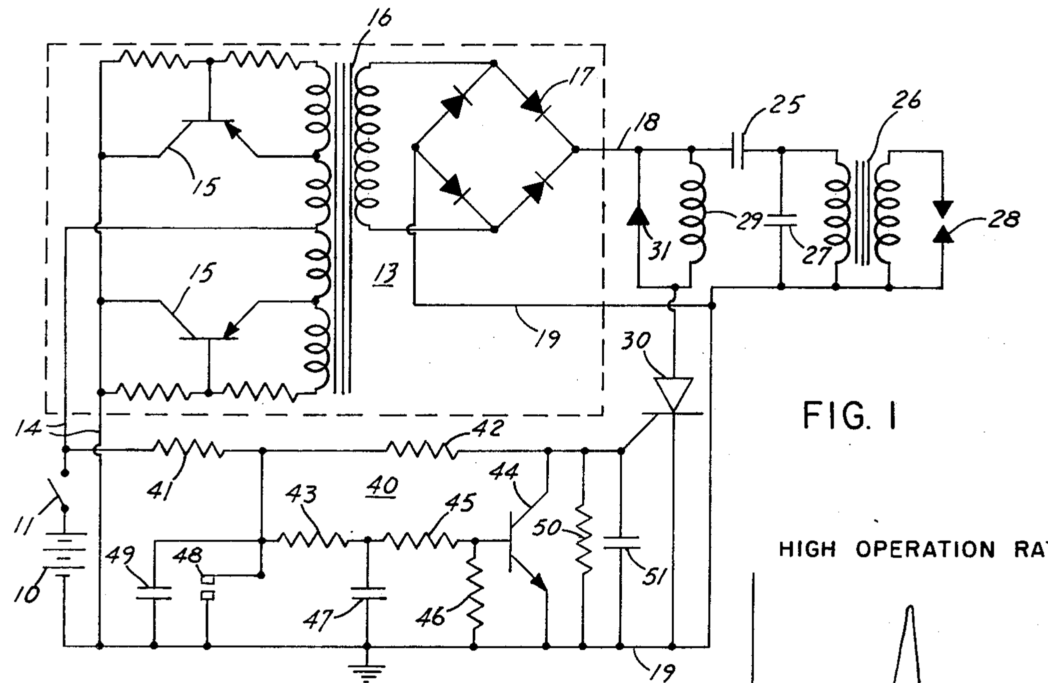


FIG. 1

NORMAL SUPPLY VOLTAGE, TEMPERATURE AND RATE

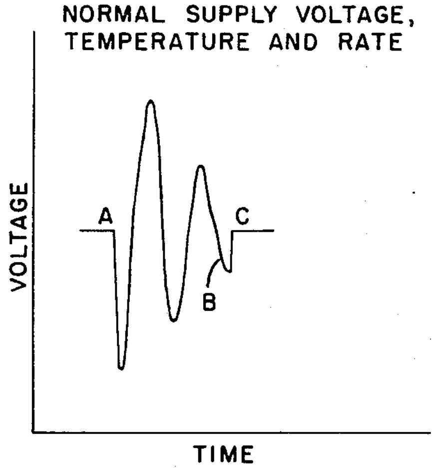


FIG. 2

LOW LEVEL OF SUPPLY VOLTAGE

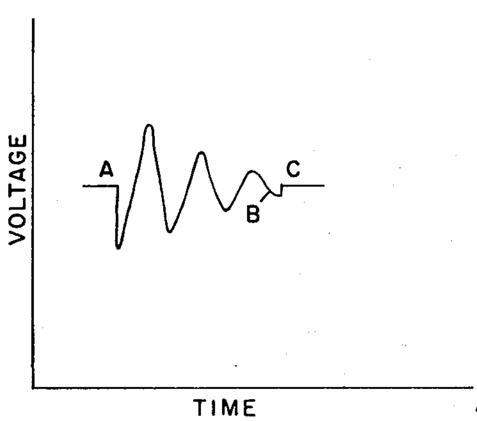


FIG. 3

HIGH OPERATION RATE

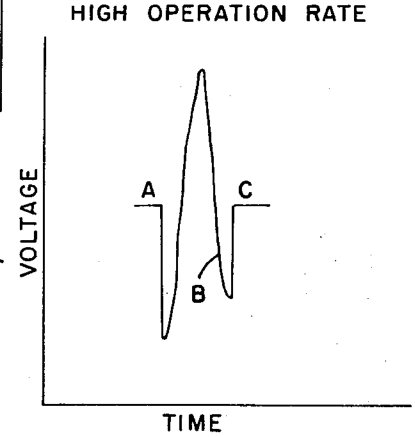


FIG. 4

LOW OPERATING TEMPERATURE

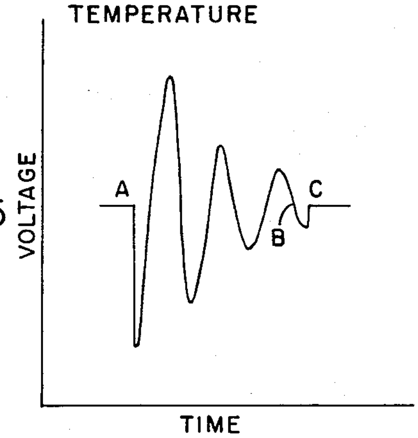


FIG. 5

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CONTROLLED VARIABLE SPARK CAPACITOR DISCHARGE IGNITION SYSTEM

The present invention relates to ignition systems and more particularly to an improved ignition system of the capacitor discharge type suitable for use with engines, such as internal combustion engines, rotating turbine engines and the like, having a source of direct current for energizing same.

Heretofore, engine ignition systems have been developed of the capacitor discharge type and one common use of such ignition systems has been in the automobile. Generally, the operation of these systems is controlled by breaker contacts which are opened and closed in synchronism with the movements of the pistons of an associated engine. Thereby, the discharge of a storage capacitor through the primary of an ignition coil is timed so that ignition sparks are delivered in a timed sequence to ignite combustible fuel which provides the energy to drive the engine. Typically, such ignition circuits have only been capable of generating sparks of substantially uniform durations and an example of such an ignition circuit is shown in U. S. Pat. application, Ser. No. 456,789 filed May 18, 1965, now Pat. No. 3,604,978 which is assigned to the assignee of the present invention.

It has been discovered that a significant disadvantage exists with such prior art ignition systems since they are only capable of generating sparks of uniform duration. This disadvantage is due to the fact that it has been found desirable to control ignition spark duration as a function of the conditions under which the ignition system and its associated engine are operated, thereby to prevent premature ignition and energy waste, reduce wear on the component parts of an ignition system, and improve overall engine efficiency. For example, it has been found desirable to increase spark duration whenever the voltage level of the D.C. source supplying the ignition circuit is low to insure complete combustion of the fuel mixture delivered to drive the engine. Likewise, it has been found desirable to increase spark duration whenever the engine is operated at low temperatures to insure complete fuel combustion. On the other hand, it has not been found necessary, nor desirable, to provide long duration sparks whenever the engine is operating at high speeds or rotation rates since spark energy is thus wasted, the components of the ignition system are unduly stressed and premature ignitions of fuel in the engine cylinders next in the firing sequence are likely to occur.

Another disadvantage frequently found with such prior art ignition systems is that they may be inadvertently triggered to discharge the storage capacitor by bounce of the breaker contacts upon closure. Such inadvertent opening of the breaker contact points, so called contact bounce, is a problem particularly associated with high speed point operation such as occurs during the high speed operation of an automobile engine.

It is accordingly, an object of the present invention to provide an improved engine ignition system which is operable to control ignition spark duration.

It is, further, an object of the present invention to provide an improved engine ignition system which controls ignition spark duration as a function of selected conditions under which the ignition system and its associated engine are operated.

It is, additionally, an object of the present invention to provide an improved engine ignition system of the capacitor discharge which controls ignition spark duration as a function of the voltage level of its associated D.C. source, the speed of its associated engine and operating temperature.

It is also an object of the present invention to provide an improved engine ignition system of the capacitor discharge type which is substantially insensitive to contact bounce thereby to eliminate the inadvertent generation of ignition sparks and prevent misfiring.

In accomplishing these and other objects, there is provided in accordance with the present invention a capacitor discharge ignition system associated with an engine in which a storage capacitor is charged to a relatively high potential by means of a low potential D.C. source and a D.C.—D.C. convertor. Switch means preferably in the form of a silicon controlled rectifier are selectively operated by means of a control circuit to connect the charged storage capacitor across the primary of an ignition coil. Thereby, energy stored in the storage capacitor is delivered to the ignition coil by the ringing action of the L–C circuit formed by the storage capacitor and the ignition coil, and ignition sparks are generated at the spark gaps of a distributor connected across the secondary of the ignition coil. The control circuit which operates the SCR switch means controls the duration of the closure of the switch means as a function of the voltage level of the D.C. source, operating temperature and engine speed, thereby to control ignition spark duration as a function of these variable operating conditions. Breaker contacts or other suitable means are included to operate the control circuit so as to time the closure of the switch means so that the ignition sparks are generated in synchronism with the movement of the engine's cylinders and the control circuit is designed so as to be not responsive to momentary openings of the breaker contact points as caused by contact bounce. Thus, an improved engine ignition system which is operable to control ignition spark duration as a function of selected variable conditions is provided.

A better understanding of the present invention may be had from the following detailed description when read in conjunction with the accompanying drawings, in which:

FIG. 1 is a schematic diagram of an ignition system according to the present invention;

FIG. 2 is a graphical representation of a typical voltage wave form generated across the ignition coil primary of the ignition system of FIG. 1 when the system is operated under supply voltage, temperature and rate conditions considered normal or standard;

FIG. 3 is a graphical representation of a typical voltage wave form generated across the ignition coil primary of the ignition system of FIG. 1 when the system is operated at a relatively low level of supply voltage with temperature and rate conditions normal;

FIG. 4 is a graphical representation of a typical voltage wave form generated across the ignition coil primary of the ignition system of FIG. 1 when the system is operated at a relatively high rate operation will supply voltage and temperature conditions normal;

FIG. 5 is a graphical representation of a typical voltage wave form generated across the ignition coil primary of the ignition system of FIG. 1 when the system is operated at a relatively low temperature with supply voltage and rate conditions normal.

Referring to the drawings in more detail, there is shown in FIG. 1 an engine ignition system including a D.C. voltage source in the form of a battery **10**. The battery **10** is a low potential D.C. source which preferably supplies approximately 12 volts D.C. Connected in series with the battery **10** to its positive pole is an ignition switch **11** for switching the ignition system on and off. A D.C.—D.C. convertor **13** has its input leads **14** connected across the series-connected battery **10** and switch **11** for receiving the voltage from the D.C. source **10**. The circuitry of the convertor **13** is shown enclosed in broken lines and includes a pair of transistors **15** parallel connected across the primary of a voltage step up transformer **16** to receive from the leads **14** the D.C. voltage supplied by the battery **10**. Connected across the secondary of the transformer **16** are the input terminals of a diode bridge **17**. The bridge **17** rectifies the alternating voltage applied to its input terminals by the transformer **16** to generate a high potential D.C. voltage across electrical leads **18** and **19** which are connected to the output terminals of the bridge **17**. The leads **18** and **19** are connected, respectively, to the positive and negative terminals of the bridge **17**. The D.C.—D.C. convertor **13** functions to convert the 12 volts D.C. received from the battery **10** into a high potential D.C. voltage of approximately 400 volts. It is noted that the construction of the convertor **13** is conventional and that a detailed discussion of its operation may be found in the article, "A New Ignition System for Cars," by R. Van Houten and John C. Schweitzer in the Oct. 5, 1964, edition of the magazine ELECTRONICS.

Connected to the lead **18** is one terminal of a storage capacitor **25**. Connected between the other terminal of the capacitor **25** and the lead **19** is the primary winding of an ignition coil or output transformer **26**. A shunting capacitor **27** is connected in parallel with the primary of the ignition coil **26** to shunt and thereby substantially eliminate the effects of any electromagnetic interference on the output generated by the ignition coil **26**. Connected across the secondary winding of the ignition coil **26** is a standard distributor and spark plugs represented by a single spark gap **28**. The distributor and spark plugs represented by the gap **28** are conventional in operation and may be operated by a mechanical drive arrangement coupled to the drive shaft of a conventional engine (not shown) which is associated with the exemplary ignition system. Thereby, potentials developed by the ignition coil **26** are delivered or distributed in a timed sequence in a well known and conventional manner to the spark gaps **28** of the spark plugs associated with the cylinders or combustion chambers of the conventional engine and ignition sparks are generated which ignite combustible fuel delivered to the engine cylinders to drive the engine. It is noted that the engine driven by the exemplary ignition circuit may be of any type which is driven by spark ignition, such as, internal combustion engines, rotating turbine engines and the like.

Connected between the leads **18** and **19** is a choke coil **29** connected in series with the anode-cathode path of conduction of a SCR **30**. The coil **29** has one terminal connected to the lead **18** and its other terminal connected to the anode electrode of the SCR **30**. The cathode electrode of SCR **30** is connected to the lead **19**. A diode **31** is connected in parallel with the coil **29** with the cathode electrode of the diode **31** connected to the lead **18** and its anode electrode connected to the point of common connection of the coil **29** and SCR **30**. The SCR **30** functions as a selectively operable switch means which when closed connects the storage capacitor **25** across the primary of the ignition coil **26**. Thereby, as is hereafter explained, the energy stored in the capacitor **25** is delivered to the ignition coil **26** so that an ignition spark is generated at the spark gap **28**. The parallel-connected diode **31** and choke **29** function to control current through the SCR **30** when it is conducting, i.e., when the switch means is closed, thereby to control the current rise through the SCR to increase the reliability of the ignition circuit.

In order to control the operation of the switch means provided by the SCR **30**, a control circuit **40** is provided which is connected to the gate electrode of the SCR **30** for closing the switch means provided by the SCR **30** by gating it into conduction. The control circuit **40** includes resistors **41, 42** and **43** which are each commonly connected at one of their terminals. The other terminals of the resistors **41, 42** and **43** are connected, respectively, to the switch **11**, the collector electrode of an NPN transistor **44** and one terminal of a resistor **45**. The other terminal of the resistor **45** is connected to the base electrode of the transsistor **44**. The emitter electrode of the transistor **44** is connected to the lead **19** and the lead **19** provides a bus of reference potential since it is connected as a return lead from the negative output of the bridge **17** to the negative pole of the battery **10**. Connected between the lead **19** and the base electrode of the transistor **44** is a resistor **46**, and a capacitor **47** is connected from the common point of connection of resistors **43, 45** to the lead **19**.

To initiate the operation of the control circuit **40** breaker points or contacts **48** are included therein connected between the common point of connection of the resistors **41–43** and the lead **19**. The breaker points **48** are conventional in construction and are operated by a mechanical arrangement or gearing (not shown) which is coupled to the drive shaft of the engine associated with the ignition system. Thereby, a series of time signals or conditions is produced which is in synchronism with the movement of the pistons in the associated engine. Although the exemplary circuit is illustrated as using breaker points as the timing means for synchronizing the operation of the control circuit **40** with engine movement, it is apparent that other means and methods may be used with equal success, such as devices which utilize magnetic, photoelectrical or Hall effect characteristics to sense the appropriate moments for firing and developing a control signal suitable for controlling the ignition system of the present invention. Connected across the breaker points **48** for developing a voltage when the points **48** are open is a points capacitor **49**.

The control circuit **40**, as is hereinafter explained, functions to generate a switch control signal the duration of which is a function of the voltage level of the battery **10**, the rate the points **48** are opened and closed, and the operating temperature of the circuitry and engine. To sense operating temperature, the transistor **44** is selected to be temperature sensitive so that its forward bias point or voltage is inversely proportional to temperature, e.g., as the temperature decreases the forward bias voltage increases. The control signal of the control circuit **40** is generated as an output across a load resistor **50** which is connected between the collector electrode of the transistor **44** and the return lead **19**. The terminal of the resistor **50** in common with the collector electrode of the transistor **44** is connected to the gate electrode of the SCR **30** so that the switch control signal developed on the load resistor **50** is applied thereto. A capacitor **51** is connected in parallel with the resistor **50** for shunting electromagnetic interference so as to eliminate such interference from the control signal applied to the gate of the SCR **30**.

During operation of the exemplary ignition system, the ignition switch **11** is closed so that low potential D.C. voltage is supplied from the battery **10** to the convertor **13** and the control circuit **40**. The D.C.—D.C. convertor **13** operates to charge the storage capacitor **25** to a high potential D.C. voltage. With the supply voltage provided by the battery **10** at its normal or standard level 12 volts, the convertor operates to charge the storage capacitor **25** to approximately 400 volts D.C. when the switch means provided by the SCR **30** is closed.

With the storage capacitor **25** charged, the breaker points **48** are opened in synchronism with engine movement. Upon the opening of the points **48**, the current flow through the resistor **41** which had been flowing through the closed contacts **48** rapidly charges the points capacitor **49** and the charged capacitor **49** establishes a current flow through the resistors **42** and **43**. The current through the resistor **42** also flows through the load resistor **50**, thereby a control voltage sufficient to bias the SCR **30** into conduction is applied to the SCR gate electrode.

With the SCR **30** conducting, the series-connected SCR **30** and choke **29** places substantially a short circuit across the leads **18** and **19**. Thereby, the energy represented by the D.C. voltage across the output terminals of the bridge **17** is dissipated and absorbed by the transformer **16** and a short is reflected into the primary of the transformer **16**. The reflected short removes the driving signal from the inverter oscillator formed by the transistors **15** and transformer **16** so as to stop the operation of the convertor **13**. The conduction of the SCR **30** also causes a closed L–C circuit to be formed made up of the charged storage capacitor **25**, the primary of the ignition coil **26**, the SCR **30**, and the parallel-connected diode **31** and choke **29**. The storage capacitor **25** thus discharges through the primary of the coil **26** so that an ignition spark is generated by the energy delivered to the coil **26** across the spark gap **28**, and the choke **29** and diode **31** function to control SCR current and the voltage rise across the ignition coil primary.

It is noted that with SCR **30** switched on or conducting that a resonant circuit is formed between the primary of the ignition coil **26** and the storage capacitor **25**. Thus, the L–C circuit formed will ring or resonant at its resonant frequency which is determined by the values of capacitance and inductance of the capacitor **25** and the primary of the coil **26**, respectively. The L–C circuit formed continues to resonant as long as the SCR **30** is forward biased by the control signal applied to its gate electrode. Once the forward bias is removed from the SCR gate electrode, current will continue to flow in the circuit until the current through the SCR **30** drops below its regenerative or holding level. Once the SCR current drops below its regenerative level, it ceases to conduct since a control voltage sufficient to bias it into conduction is no longer applied to the SCR gate electroce. For further discussion of the operation of an L–C circuit having a SCR connected therein as a switch means, refer to assignee's earlier mentioned U.S. Pat. Application, Ser. No. 456,789, filed May 18, 1965.

The number of cycles the L–C circuit formed by the storage capacitor **15** and the ignition coil primary resonates or rings is determined by the time interval which the SCR **30** conducts. Likewise this time interval of SCR conduction determines the duration of the energy pulses supplied to the distributor **28** by the coil **26** and hence ignition spark durations. The control circuit **40** determines the time interval the SCR **30** is gated on by means of an R–C timing circuit formed by resistors **43, 45** and **46** and the capacitor **47**. As above-mentioned, the charged points capacitor **49** causes a current to flow through the resistor **43**. The current flow in the resistor **43** in turn progressively charges the capacitor **47**, thereby inducing a rising current in the resistors **45** and **46**. The resistors **45** and **46** function as a voltage divider for applying a bias voltage to the base electrode of the transistor **44** which functions as a control electrode and once a predetermined current level is induced in the resistors **45** and **46**, a bias voltage sufficient to turn on or bias into conduction the transistor **44** is generated across the resistor **46**. Once the transistor **44** conducts, a substantial portion of the current through the load resistor **50** is shunted to the return lead **19** through the collector-emitter path of the transistor **44**. Thereby, the switch control voltage generated on the load resistor **50** and applied to the SCR gate electrode decreases from its first level which was sufficient to forward bias the SCR **30** to a second lower level which is not sufficient to forward bias the SCR **30**. As before-mentioned, the SCR **30** then continues to conduct until the current level therethrough drops below the SCR's regenerative level at which time the SCR **30** turns off and ceases to conduct. Once the SCR **30** no longer conducts, the convertor **30** recommences operation and recharges the storage capacitor **25**.

Subsequent to the switching off of the switching means provided by the SCR **30**, the breaker contacts **48** are closed by engine movement. Upon closure of the points **48**, the capacitor **49** discharges through the closed points **48** and the capacitor **47** discharges through the current paths provided by the resistor **43**, points **48** and resistors **45, 46**. After the points **48** have been closed for a sufficient time interval, the current through the resistor **46** drops below the level required to generate a voltage sufficient to forward bias the transistor **44**. The transistor **44** thus turns off so as to allow subsequent retriggering of the SCR **40** at the next opening of the breaker points **48**. It is noted that the SCR **30** will not be triggered into conduction by brief openings of the contacts **48** caused by contact bounce since the capacitor **47** provides a filtering effect. The capacitor **47** along with its associated resistors provides a time constant such that the points **48** must be closed for a sufficient time to discharge the capacitor **47** below the voltage required to turn on the transistor **44**, i.e., the capacitor **47** must be discharged to the level at which transistor **44** becomes non-conductive before the current in the resistors **42** and **50** will be sufficient to forward bias the SCR **30**. Thus, if the transistor **44** is not turned off, the SCR **30** will not conduct even if the points **48** are opened so that the ignition circuit is substantially insensitive to contact bounce. It should also be noted that capacitor **47** provides speed limiting of a motor. At low RPM, capacitor **47** discharges completely through resistor **43**. At high speeds, capacitor **47** does not have sufficient time to completely discharge while points **48** are closed and by proper selection of the value of capacitor **47** the upper limit of the speed of a motor may be established above which capacitor **47** will not be permitted to discharge sufficiently to allow transistor **44** to become non-conductive and permit the SCR to be triggered into conduction. As one example, component values were selected to prevent conduction of the SCR at engine speeds above 8000 RPM to prevent damage to the engine.

As before mentioned, the control circuit **40** operates to control the time the SCR **30** is gated on as a function of the level of voltage of the battery **10**, the rate the breaker contacts **48** are opened and closed, and the operating temperature of the ignition circuit and its associated engine. Thereby, the durations of the ignition sparks generated across the spark gaps **28** are controlled as a function of supply voltage level, engine speed and operating temperature. In order to explain the manner in which the control circuit **40** functions to control spark duration, reference is made to the graphs of FIGS. **2–5** in which the points designated A, B and C indicate, respectively, the instants when the SCR **30** is gated on, gated off and ceases to conduct.

Referring to FIG. **2**, the graph there shown illustrates a typical wave form generated as a function of time across the primary of the ignition coil **26** with supply voltage, temperature and rate conditions normal or standard. A normal supply voltage is considered to be a voltage level of approximately **6** or **12** volts as supplied by the battery **10** to the control circuit **40** and the convertor **13**. A normal operating temperature is considered to be the ambient temperature at which the ignition system is designed to operate. A normal rate is considered to be the rate at which the breaker contacts **48** are opening and closing as a result of engine movement when the engine is not being driven excessively fast. Under these normal conditions, the SCR **30** is biased into conduction at point A by opening of the contacts **48**. The capacitor **25** and ignition coil **26** then resonate to generate a spark discharge across the gap **28** and the values of the circuit components making up the control circuit **40** are appropriately selected so that under such normal conditions the transistor **44** is turned on, and thus the SCR gate electrode is biased off, at the point designed B in FIG. **2**. The SCR **30** continues to conduct until the point designated C at which instant the SCR current falls below the regenerative level. Thus, a spark duration equal to approximately two complete cycles of the resonant L–C circuit is generated across the spark gap **28** under normal supply voltage, temperature and rate conditions.

If the level of voltage supplied by the battery **10** decreases, the filter capacitor **25** will not be charged to as high a voltage level and consequently a longer spark duration is necessary to generate an ignition spark across the spark gap **28** having approximately the same amount of energy as a spark generated by the voltage wave form of FIG. **2**. The control circuit **40** generates an ignition spark of longer duration, as shown in FIG. **3**, since if the supply voltage is decreased, the current supplied through the resistor **43** to the capacitor **47** is correspondingly decreased. Thus, the capacitor **47** is charged more slowly with the result that SCR **30** is forwarded biased for a longer time since it takes a longer time interval for the current flowing from the capacitor **47** through the resistor **46** to reach the level necessary to bias the transistor **44** into conduction. As shown in FIG. **3**, the voltage wave form across the primary of the ignition coil **26** has a smaller amplitude than that of FIG. **2** since the capacitor **25** is initially charged to a lower voltage due to the decreased voltage level supplied by the battery **10**. As shown in FIG. **3**, the transistor **44** is turned on to shunt the SCR gate electrode at the point designated B so that the L–C circuit generates an ignition spark of substantially three complete cycles of resonance as measured between points A and C in response to the voltage wave form of FIG. **3**.

In the case where the engine associated with the ignition system is operated at an extremely high rate, the rate the points **48** are opened and closed is correspondingly increased. As a result of the rapid operation of the points **48**, a higher than normal residual charge remains on the capacitor **47** due to the time constant provided by the values of the resistors **43**, **45** and **46** and the capacitor **47**. This increased residual charge results in a decreased time interval from the opening of the points **48** to the turning on of the transistor **44**. Thus, the transistor **44** is turned on to shunt the SCR gate electrode at the point designated B in FIG. **4** so that an ignition spark having a duration of substantially only one complete cycle of the L–C circuit is generated in response to the voltage wave form of FIG. **4**. Such a shorter spark duration is desirable since at high point operation rates long duration sparks waste energy, unduly stress ignition components and may prematurely fire the spark plugs of succeeding engine cylinders.

The graph shown in FIG. **5** illustrates the effect of low temperature on the ignition system. As the temperature is decreased, the forward bias point of the transistor **44**, i.e., the voltage level necessary to be applied to the transistor's base electrode to turn the transistor on, increase. As a result of this voltage increase as a function of temperature decrease, the capacitor **47** must be charged to a higher level to turn on the transistor **44**. Consequently, the SCR **20** is gated on for a longer interval so that a longer duration spark is generated which corresponds to the voltage wave form of FIG. **5**. The wave form of FIG. **5** has a duration of substantially three cycles of resonance of the L–C circuit and it is desirable at low temperatures to generate long duration sparks since more energy is necessary to efficiently ignite and combust cold fuel.

It is noted that the relative effects of variations in supply voltage levels, temperature and rates of point operation may be varied and set as desired by the appropriate selection of the values of circuit components. While above the situations were discussed where only one of the variable conditions varied from the normal, it is noted that the voltage level, temperature and rate of point operation could all vary from the normal simultaneously and that depending on the specific conditions, ignitions sparks having durations of approximately ½ cycle, 1 cycle, 1 ½ cycles, 2 cycles, 2 ½ cycles, 3 cycles, etc., could be generated as appropriate by the exemplary ignition circuit. It further noted that various equivalent switching devices could be used for the SCR **30** and the transistor **44**, e.g., an SCR could be used for the transistor **44**. It should also be noted that a gating diode and resistors may be employed such that the charge and discharge times at capacitor **47** can be independently controlled.

Thus, there has been provided an improved ignition system which is operable to control ignition spark duration as a function of selected variable conditions. The ignition system is associated with a conventional engine of the type driven by ignition sparks and the spark durations are controlled as a function of engine speed as represented by the rate of breaker point operation, operating temperature as measured by a temperature sensitive switch means provided by a transistor and supply voltage level. An SCR switching means is provided for controlling the generation of ignition sparks which is operated by a control circuit in an extremely stable and reliable manner. Additionally, capacitors are connected across the ignition coil primary and the output of the control circuit to shunt and dissipate high frequency interference so as to prevent inadvertent generation of ignition sparks and insure stable operation of the SCR switch means, respectively.

While there have been described what is considered to be the preferred embodiment of the present invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the spirit and scope of the present invention.

What is claimed is:

1. An ignition system for delivering pulses of energy of controlled durations to distributor means of an engine of the type having combustion chambers with a spark plug associated with each of said combustion chambers so that ignition sparks of controlled durations are generated across the spark gaps of said spark plugs to ignite combustible fuel delivered to said combustion chambers; said ignition system comprising:

a storage capacitor;

a charging circuit having input and output terminals, said charging circuit having its output terminals connected across said storage capacitor and being operable to charge said storage capacitor to a high potential D.C. voltage when a low potential D.C. voltage source is connected to its input terminals;

an ignition coil having primary and secondary windings, said ignition coil having its secondary winding connected to said distributor means;

timing means for generating a series of time signals corresponding to the movements of said engine;

control circuit means responsive to each of said time signals for generating a switch control signal, said control circuit means being operable to sense the level of D.C. voltage supplied to the input terminals of said charging circuit and generate switch control signals having durations which are a function of the level of said D.C. voltage supplied; and

switch means responsive to each of said switch control signals for connecting said storage capacitor in closed circuit with the primary winding of said ignition coil during a time interval substantially equal to the duration of said switch control signal whereby an L-C circuit is formed by said storage capacitor and the primary winding of said ignition coil which resonates during the time interval said storage capacitor and said primary winding are connected in closed circuit so that a pulse of energy of controlled duration is delivered by the secondary winding of said ignition coil to said distributor means to generate an ignition spark of corresponding duration.

2. The invention recited in claim **1**, wherein said control circuit means is responsive to the rate at which said time signals are generated to generate switch control signals having durations which are also a function of the speed of said engine as measured by the rate at which said time signals are generated.

3. An ignition system for delivering pulses of energy of controlled durations to distributor means of an engine of the type having combustion chambers with a spark plug associated with each of said combustion chambers so that ignition sparks of controlled durations are generated across the spark gaps of said spark plugs to ignite combustible fuel delivered to said combustion chambers, said ignition system comprising:

a storage capacitor;

a charging circuit having input and output terminals, said charging circuit having its output terminals connected across said storage capacitor and being operable to charge said storage capacitor to a high potential D.C. voltage when a low potential D.C. voltage source is connected to its input terminals;

an ignition coil having primary and secondary windings, said ignition coil having its secondary winding connected to said distributor means;

a silicon controlled rectifier having anode, cathode and gate electrodes;

electrical leads connecting said storage capacitor, the primary winding of said ignition coil, and the anode-cathode path of said silicon controlled rectifier in a closed circuit so that said silicon controlled rectifier functions as a switch for controlling the operation of the L–C circuit formed by said storage capacitor and said primary winding;

breaker contact means associated with said engine for opening and closing in synchronism with the movements of said engine so as to generate a series of time signals corresponding to the time interval said contact means are open;

control circuit means responsive to each of said time signals for generating a control signal having a duration which is a function of the level of D.C. voltage supplied to the input terminals of said charging circuit, operating temperature and engine speed as represented by the rate at which said time signals are generated by said contact means, said control circuit means being connected to the gate electrode of said silicon controlled rectifier to supply said control signals generated thereto to bias said silicon controlled rectifier into conduction whereby the L-C circuit formed by said storage capacitor and the primary winding of said ignition coil resonates during the time interval said silicon controlled rectifier conducts so that a pulse of energy of controlled duration is delivered by the secondary winding of said ignition coil to said distributor means to generate an ignition spark of corresponding duration.

4. The invention recited in claim **3** including a load resistor in said control circuit means connected to the gate electrode of said silicon controlled rectifier and wherein said control circuit means is operable to generate said control signals applied to said gate electrode across said load resistor and said control circuit means includes:

switch means having a control electrode to which is applied a turn on voltage to bias said switch means into conduction, said switch means being temperature sensitive so that its turn on voltage varies as a function of temperature, said switch means being connected across said load resistor to shunt said load resistor whenever said switch means conducts; and

an R–C circuit means having terminals for connection to the same D.C. voltage source connected to the input terminals of said charging circuit whereby to sense and be driven by said same D.C. source, said R–C circuit means being connected to the control electrode of said switch means to supply bias voltage thereto, said R–C circuit means being operable to generate a bias voltage the magnitude of which increases at a rate directly proportional to the voltage level of said same D.C. source connected thereto for biasing said switch means into conduction whenever said bias voltage equals the turn on voltage of said switch means, said R–C circuit means being connected to said contact means for discharge of its capacitive portion through said contact means upon contact closure so that the residual charge remaining on said capacitive portion when said contact means reopens is a function of engine speed as represented by the rate said contact means are opened and closed.

5. The invention recited in claim **4** wherein said switch means is a transistor having its collector and emitter electrodes connected across said load resistor and its base electrode is said control electrode.

6. The invention recited in claim **5** wherein a parallel-connected choke coil and diode are connected in series with the anode-cathode path of said silicon controlled electrode to control the rate of current flow therethrough.

7. The invention recited in claim **6** including capacitive means for shunting electromagnetic interference are connected across the primary winding of said ignition coil and across said load resistor to enhance the reliability of said ignition system.

8. The invention recited in claim **7** wherein:

said charging circuit is a D.C.—D.C. convertor which includes a voltage transformer; and

said silicon controlled rectifier is connected to short the secondary winding of said voltage transformer to stop the operation of said charging circuit whenever said silicon controlled rectifier is conducting.

9. In a capacitor discharge type engine ignition system for delivering pulses of energy to the distributor means of a combustion engine wherein a storage capacitor is charged to a high potential by power supplied from a low potential D.C. source and first switch means are selectively operated to connect said storage capacitor in closed circuit with the primary of an ignition coil to form an L–C circuit so that said L–C circuit resonates to generate an ignition spark of duration corresponding to the interval of resonance across a spark gap connected by said distributor means across the secondary winding of said ignition coil, the improvement of:

breaker contact means associated with said engine for opening and closing in synchronism with the movements of said engine so as to generate a series of time signals corresponding to the time intervals said contact means are open;

circuit means responsive to said time signals and connected to said first switch means for generating first switch control signals during said time intervals and applying said first switch control signals to said first switch means to operate said first switch means;

second selectively operable switch means connected to shunt said first switch control signals away from said first switch means whenever said second switch means is conducting; and

R–C circuit means connected to said breaker contact means and said second switch means for generating second switch control signals during said time intervals to control the operation of said second switch means so that the operation of said first switch means is controlled by said second switch means and is substantially unaffected by any contact bounce of said breaker contact means.

10. An ignition system for delivering pulses of energy of controlled durations to distributor means of an engine of the type having combustion chambers with a spark plug associated with each of said combustion chambers so that ignition sparks of controlled durations are generated across the spark gaps of said spark plugs to ignite combustible fuel delivered to said combustion chambers; said ignition system comprising:

a storage capacitor;

a charging circuit having input and output terminals, said charging circuit having its output terminals connected across said storage capacitor and being operable to charge said storage capacitor to a high potential D.C. voltage when a low potential D.C. voltage source is connected to its input terminals;

an ignition coil having primary and secondary windings, said ignition coil having its secondary winding connected to said distributor means;

timing means for generating a series of time signals corresponding to the movements of said engine;

control circuit means responsive to each of said time signals for generating a switch control signal, said control circuit means being operable to sense the level of D.C. voltage supplied to the input terminals of said charging circuit and generate switch control signals having durations which are an inverse function of the level of said D.C. voltage supplied; and

switch means responsive to each of said switch control signals for connecting said storage capacitor in closed circuit with the primary winding of said ignition coil during a time interval substantially equal to the duration of said switch control signal whereby an L–C circuit is formed by said storage capacitor and the primary winding of said ignition coil which resonates during the time interval said storage capacitor and said primary winding are connected in closed circuit so that a pulse of energy of controlled duration is delivered by the secondary winding of said ignition coil to said distributor means to generate an ignition spark of corresponding duration.

11. An ignition system for delivering pulses of energy of controlled durations to distributor means of an engine of the type having combustion chambers with a spark plug associated with each of said combustion chambers so that ignition sparks of controlled durations are generated across the spark gaps of said spark plugs to ignite combustible fuel delivered to said combustion chambers; said ignition system comprising:

a storage capacitor;

a charging circuit having input and output terminals, said charging circuit having its output terminals connected across said storage capacitor and being operable to charge said storage capacitor to a high potential D.C. voltage when a low potential D.C. voltage source is connected to its input terminals;

an ignition coil having primary and secondary windings, said ignition coil having its secondary winding connected to said distributor means;

timing means for generating a series of time signals corresponding to the movements of said engine;

control circuit means responsive to each of said time signals for generating a switch control signal, said control circuit means being operable to sense engine operating temperature and generate switch control signals having durations which are an inverse function of said operating temperature sensed; and

switch means responsive to each of said switch control signals for connecting said storage capacitor in closed circuit with the primary winding of said ignition coil during a time interval substantially equal to the duration of said switch control signal whereby an L-C circuit is formed by said storage capacitor and the primary winding of said ignition coil which resonates during the time interval said storage capacitor and said primary winding are connected in closed circuit so that a pulse of energy of controlled duration is delivered by the secondary winding of said ignition coil to said distributor means to generate an ignition spark of corresponding duration.

12. An ignition system for delivering pulses of energy of controlled durations to distributor means of an engine of the type having combustion chambers with a spark plug associated with each of said combustion chambers so that ignition sparks of controlled durations are generated across the spark gaps of said spark plugs to ignite combustible fuel delivered to said combustion chambers; said ignition system comprising;

a storage capacitor;

a charging circuit having input and output terminals, said charging circuit having its output terminals connected across said storage capacitor and being operable to charge said storage capacitor to a high potential D.C. voltage when a low potential D.C. voltage source is connected to its input terminals;

an ignition coil having primary and secondary windings, said ignition coil having its secondary winding connected to said distributor means;

timing means for generating a series of time signals corresponding to the movements of said engine;

control circuit means responsive to each of said time signals for generating a switch control signal, said control circuit means including means for sensing engine operating temperature and being operable to generate switch control signals having durations which are a function of said engine operating temperature sensed; and

switch means responsive to each of said switch control signals for connecting said storage capacitor in closed circuit with the primary winding of said ignition coil during a time interval substantially equal to the duration of said switch control signal whereby an L-C circuit is formed by said storage capacitor and the primary winding of said ignition coil which resonates during the time interval said storage capacitor and said primary winding are connected in closed circuit so that a pulse of energy of controlled duration is delivered by the secondary winding of said ignition coil to said distributor means to generate an ignition spark of corresponding duration.

13. The invention recited in claim **12** wherein said means for sensing engine operating temperature is a temperature sensitive transistor.

14. An ignition system for delivering pulses of energy of controlled durations to distributor means of an engine of the type having combustion chambers with a spark plug associated with each of said combustion chambers so that ignition sparks of controlled durations are generated across the spark gaps of said spark plugs to ignite combustible fuel delivered to said combustion chambers; said ignition system comprising:

a storage capacitor;

a charging circuit having input and output terminals, said charging circuit having its output terminals connected across said storage capacitor and being operable to charge said storage capacitor to a high potential D.C. voltage when a low potential D.C. voltage source is connected to its input terminals;

an ignition coil having primary and secondary windings, said ignition coil having its secondary winding connected to said distributor means;

timing means for generating a series of time signals corresponding to the movements of said engine;

control circuit means responsive to each of said time signals for generating a switch control signal, said control circuit means being operable to sense the level of D.C. voltage supplied to the input terminals of said charging circuit and the engine operating temperature and generate switch control signals having durations which are inversely proportional to each of the variables the level of said D.C. voltage supplied, said engines operating temperature and the speed of said engine as measured by the rate at which said time signals are generated; and switch means responsive to each of said switch control signals for connecting said storage capacitor in closed circuit with the primary winding of said ignition coil during a time interval substantially equal to the duration of said switch control signal whereby an L–C circuit is formed by said storage capacitor and the primary winding of said ignition coil which resonates during the time interval said storage capacitor and said primary winding are connected in closed circuit so that a pulse of energy of controlled duration is delivered by the secondary winding of said ignition coil to said distributor means to generate an ignition spark of corresponding duration.

15. A method of controlling the generation of ignition sparks across a spark gap in the combustion chamber of an engine which comprises:

charging a capacitor from a D.C. voltage source to a voltage proportional to the voltage level of said D.C. voltage source;

selectively commencing the discharge of said capacitor in timed relation with the movement of the engine to generate a series of timed spark across said spark gap;

controlling the length of each time period said capacitor is selectively discharged as a function of the voltage level of said D.C. voltage source, the speed of said engine and the operating temperature of said engine whereby to control the durations of the sparks generated across said spark gap.

16. The method of claim **15** wherein:

said capacitor is charged to a voltage directly proportional to the voltage level of said D.C. voltage source; and

the length of each time period said capacitor is selectively discharged is inversely proportional to each of the variables the voltage level of said D.C. voltage source, the speed of said engine and the operating temperature of said engine.

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