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ELECTRONIC IGNITION SYSTEM
Filed July 15, 1963

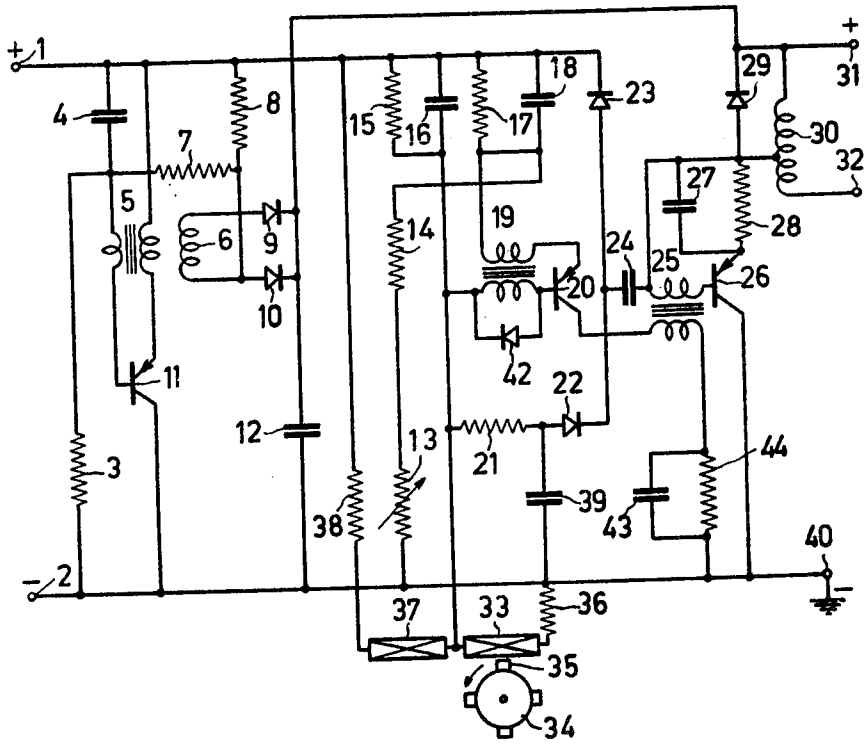


FIG.1

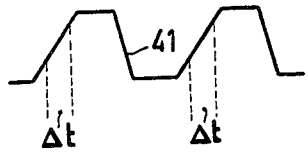


FIG. 2

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ELECTRONIC IGNITION SYSTEM

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This invention relates to electronic ignition systems and more particularly to improvements in transistorized automotive ignition systems.

Transistorized automotive ignition systems are known and may be of two basic types; one in which a single ignition spark is produced, as exemplified by United States Patent No. 2,966,615, issued December 27, 1960, and a second or multi-spark of the type disclosed in United States Patent No. 2,898,392, issued August 4, 1959.

A common shortcoming of transistorized or standard ignition systems is the drop in spark potential encountered in starting the engine when the electrical starting motor puts a heavy current drain on the battery and the fall-off in potential at higher engine speeds when insufficient time is allowed for current build-up in the ignition coil.

In ignition systems using a magnetic induction type trigger of the type shown in U.S. Patent 2,898,392, the initiation of the spark producing oscillator action is dependent on the amplitude of the voltage induced by magnetic induction. This variation in voltage amplitude can be utilized to provide an automatic ignition timing advance in response to engine speed. However, variations in the induction gap may cause erratic timing of the spark discharge in one cylinder relative to the spark discharge of another cylinder in a multi-cylinder engine.

It is, therefore, an object of the present invention to provide an ignition system in which the spark potential does not drop substantially on engine starting.

It is a further object of the invention to provide an induction timing system which is substantially independent of the induction gap.

It is another object of this invention to provide an ignition system producing a spark ignition potential which is substantially constant with speed.

It is another object of the invention to provide an ignition system whose power consumption is low for low speeds thereby producing a more efficient ignition system.

Other objects and advantages of the invention will become apparent as the description proceeds.

In accordance with one embodiment of the present invention, the battery voltage is stepped up from its nominal value of 6 or 12 volts, by means of a converter, to a value of approximately 50 volts which is applied to the transistorized ignition system per se.

A further feature of the invention resides in the application of a high voltage pulse to the primary of the ignition transformer to produce a high ignition voltage in the secondary of this transformer. The application of this high voltage pulse obviates the necessity for establishing a current in the primary of the ignition transformer and abruptly interrupting it to produce the ignition pulse voltage, as is done in standard ignition systems.

The ignition system preferably comprises a mono-stable oscillator controlled by a Hall effect transducer. The timing of the monostable oscillator pusle is advanced with engine speed and retarded by accelerator pedal depression. The output of the oscillator is supplied to a normally non-conducting power transistor which is switched on to produce a high voltage output pulse. This output pulse is applied to the primary of the ignition transformer resulting in an ignition spark discharge in the appropriate

spark plug which is then connected in series with the secondary of the ignition transformer.

The invention will now be described with reference to the accompanying drawing in which:

FIGURE 1 is a schematic circuit diagram of the portion of the ignition system with which the present invention is concerned, and,

FIGURE 2 is a waveform of the triggering voltage used to initiate the spark discharge.

Referring now to the drawing, terminals **1, 2** represent the positive and negative terminals, respectively, of the automobile storage battery having a potential of, for instance, 12 volts. A first transistor **11** has its base electrode regeneratively connected to its emitter electrode by means of the windings of a transformer **5**. Base bias is supplied thereto by means of a bleeder network composed of resistors **3, 7, 8** and stabilized by a capacitor **4**. The transistor circuit is self-oscillating and a tertiary winding **6** on the core of transformer **5** supplies the oscillations, produced by transistor **11**, to a rectifier system including diodes **9, 10** and storage capacitor **12**. A cross capacitor **12** a direct current voltage of approximately 50 volts is produced with terminal **31** positive with respect to grounded terminal **40**. Capacitor **12** should have sufficient capacity to maintain the potential for several spark discharges when no further charge is being supplied thereto by the converter; a condition which may exist during electrical cranking of the engine.

Referring now to transistor **20**, the mono-stable oscillator, a positive potential with respect to terminal **40** is supplied to the emitter. This potential is determined by resistance dividing network **13, 14, 17** and the potential between terminals **1** and **2**. The value of this potential is dependent on the setting of resistance **13** which is controlled by the accelerator pedal so as to provide a less positive potential at the emitter of transistor **20** when the pedal is depressed. The voltage at the base electrode of transistor **20** is determined initially by resistances **15, 36, 38** and the resistance value of Hall effect semi-conductors **33, 37**, and has a value such that transistor **20** is normally in a cutoff condition. Capacitor **16** acts as a pulse voltage bypass. Diode **42** ensures that transistor **20** and its associated circuitry produces only a single pulse, the return pulse being clamped out by the diode so that blocking oscillation does not take place. Resistors **15** and **17** and diode **23** are connected to termial **1** so that when the ignition switch is off there is no voltage applied to transistor **20** and therefore spurious pulses are not produced. In addition, the current drain on capacitor **12** is eliminated when the engine is stopped.

The collector electrode of transistor **20** is connected through the primary winding of a transformer **25** and the parallel network composed of capacitor **43** and resistor **44** to terminal **40**. Resistor **44**, bypassed by capacitor **43**, is designed to limit the standing current of transistor **20** to a suitable value. A positive voltage substantially equal to the supply voltage, i.e. 50 volts, is supplied to the base electrode of transistor **26** through the secondary winding of transformer **25** and a portion of an inductance coil **30**. The collector electrode of transistor **26** is connected to grounded terminal **40**. The emitter electrode of transistor **26** is connected to the positive terminal **31** through the parallel circuit composed of resistor **28** and capacitor **27** and the coil **30** in series therewith. Terminals **31, 32** are adapted to be connected to the terminals of the primary winding of the standard ignition coil of the engine. Due to the fact that the base electrode of transistor **26** is substantially at the potential of the emitter, the transistor **26** is normally in cutoff condition.

Diode **29** acts as a damping diode for transformers **25, 30** respectively. Diode **22** rectifies the initial pulse volt-

age appearing in transformer 30 to charge capacitor 39 in a negative direction. This voltage effects the bias of transistor 20, as will be explained subsequently.

The operation of the ignition circuit will now be described. Application of the 12 volts battery voltage to terminals 1 and 2 by means of the ignition switch causes transistor 11 to produce oscillations which are rectified by diodes 9, 10 to produce a voltage of, for instance, 50 volts across capacitor 12 with the polarity as illustrated. Since a converter power supply is used, the system may be adapted for a wide range of storage battery voltages by making changes in the converter circuit only. The ignition circuit is then standard for all types of storage battery.

Referring now to the ignition circuit per se, transistor 20 is provided with an emitter voltage somewhat negative with respect to the positive terminal of the 12 volt supply. The actual voltage thereof is determined by the setting of variable resistor 13 controlled by the accelerator pedal to provide a voltage which changes in a negative direction when the accelerator pedal is depressed. The base electrode bias of transistor 20 is initially determined by resistors 15, 36, 38 and Hall effect semi-conductors 33, 37 and is designed so that the transistor is normally cut-off when no magnetic bias is applied to the semi-conductor elements 33, 37. A rotating disc 34 is provided with permanent magnet members 35 which, when the disc rotates, each successively applies a moving field to element 33 and then element 37 so that the base electrode voltage of transistor 20 first is moved positive, due to the increased resistance of element 33, and then negative due to the subsequent increase of the resistance of element 37, the resistance of element 33 having returned to normal. It is thus seen that the magnets 35 of rotating disc 34 intermittently apply a magnetic field to the Hall-effect devices 33 and 37. Since the network formed by resistors 15, 36, 38 and elements 33, 37 is chosen such that transistor 20 is normally cut-off, the differences in the gaps between the elements and individual magnets 35 will not affect the timing of the ignition pulses since the elements will be equally affected by the gaps. In the interest of clarity, the schematic diagram shows elements 33, 37 as being spaced apart. However, in actual physical location, they will be immediately adjacent to each other. The increase of the resistance of element 37 is designed to be sufficient to reduce the base bias of transistor 20 to the point where regenerative current conduction will take place due to the voltage feedback supplied by transformer 19.

The regeneratively produced collector current which flows in transistor 20 produces a voltage pulse in transformer 25 which is supplied as a negative pulse to the base electrode of normally cut-off power transistor 26 to suddenly render it heavily conducting. An emitter current, in the order of amps, flows in transistor 26 since the full voltage of the power supply appears across the transistor and the portion of the winding of transformer 30 in series therewith. A stepped-up voltage, of, for instance, 200 volts, appears between terminals 31, 32 and is applied to the primary of the ignition transformer to produce the high secondary voltage necessary for ignition.

Although the embodiment of the invention described envisages coil 30 as a separate element which applies a high voltage to the standard ignition transformer primary, it is equally possible that coil 30 be the ignition transformer itself which, if this is the case, and as will be obvious, must be designed for this application. Due to the fact that the voltage is suddenly applied to the ignition coil primary, time for current build-up is sufficiently short so that it does not become a factor at higher engine r.p.m.'s.

The pulse of voltage produced across the portion of transformer 30 is applied through capacitor 24 to diode 22 to produce a voltage on capacitor 39 which is negative with respect to terminal 40. This voltage increases negatively with pulse frequency, i.e. engine r.p.m., since capacitor 39 is large as compared to capacitor 24. The circuit acts as an automatic ignition advance since it reduces the positive bias on the base electrode of transistor 20. The incorporation of this circuit obviates the use of a centrifugal ignition advance system.

In FIGURE 2, waveform 41 illustrates the change of resistance of element 33 and similarly the waveform of voltage applied to the base electrode of transistor 20. The dotted lines show the range of variation of the base current cut-off point of this transistor due to the variation of the voltage supplied by diode 22 and capacitor 39 with engine r.p.m. change.

By properly contouring the pole faces of magnets 35, a further automatic ignition advance with increase of r.p.m. can be provided to offset the effect of the accelerator pedal control of variable resistor 13 such that the initial depressing of the accelerator retards the ignition pulse but when the engine r.p.m. has increased to normal, the retardation is cancelled by the advance provided by the pole face contour. The number of pole faces required is dependent on the number of cylinders of the engine and the relative speed of revolution of disc 34 with respect to the engine crankshaft, as is well known.

If desired, a bistable transistorized multivibrator circuit or other suitable pulse producing source may replace the monostable-oscillator comprising transistor 20, or a mechanical timing system, i.e. breaker points, may be used in conjunction with transformer 25 and a source of voltage.

Although a preferred embodiment of my invention has been described, modifications thereof may be made by those skilled in the art which do not depart from the spirit and scope of this invention, as defined by the appended claims.

What is claimed is:

1. An ignition system for an internal combustion engine, comprising a source of electric energy, a semiconductor device having a main current path and a control electrode for controlling the current flow therein, a transformer having a primary winding and a secondary winding for producing an ignition pulse, means connecting said primary winding to said main current path of said semiconductor device and to said electric energy source, a source of control voltage operatively associated with said engine so as to produce a voltage which varies in timed relation with said engine, said voltage source comprising variable impedance means in which the impedance varies in synchronism with the engine to produce a predetermined variation in voltage amplitude over an engine cycle which is substantially independent of engine speed, and means connecting said voltage source to said control electrode so as to switch said semiconductor main path to a low impedance condition whereby substantially the full voltage of said electric energy source is applied to the primary winding to produce said ignition pulse in said secondary winding.

2. Apparatus as described in claim 1 wherein said variable impedance means comprises a semiconductor Hall-effect device and means operable in timed relation with the engine for selectively applying a magnetic field to said Hall-effect device.

3. Apparatus as described in claim 2 wherein said control voltage source further comprises a trigger circuit responsive to a change of voltage produced by said Hall-effect device to produce a control pulse, and means for supplying said control pulse to the control electrode of said semiconductor device, said semiconductor device further comprising means for biasing said semiconductor device so as to prevent current flow in said main current path in the absence of said control pulse at the control electrode thereof.

4. Apparatus as described in claim 3 wherein said semiconductor device includes an output circuit and said trigger circuit includes an input circuit, said apparatus further

comprising automatic ignition advance means, said ignition advance means comprising a feedback circuit interconnecting said output circuit and said input circuit whereby a portion of said ignition pulse is coupled to the input circuit of said trigger circuit so as to vary the instant at which said control pulse is produced in an engine cycle, said control voltage source being operable to vary the frequency of the control pulses produced as a function of the engine speed.

5. An ignition system for an internal combustion engine comprising a pair of input terminals for a source of voltage of a given amplitude, means connected to said input terminals for converting said given voltage to a second voltage of higher amplitude, a semiconductor device having a main current path and a control electrode for controlling the current flow therein, a transformer having a primary winding and a secondary winding for producing an ignition pulse, means connecting said primary winding and said main current path in series circuit across the output of said converting means, a pulse generating circuit connected to said input terminals comprising variable impedance means in which the impedance varies in synchronism with the engine, said impedance means having a given range of impedance variations over an engine cycle which is substantially independent of engine speed, means for biasing said semiconductor device so as to prevent current flow in said main current path, and means for coupling the pulses produced in said pulse generating means to said control electrode so as to switch said semiconductor main path to a low impedance condition thereby to initiate current flow therein and in said primary winding to produce said ignition pulse in said secondary winding.

6. Apparatus as described in claim 5 wherein said variable impedance means comprises first and second serially connected semiconductor Hall-effect devices connected to said input terminals and means for sequentially applying a magnetic field to said Hall-effect devices whereby a voltage change is produced across each of said Hall-effect devices for controlling the operation of said pulse generating means.

7. An ignition system for an internal combustion engine comprising a source of electric energy, a semiconductor device having a main current path and a control electrode for controlling the current flow therein, a transformer having a primary winding and a secondary winding for producing an ignition pulse, means connecting said primary winding to said main current path of said semiconductor device and to said electric energy source, means for applying a bias voltage to said semiconductor device of a magnitude to prevent the flow of current in said main current path, a trigger circuit operable in timed relation with said engine and coupled to said control electrode for supplying thereto a control pulse to switch said main current path to a low impedance condition thereby to apply substantially the full voltage of said energy source to said primary winding to produce said ignition pulse in said secondary winding, and ignition timing means coupled to said trigger circuit for controlling the operation thereof, said timing means comprising a bridge circuit having first and second semiconductor Hall-effect devices in first and second arms thereof, respectively, said first and second Hall-effect devices being positioned adjacent each other, means for applying a voltage to the input of said bridge circuit, means for sequentially applying a moving magnetic field to said first and second Hall-effect devices which alternately unbalances the bridge circuit in one direction and then the other to produce a voltage change at the output of the bridge circuit, and means coupling the output of said bridge circuit to the input of said trigger circuit.

8. Apparatus as described in claim 7 wherein said trigger circuit comprises a transistor having an emitter and a collector, and means adapted to be controlled by the engine throttle setting for varying the collector to emitter voltage of said transistor inversely with respect to said engine throttle setting.

9. Apparatus as described in claim 7 further comprising a second transformer having a primary and a secondary winding, means connecting said second transformer secondary winding in the control electrode circuit of said semiconductor device, and means connecting said second transformer primary winding to the output of said trigger circuit whereby said trigger circuit periodically supplies a current pulse to said second transformer primary winding.

10. Apparatus as described in claim 9 wherein said trigger circuit comprises a transistor having base, emitter and collector electrodes, means connecting the emitter-collector circuit of said transistor to said second transformer primary winding, means for applying a bias voltage between said base and emitter electrodes of a magnitude and polarity to prevent current flow in said emitter-collector circuit, means for regeneratively coupling said emitter-collector circuit to the base circuit of said transistor, and means coupling the emitter-base circuit of said transistor to the output of said bridge circuit, whereby the effective base voltage is increased and then decreased in response to the unbalance of said bridge circuit to produce a current pulse in the emitter-collector circuit of said transistor.

11. Apparatus as described in claim 7 wherein said trigger circuit comprises a transistor having a control electrode, and an ignition advance circuit comprising means for coupling a portion of the ignition pulse produced in the output circuit of said semiconductor device to the control electrode of said transistor in a sense which tends to cut off said transistor.

12. Apparatus as described in claim 11 wherein said coupling means comprises a diode and a storage capacitor connected in series circuit whereby said capacitor stores an electric charge proportional to the frequency of the ignition pulses, and means for applying the voltage of said capacitor to the control electrode of said transistor in a sense to provide an automatic ignition advance with increased engine speed.

13. An ignition system for an internal combustion engine comprising a source of electric energy, a semiconductor device having a main current path and a control electrode for controlling the current flow therein, a transformer having a primary winding and a secondary winding for producing an ignition pulse, means connecting said primary winding to said main current path of said semiconductor device and to said electric energy source, pulse generating means coupled to said control electrode for initiating and interrupting current flow in said main current path of said semiconductor device, and ignition timing means driven by said engine in timed relation therewith and coupled to said pulse generating means to control the production of pulses therein, said timing means comprising a control circuit including output means coupled to said pulse generating means and first and second semiconductor Hall-effect devices connected across a source of voltage, and means driven by said engine for sequentially passing a magnetic field across said first and second Hall-effect devices thereby to alter current flow therein and produce a varying voltage at said output means.

14. Apparatus as described in claim 13 wherein the frequency of the pulses produced by said pulse generating means is a function of engine speed, said apparatus further comprising means for providing automatic ignition advance with increased engine speed, said ignition advance means comprising integrating means coupled to the input of said pulse generating means to control the instant at which said pulses are produced in an engine cycle, and means for coupling a portion of the produced ignition pulse to said integrating means whereby said integrating means produces a voltage which varies with the pulse frequency.

15. Apparatus as described in claim 14 further comprising an adjustable resistor connected across a source of voltage, said adjustable resistor being adapted to vary its resistance in response to the setting of the engine throttle, and means connecting said adjustable resistor to supply a varying voltage to said pulse generating means in a sense to oppose the integrated voltage supplied by said integrating means.

16. An ignition system for an internal combustion engine comprising a source of electric energy, a semiconductor device having an output circuit and an input circuit for controlling current flow therein, a transformer having a primary winding and a secondary winding for producing an ignition pulse, means connecting said primary winding in said output circuit and to said energy source, means connected to said input circuit for applying a bias voltage to said semiconductor device to prevent current flow therein, a pulse generating circuit coupled to said semiconductor device input circuit for controlling conduction in said semiconductor device, said pulse generating circuit comprising ignition timing means operable in timed relation with said engine to cause said pulse generating circuit to produce a sequence of electrical pulses having a frequency which is a function of engine speed, said ignition timing means comprising a circuit having first and second series connected semiconductor Hall-effect devices positioned adjacent each other, means for applying a voltage to said first and second Hall-effect devices, means driven by said engine for alternately passing a magnetic field across said first and second Hall-effect devices thereby to alter the current flow therein and produce a varying voltage at an intermediate point of said circuit, and means for coupling

the varying voltage at said intermediate point to said pulse generating circuit to control the production of pulses therein.

17. An ignition system for an internal combustion engine comprising pulse generating means, a timing circuit for controlling the operation of said pulse generating means comprising a semiconductor Hall-effect device connected across a source of voltage and means operable in timed relation with the engine for selectively applying a magnetic field to said Hall-effect device to produce a varying voltage of constant amplitude at the output of said timing circuit, said pulse generating means being responsive to said varying voltage to produce a sequence of electrical pulses having a frequency which is a function of engine speed, a semiconductor device having a main current path and a control electrode for controlling the current flow therein, a transformer having a primary winding and a secondary winding for producing an ignition pulse, means connecting said primary winding to said main current path of said semiconductor device, and means for coupling the output of said pulse generating means to said control electrode so as to switch said semiconductor main path to a low impedance condition at the occurrence of each electrical pulse thereby to produce said ignition pulse in said secondary winding.

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