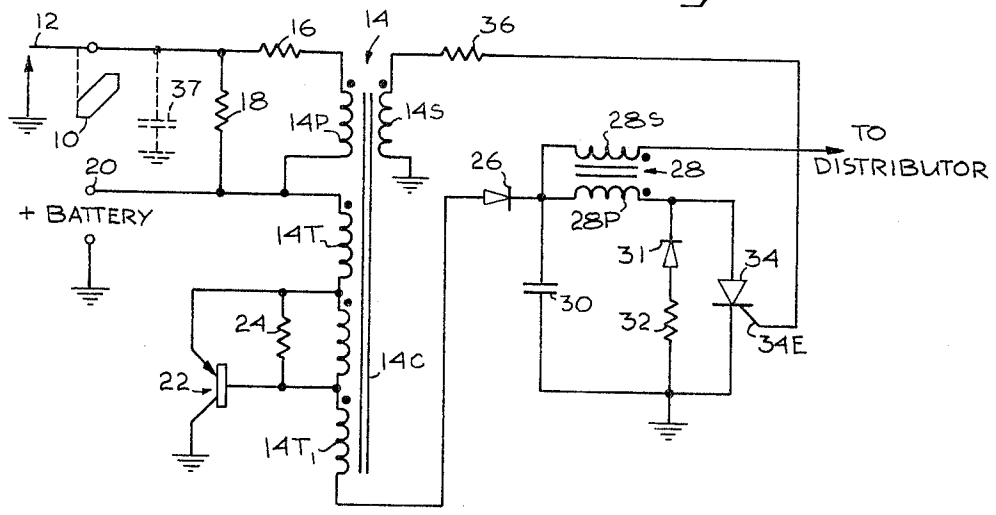
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INTERNAL COMBUSTION ENGINE IGNITION SYSTEM

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*Fig. 1*



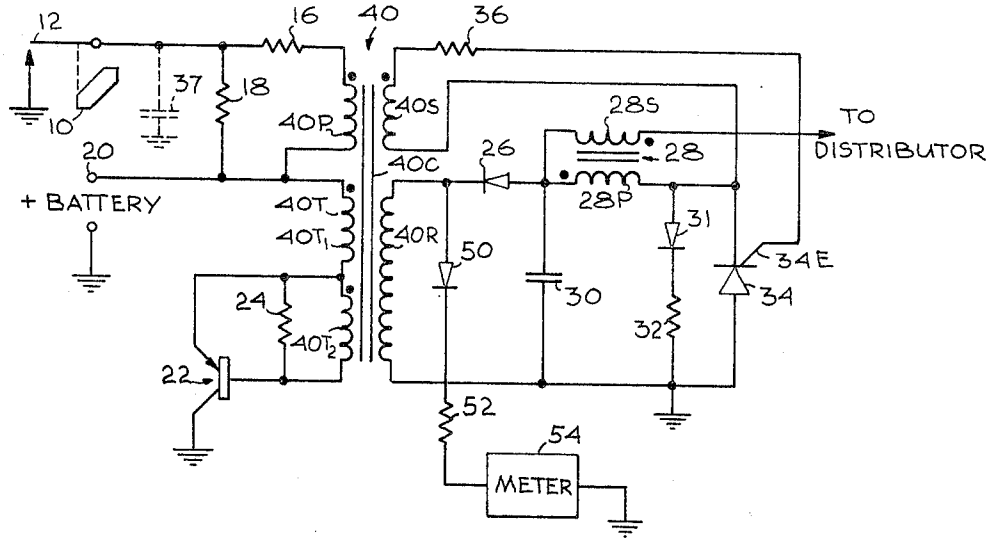




*Fig. 2*

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# INTERNAL COMBUSTION ENGINE IGNITION SYSTEM

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This invention relates to internal combustion engine ignition systems and more particularly to an improved electronic ignition system.

It has been found that in the usual ignition system of the type wherein current through the primary winding of the transformer is interrupted and the interrupted current pulses in the secondary winding are then distributed to spark plugs, as the engine speed increases the voltage supplied to each spark plug for causing discharge thereof begins to drop off. Furthermore, because of the current carrying requirements for the points or contacts used in the ignition system, these contacts wear out and must be periodically replaced, together with the spark plugs. By using electronic means for obtaining and maintaining the voltage delivered to the spark plugs constant, regardless of the speed of the motor, it has been found that not only is there an improvement in performance of the engine, but also the points and spark plugs need not be replaced nearly as often as they did before.

Accordingly, an object of this invention is the provision of a novel and unique electronic circuit arrangement for the ignition system of an internal combustion engine.

Yet another object of the present invention is the provision of a circuit arrangement for an automobile ignition system which can improve the operating characteristics of the internal combustion engine.

Still another object of the present invention is the provision of a circuit arrangement for an ignition system using all solid state components.

These and other objects of the present invention may be achieved in an arrangement wherein the breaker points, normally associated with an internal combustion engine, are connected in series with a transformer primary winding to cause current flow therethrough when they are closed. Also wound on the core of this transformer are other windings. A transistor is connected to two other windings to establish therewith a blocking oscillator. Still another of these windings is connected to a network which includes a capacitor which is connected in series with a silicon controlled rectifier. This series circuit is connected across the primary winding of a step-up transformer. The secondary winding of this step-up transformer is connected to the distributor points of the internal combustion engine.

Whenever the breaker points close, current flows through the primary winding of the first transformer, establishing a relatively weak magnetic field in the transformer core material. Nothing happens, however, until the breaker points open at which time the collapsing magnetic field induces a voltage of proper polarity to cause the blocking oscillator transistor and silicon controlled rectifier to become conductive simultaneously. Rendering the silicon controlled rectifier conductive causes the discharge of the capacitor through the primary winding of the step-up transformer generating a voltage at the secondary of the step-up transformer of sufficient magnitude to cause the energy previously stored in the capacitor to be dissipated as a spark in the gap of a spark plug. After discharging the capacitor the silicon controlled rectifier returns to its nonconducting state.

Meanwhile, the action of the blocking oscillator causes the supply battery voltage to be continually applied to one of the primary windings of the first transformer,



causing an increasing amount of energy to be stored in the magnetic field in the transformer core material. The energy storing process continues past the time at which the spark voltage is supplied by the step-up transformer and the silicon controlled rectifier again becomes nonconductive up until the time at which the magnetic core of the first transformer saturates and the coupling between the two transformer windings associated with the blocking oscillator drops sufficiently to terminate the blocking cycle. As the magnetic field established as a result of the action of the blocking oscillator collapses, a current is caused to flow into the capacitor charging it up until its electrostatic field contains essentially that energy previously stored in the magnetic field of the first transformer. The capacitor retains this charge until the silicon controlled rectifier is rendered operative by the subsequent closing, then opening, of the breaker points.

The system may be made to operate in much the same way by reversing the polarity of the winding on the first transformer which recharges the capacitor such that at the beginning of the blocking oscillator cycle a current of the proper direction is immediately available to recharge the capacitor. Proper functioning then requires that the silicon controlled rectifier be capable of returning to its nonconducting state during the short time in which it is reverse biased because of the oscillation resulting from the operation of the step-up transformer in obtaining the spark. Operation in the first mentioned manner is preferred because of the less stringent requirements placed upon the silicon controlled rectifier, particularly regarding its ability to turn off rapidly.

The novel features that are considered characteristic of this invention are set forth with particularity in the appended claims. The invention itself, both as to its organization and method of operation as well as additional objects and advantages thereof, will best be understood from the following description when read in connection with the accompanying drawings, in which:

FIGURE 1 is a circuit diagram of an embodiment of the invention.

FIGURE 2 is a circuit diagram of an alternative arrangement of the invention which is preferred.

Referring now to FIGURE 1, the usual ignition system of an internal combustion engine has a rotating cam **10**, which is driven by the engine. This cam causes the breaker points **12** to open and close in well known fashion when it is desired to produce a voltage for application to the spark plugs of the engine. In accordance with this invention, a transformer **14** is provided having a primary winding **14P**, a secondary winding **14S**, and a tapped tertiary winding **14T**, all wound on the same core **14C**. The breaker points **12** are connected through a first resistor **16** to one end of the primary winding **14P**. The usual battery is connected through a terminal **20** to the other end of the primary winding **14P** and also to one end of the tapped tertiary winding **14T**. A second resistor **18** connects from between the breaker points **12** and the resistor **16** to the battery terminal **20**.

A transistor **22** has its emitter connected to one tap of the transformer winding **14T** and its base connected to a second tap of the transformer winding **14T**. Its collector is connected to ground. It will be recognized that the transistor **22** and tertiary winding **14T** are connected to form a blocking oscillator. A resistor **24** is connected between the base and emitter of transistor **22**.

The end of the tertiary winding **14T** not connected to the battery is connected to a diode **26**. The diode **26** has its cathode connected to one end of both the primary winding **28P** and secondary winding **28S** of the main or step-up transformer **28** of the ignition system. A capacitor **30** is connected between said one end of the primary winding **28P** and ground. Another diode

31 which is connected in series with a damping resistor 32 is connected between the other end of the primary winding 28P and ground. A silicon controlled rectifier 34 has its anode connected to said other end of the primary winding 28P and its cathode connected to ground. The control electrode 34E of the silicon controlled rectifier is connected through a resistor 36 to one end of the secondary winding 14S. The other end of the secondary winding 14S is connected to ground. The other end of the secondary winding 28S is connected to the usual distributor for the internal combustion engine ignition system.

In operation, assume that the breaker points 12 close. This causes a current flow from the battery through the primary winding 14P. Although a voltage is induced in the secondary winding 14S, this has no effect on the silicon controlled rectifier since the polarity of this voltage is opposite to that required to render the silicon controlled rectifier conductive. The transistor 22 is biased by current flow through the winding 14T to be nonconductive. It remains nonconductive even though there is a current flow through the primary winding 14P. However, as soon as the breaker points open, the collapsing magnetic field in the core 14C induces a voltage in the winding 14S of a proper polarity to render the silicon controlled rectifier conductive. This causes a discharge of the capacitor 30 through the primary winding 28P. The voltage to charge capacitor 30 is obtained in a manner to be described.

The interruption of flow through the primary winding 14P also results in inducing a voltage in winding 14T having a polarity to render transistor 22 conductive. This has the effect of inducing a voltage in the turns of the tertiary winding 14T whereby the voltage potential between the base and emitter increases in typical blocking oscillator fashion whereby transistor 22 is shortly driven into saturation. The turns ratio of the tapped tertiary windings are selected such that a voltage on the order of 400 volts is established by the blocking oscillator across the step-up portion $14T_1$ of the winding which is connected between the base of the transistor 22 and the diode 26. However, the diode 26 is poled to prevent any current flow when the blocking oscillator transistor is operative. At the termination of the operation of the blocking oscillator, as a result of the collapse of the magnetic flux in the transformer core 14C, a reverse voltage of proper polarity is established across the winding $14T_1$ with the result that the capacitor 30 can then be charged up through the diode 26.

When the breaker points are next closed, then opened, the resulting voltage applied to the control electrode 34E of the silicon controlled rectifier renders the silicon controlled rectifier 34 conductive for a sufficient interval to enable the capacitor 30 to discharge in a path including the primary winding 28P and the silicon controlled rectifier 34. This induces a voltage in the secondary winding 28S which is applied to whichever one of the spark plugs is connected thereto by the distributor points, not shown. Diode 31 and resistor 32 are used to damp the unwanted oscillation resulting after the operation of the step-up transformer in obtaining the spark. The termination of the operation of the blocking oscillator induces a voltage in the secondary winding 14S which has a polarity to turn off the silicon controlled rectifier, if not already nonconductive. Thus, it will not interfere with the charging up of capacitor 30.

Since the transistor 22 is driven into saturation when operated as a blocking oscillator, the amount of magnetic flux from which a voltage for charging capacitor 30 is derived is always substantially constant. Therefore, the energy available for charging up the capacitor 30 will remain constant. The blocking oscillator is not triggered and also the silicon controlled rectifier is not rendered conductive until after the breaker points open. Therefore, the timing of these operations is fixed and occurs regardless of chatter or other possible defects of the breaker points. Thus the time at which a discharge voltage is applied to the spark plugs may be fixed accurately.

While resistors 18 and 24 shown in the circuit diagram may be omitted, and the system will still operate, their use is preferred. The reason is that the resistor 18 allows a degree of freedom in choosing the level of current flow in the control breaker points. Values of current sufficient to insure reliable firing of the blocking oscillator are typically about a few milliamperes. This level of current may be too small to keep the breaker points from fouling because of the presence of contaminants in the distributor housing, such as dirt, oil, oil vapor, etc. Extra shunt current to flow in these circuits to help keep them clear is thus made available by using the shunt resistor 18, while the operation of the remainder of the circuit is unaffected. The larger current is also sufficient to cause the capacitor, normally found across the breaker points in conventional ignition systems, to charge sufficiently fast upon point opening to leave the operation of the circuit unaffected. This capacitor 37 is represented by dotted lines. Thus with the incorporation of the resistor 18, the capacitor may be left in place if desired, when a conventional ignition system is adapted to the electronic ignition system.

The resistor 24 is used for establishing the point of the firing of the blocking oscillator. The value of the resistor is typically 10 ohms, a value sufficiently large to leave the efficiency of the blocking oscillator essentially unchanged at high current levels or where the transistor is saturated, since under these conditions the input resistance of the transistor base proper, referred to the emitter is low, typically 1 ohm. The operation at low levels (near cutoff) of transistor current is greatly affected. Under cutoff conditions, the input impedance of the base is quite high (much higher than 10 ohms) and the effect of input impedance of the resistor-transistor combination is limited by the value of the resistor 24. This has the effect of "spoiling" the current gain of the transistor at low levels while leaving its current gain at high levels relatively unaffected. The point at which the loop gain of the blocking oscillator is unity and becomes regenerative is determined by the effectiveness of this "spoiling" action and the turns ratio of the emitter to the emitter-base windings on the transformer. Thus the effect of resistor 24 is to make the point of firing the blocking oscillator a function which may be analytically determined and controlled and not an uncontrolled function of temperature, stray capacitances in the transformer, leakage currents, etc.

If a tachometer reading is desired indicative of the speed of operation of the system, then the circuit shown in FIGURE 1 may be employed for this purpose. As each voltage for discharging a spark plug is obtained from the system, a fixed specific charge is required (and supplied by the blocking oscillator) to recharge the capacitor 30 for the next firing. The interval of time between successive passages of this fixed charge into the capacitor is inversely proportional to the spark rate. Therefore, the charge rate (and hence the current) flowing into the capacitor is proporitional to the spark rate and also proportional to the engine speed. By placing a milliammeter in series with the lead applying charging current to the capacitor 30, an accurate tachometer is obtained. This milliammeter may be inserted between the end of the winding $14T_1$ and the diode 26.

FIGURE 2 shows a preferred circuit arrangement for the embodiment of the invention. Effectively identical circuit components are employed except for the transformer to which the blocking oscillator is connected. Accordingly, similar functioning structures will bear the same reference numbers. The transformer 40 has a primary winding 40P to which the resistor 16 is connected and also to which the battery terminal 20 is connected as before. A secondary winding 40S has one end connected through resistor 36 to the control electrode 34E

of the silicon controlled rectifier. The other end of the secondary winding 40S is connected to the cathode of the silicon controlled rectifier 34. A tertiary winding 40T has a first portion $40T_1$ connected between the battery terminal 20 and the emitter of the blocking oscillator transistor 22, and a second portion $40T_2$ connected between the emitter and base of the transistor 22. A step-up winding 40R is separately wound on the core 40C of the transformer for the purpose of having induced therein a voltage which is employed to charge up capacitor 30.

The reason that this circuit arrangement is preferred, is that although its operation is identical with the operation described for FIGURE 1, the capacitor 30 may be charged to a negative voltage with respect to ground with this arrangement. This configuration requires more turns on the secondary winding of the main transformer as compared to the circuit of FIGURE 1. However, the advantage is that the anode of the silicon controlled rectifier is at chassis ground and that fewer turns are required on the secondary 28S of step-up transformer 28 to obtain the same high amplitude negative pulse from the negatively charged capacitor. Further, it is easier to include a "fail safe" electronic tachometer with this system. This can be done by connecting a diode 50 to the junction between the diode 26 and the winding 40R. The diode 50 is connected through a current limiting resistor 52 to a microammeter 54 which is connected to ground. The meter is calibrated to operate as a tachometer. The basis for such tachometer is that since the net flux switched in the transformer 40 for each cycle is constant then the current which is caused to flow in the meter is proportional to the net switched flux and thus to the spark rate. Opening the connection to the meter or shorting the meter will have no effect on the operation of the ignition system.

There has accordingly been described and claimed herein a novel, useful, and improved electronic ignition system for internal combustion engines, whereby better performance is obtained for the engine since the energy for spark plug discharge is electronically determined, after the opening of breaker points, and not as a direct consequence thereof. While the invention is shown using only solid state components, it is within the ability of those skilled in the art to use a gaseous discharge tube, such as a thyratron, instead of a silicon controlled rectifier, and gaseous or vacuum diodes instead of solid state diodes, without departing from the spirit and scope of the invention.

What is claimed is:

1. In an internal combustion engine of the type wherein breaker points are employed for making and breaking a connection to a battery whereby current is made to flow through the primary winding of a step-up transformer and then interrupted, and the secondary winding of the step-up transformer is connected through a distributor to spark plugs, the improvement comprising a transformer having a common core on which there are wound a primary winding, a secondary winding, a tertiary winding including a first winding portion, a second winding portion, and a step-up winding portion, means connecting said primary winding to said battery through said breaker points, a controlled rectifier having a control electrode, a capacitor, means connecting said control electrode to said secondary winding, means connecting said capacitor and controlled rectifier in series and across said step-up transformer primary winding, means connecting said tertiary winding in series with said primary winding of said step-up transformer, means establishing a blocking oscillator including a transistor having a base emitter, and collector electrodes, means connecting said transistor base and emitter respectively to the opposite ends of said second winding, and means connecting said battery across said tertiary winding, said primary winding of said step-up transformer and said controlled rectifier.

2. The improvement recited in claim 1 wherein said means connecting said tertiary winding in series with said primary winding of said step-up transformer includes a diode, said diode being poled to prevent current flow from said tertiary winding during operation of said blocking oscillator to thereby prevent said capacitor from being charged until said blocking oscillator ceases operation.

3. In an internal combustion engine of the type wherein breaker points are employed for making and breaking a connection to a battery whereby current is made to flow through the primary winding of a step-up transformer and then interrupted, and the secondary winding of the step-up transformer is connected through a distributor to spark plugs, the improvement comprising a transformer having a core on which are wound a primary winding, a secondary winding, a tertiary winding including a first portion connected in series with a second portion, and a step-up winding, means connecting said battery through said breaker points to said primary winding, means establishnig a blocking oscillator including a transistor having a base, emitter, and collector electrode, means connecting said emitter and base electrode respectively to opposite ends of said second winding portion, and means connecting said battery between said collector and said first winding portion, a controlled rectifier having a control electrode, means connecting said control electrode to said secondary winding, means connecting said controlled rectifier between one end of the primary winding of said step-up transformer and one side of said step-up winding, means connecting the other side of said step-up winding to the other end of the primary winding of said step-up transformer, a capacitor, and means connecting said capacitor across said step-up winding.

4. The improvement recited in claim 3 wherein said means connecting the other side of said step-up winding to the other end of said primary winding of said step-up transformer includes a diode, said diode being poled to prevent current flow from said step-up winding during operation of said blocking oscillator to thereby prevent said capacitor from being charged until said blocking oscillator ceases operation.

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