

Oct. 4, 1960

B. H. SHORT
IGNITION SYSTEM

2,955,248

Filed July 25, 1957

2 Sheets-Sheet 1

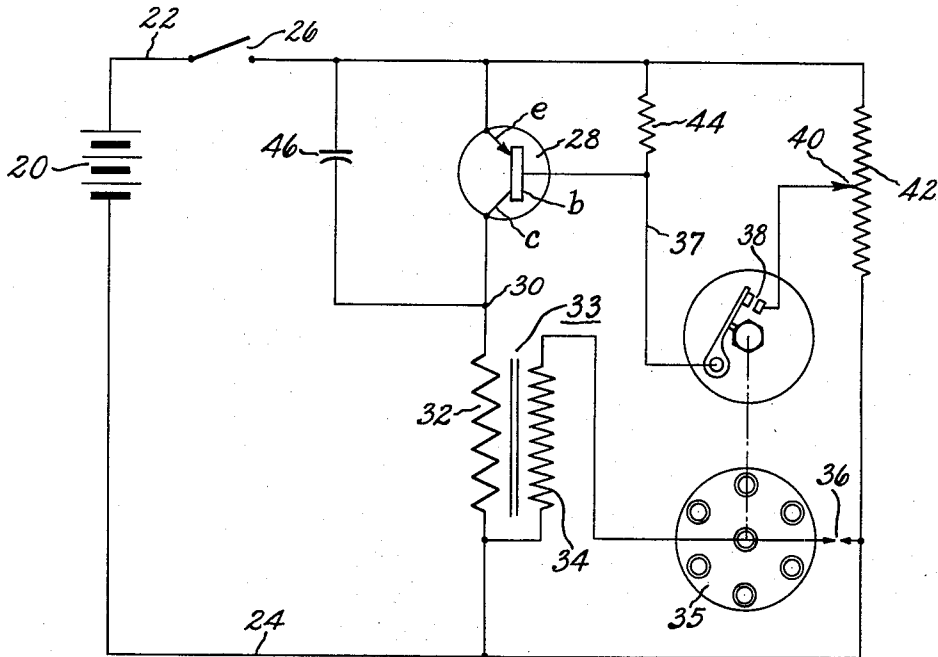


Fig. 1.

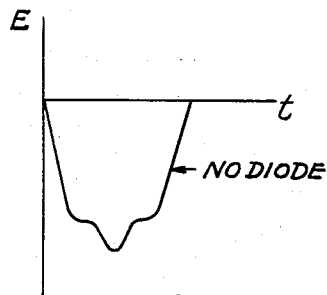


Fig. 2.

INVENTOR.
BROOKS H. SHORT
BY *John D. Mann*
ATTORNEY

Oct. 4, 1960

B. H. SHORT
IGNITION SYSTEM

2,955,248

Filed July 25, 1957

2 Sheets-Sheet 2

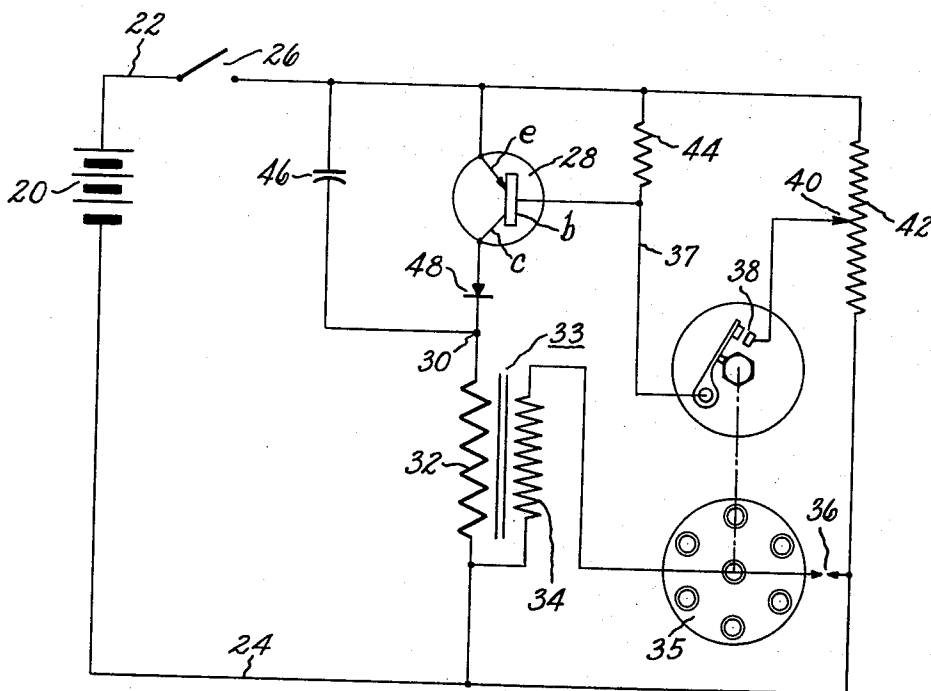


Fig. 3.

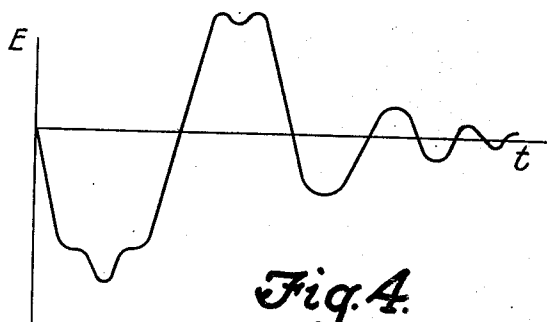


Fig. 4.

INVENTOR.
BROOKS H. SHORT
BY
John T. Mann
ATTORNEY

2,955,248

IGNITION SYSTEM

Brooks H. Short, Anderson, Ind., assignor to General Motors Corporation, Detroit, Mich., a corporation of Delaware

Filed July 25, 1957, Ser. No. 674,126

6 Claims. (Cl. 323-58)

This invention relates to an ignition system for an internal combustion engine and more particularly to an ignition system wherein a transistor controls the charging and discharging of an ignition transformer. This application is a continuation-in-part of my copending application Ser. No. 579,332, filed April 19, 1956.

In present-day ignition systems, the current to the primary winding of the ignition coil passes through a set of mechanically actuated breaker points from a source of D.C. current and voltage, such as a storage battery. The ignition coils used in these systems are a type of pulse transformer and have a primary and secondary coil winding. The flow of current in the primary coil winding will cause energy to be stored in the magnetic system of the coil. It has been found that this stored energy is equal to

$$\frac{Li^2}{2}$$

joules where L is the primary inductance of the coil in henries and i is the current in the primary coil winding in amperes.

When the breaker points of the system separate, this stored energy is quickly released from the magnetic system and charges the capacities of the primary and the secondary systems. The proportion of energy going to each system is determined by the relative capacities and inductances of each.

It is generally known that the value of the primary current when the contact points open decreases with engine speed, as can be determined by the relation

$$i = \frac{E}{R} \left(1 - e^{-\frac{Rt}{L}} \right)$$

where E is the source voltage, R is the total resistance of the primary circuit, L is the primary inductance in henries, $e=2.718$, and t is the time the contact points were closed in seconds. At low speeds, the quantity

$$\left(e^{-\frac{Rt}{L}} \right)$$

is insignificant and the primary current is equal approximately to E/R . It has been found, however, that at top speeds the decrease in t will cause the current in the primary to be decreased to about 50% of the low speed value. Further, it will be seen from the formula that any increase in L will decrease the current at the breaker at high speeds so as to reduce the stored energy input.

From the above it is apparent that since the energy input is

$$\frac{Li^2}{2}$$

an increase in either L or i will result in an increase in the energy stored in the primary winding. An increase in L , however, will result in a decrease in current in the primary circuit at high speed. The current in the present-day ignition systems heretofore has been limited to a value that can be carried by the breaker points without deterioration when the engine is at low speeds. This current is limited to a maximum of about $4\frac{1}{2}$ amperes as it has been found that currents higher than this value would result in breaker point failures.

When the circuit according to the present invention is employed, the current to the primary coil winding may reach the value of 8 to 10 amperes without damage to the components of the system. In fact, the breaker points of the system of my invention will have almost an indefinite life because of the small currents which will pass therethrough. Further, it is apparent that when a current of this magnitude is employed, the inductance of the primary circuit can be reduced to a much lower value than is used in the present-day systems. This, of course, will improve the current at the break at high speeds.

It is also known that the coil output wave front shape is dependent to an extent on the total inductance and capacitance of the primary circuit, and that the wave front becomes steeper as the total inductance or total capacitance of the primary circuit is reduced. A steep output wave front means that less time will be required to raise the secondary voltage to plug firing potential. Because of the short time, any energy loss due to fouled plugs is radically reduced, leaving the greater portion of the available energy for raising the plug to firing potential. This means that fouled spark plugs may be more readily fired.

The above advantages are achieved by controlling the current flow in the primary winding of an ignition coil by a transistor to provide a simple, trouble-free ignition system which will be reliable in its operation. The transistor when used in the ignition system possesses further advantages over devices heretofore used as it conducts at the voltage output of the storage battery and does not require a warm-up time. This latter characteristic of a transistor will make ignition available at the very instant the ignition key is turned on.

It should be noted that by using a transistor the normal battery voltages that are used on present-day internal combustion driven vehicles are sufficient to render the transistor conductive or non-conductive at the proper times. This has a great advantage as the battery voltage need not be stepped up by the use of vibrator power packs and the like in order to operate the transistor. Moreover, the transistor need not be supplied with an energizing voltage for a cathode, or emitting element as the transistor does not employ such an element. In internal combustion driven conveyances, the electrical parts of an ignition system are subjected to vibration by road shock and the like, which is very harmful to many electronic components such as vacuum tubes. The transistor is more reliable in operation as it can withstand the shock forces that are inherent in internal combustion driven vehicles.

It is therefore an object of the present invention to control the current flow in an ignition coil with a transistor, the conduction of which is controlled by a set of mechanically actuated breaker points.

A further object of the present invention is to use a transistor to control the circuit to the primary winding of an ignition transformer.

Another object of the present invention is to control the current flow from the battery to the primary windings of an ignition coil by a transistor that has its collector

3 and emitter directly connected in circuit with the battery and coil winding and has its base in circuit with a pair of timer points which are mechanically actuated.

Still another object of this invention is to provide an ignition circuit wherein an ignition coil winding is connected to a transistor and wherein the transistor controls the current flow to the coil winding, there being a unidirectional current conducting element interposed between the transistor and coil winding to prevent current flow in a direction from the coil winding to the transistor.

A further object of this invention is to provide an ignition control circuit wherein the primary winding of an ignition coil is connected in series with a transistor across a direct current voltage supply and wherein a silicon diode is connected between the transistor and primary winding to prevent current flow from the primary winding to the transistor.

Further objects and advantages of the present invention will be apparent from the following description, reference being had to the accompanying drawings, wherein a preferred embodiment of the present invention is clearly shown.

In the drawings:

Figure 1 is an electric circuit diagram of an ignition system employing a transistor for controlling the current flow to the primary winding of an ignition coil;

Figure 2 is a graphical representation showing the relationship between voltage and time in the secondary coil winding of an ignition coil when the ignition coil is connected in the circuit shown in Fig. 2;

Figure 3 is an improved electric circuit diagram of an ignition system made in accordance with this invention; and

Figure 4 is a graphical representation showing the relationship between time and voltage in the secondary coil winding of an ignition coil when the ignition coil is connected in the circuit shown in Fig. 2.

In the drawings the numeral 20 designates a storage battery which acts as a source of current for an ignition system of an internal combustion engine. The storage battery is of sufficient voltage to operate the electrical devices used on an internal combustion driven vehicle. Thus, for automobile use, the battery preferably is of the standard 6 or 12-volt size. For larger internal combustion driven conveyances such as trucks or buses, the battery may be as large as 32 or 48 volts. The ignition switch 26 is used to make and break the circuit to the ignition system, as will be hereinafter described.

The transistor 28 shown is of the well-known PNP type having a base *b*, a collector *c* and an emitter *e*. The PNP transistor as used in the circuit shown is characterized by the fact that current in the order of 8 to 10 amperes will flow from the emitter *e* to the collector *c* whenever the base *b* is sufficiently negative with respect to the emitter *e* and the emitter *e* is sufficiently positive with respect to the collector *c*. The transistor 28 further will not at any time pass current from the emitter to the collector when the voltage of the emitter is positive with respect to the collector by an amount up to 1,000 volts, if the base is not supplied with current. Another characteristic of the transistor shown is that the current flow between the emitter and collector is a function of the flow of current between the emitter and base which, in turn, is a function of the voltage difference between the emitter and base.

The emitter *e* of transistor 28 is connected to positive lead 22. The collector *c* of the transistor 28 is connected through a junction 30 and the primary coil winding 32 of an ignition transformer 33 to the negative lead 24. A satisfactory ignition transformer may have a primary to secondary turns ratio of 1 to 300. The secondary coil winding 34 supplies the ignition current and power through a distributor 35 to the spark plugs, diagrammatically shown at 36. The coil winding 34 has one end connected to the grounded side of the primary

coil winding 32 and the other end connected through the distributor 35 to the spark plugs 36 in the conventional manner.

The base *b* of transistor 28 is connected by a lead 37 through the breaker points 38 to the tap 40 on the resistance 42. The operation of the breaker points 38 and distributor 35 are so regulated that points 38 open at the optimum instant for engine firing, and the circuit through the distributor 35 to the spark plugs 36 is established simultaneously therewith. The resistor 42 preferably has a value of 16 ohms for a battery voltage of 12 volts and will have a proportionately higher value for higher battery voltages such as 32 or 48 volts. The resistance 42 is connected across leads 22 and 24, and a resistance 44 is connected across leads 22 and 37. The resistor 44 preferably has a value of 50 ohms for a battery voltage of 12 volts and is likewise made proportionately higher in resistance where the voltage is 32 volts or 48 volts. The condenser 46, which is connected between lead 22 and junction 30, minimizes voltage surges across the emitter and collector of transistor 28, and partially controls the wave front. This condenser can be eliminated in some cases, where the inherent capacity of the transistor is sufficient.

When the ignition switch 26 is initially closed, the circuit shown will be immediately energized. When the points 38 are open, the base *b* of transistor 28 will be at the same potential as the emitter *e* because of the resistance 44. The flow of current through resistance 42 will cause tap 40 to be negative relative to lead 22. Thus, when points 38 close, the base *b* of the transistor will become negative relative to the emitter *e*. When the base *b* is negative relative to emitter *e*, the transistor 28 will immediately conduct and pass current to the primary coil winding to build up magnetic flux therein. This flux represents energy that is stored in the ignition coil.

When the breaker points 38 open, the emitter to the base circuit of transistor 28 is broken and the transistor 28 immediately stops conducting current. In this connection, as the collector current in a transistor is much greater than the base current will be flowing through the points 38 at the instant they open. This will assure practically an indefinite point life. When the current through the collector ceases, the stored energy in the ignition coil will be released to cause the spark plugs to ignite, as is well known to those skilled in the art.

If desired, the PNP type transistor may be replaced by an NPN type if the components of the circuit are properly reversed. Further, the variable resistance 42 may be a fixed resistance if the ohmic value selected is sufficient to provide the proper voltage drop between the base and emitter when the points are closed to provide sufficient current to energize the primary coil winding.

Referring now to Fig. 3, an improved ignition control circuit is shown which employs a silicon diode. The same reference numerals that were used in Fig. 1 have been used in Fig. 3 to denote the identical component parts of the circuits. The circuit of Fig. 3 differs from the circuit of Fig. 1 in that a silicon diode 48 is connected between the collector *c* and one side of the primary coil winding 32 of the ignition coil. The silicon diode has a rating of 10 amperes in a forward direction and has at least a 300-volt reverse voltage rating. The diode freely passes current in one direction and is connected in the ignition circuit so as to pass current from transistor 28 to the primary coil winding 32. The diode blocks flow of current in a reverse direction and thus blocks any flow of current moving toward collector *c* of transistor 28.

In order to understand the function of the silicon diode 48, reference should be had to Figs. 2 and 4 of the drawings which show the curves of voltage across the secondary winding of the ignition coil versus time for the circuits shown respectively in Figs. 1 and 3. By comparing the curves of Figs. 2 and 4, it can be seen that the second-

ary voltage transient with the circuit of Fig. 3 is prolonged in time as compared with the secondary voltage that is produced with the circuit shown in Fig. 1. With the circuit of Fig. 3 that employs the silicon diode, a train of oscillations is set up whereas in the circuit of Fig. 1, the oscillation is cut short to a single pulse, which reduces the time that voltage is supplied to the spark plugs.

If a comparison is made between the operation of the circuits shown in Figs. 1 and 3, the reason for the difference in secondary voltages produced by the circuits is readily apparent. Thus, in the circuits of Figs. 1 and 3, when transistor 28 is conducting, current passes from the battery 20, through transistor 28, and then through the primary winding 32 of ignition coil 33. This occurs when the breaker points 38 are closed, and the current through primary winding increases with the elapse of time, as is well known to those skilled in the art. When breaker points 38 open, the transistor 28 is rendered non-conductive to break the circuit between battery 20 and the primary winding 32. With the circuit broken, a voltage of self induction appears in the primary coil winding as a result of the energy that was stored in the coil during the time the coil was connected with the battery. Since the primary coil is effectively connected directly across the condenser 46, the condenser is charged by this self-induced voltage to a polarity wherein the side of the condenser connected to primary coil 32 is negative and the opposite side, positive. 180 electrical degrees later, this condenser polarity is reversed.

To this point in the operation of the circuits shown in Figs. 1 and 3, the silicon diode 48 has made no difference in operation of the two circuits. Immediately following the charging of condenser 46, the condenser discharges and at this point in circuit operation the diode brings about a different operation for each circuit. In the circuit of Fig. 1 the condenser discharges through the transistor in a direction reverse to the direction of current flow when the battery is supplying current to the coil. The reverse flow is due to the fact that collector *c* of transistor 28 is rendered positive with respect to the emitter *e* when the condenser is charged to a polarity wherein the bottom end of condenser 46 is positive. This reverse flow of current dissipates substantially all of the energy stored in the condenser in I^2R losses in the transistor and in the leads connecting the transistor and condenser. This dissipating of the energy stored in the condenser accounts for the shortened time of secondary voltage which is illustrated in Fig. 2 and which is induced therein by the variation of primary coil current.

When the condenser 46 discharges in the circuit of Fig. 3, the diode 48 blocks reverse current through the transistor and the energy stored in the condenser is transferred to the primary coil 32 rather than being dissipated in the transistor and associated leads, as is the case with the circuit of Fig. 1. The condenser and primary coil thus form an oscillatory circuit producing an oscillating current in the primary coil and inducing a secondary voltage, as shown in Fig. 4. The energy initially supplied to the primary coil by the battery is thus preserved rather than being dissipated, with the circuit of Fig. 3. It thus can be seen that the circuit of Fig. 3 produces a train of oscillations to provide a secondary voltage of longer duration as compared to the secondary voltage produced by the circuit of Fig. 1. The circuit of Fig. 3 thus provides for improved sparking characteristics at spark plugs 36.

In summary, it should be noted that the use of a transistor in an ignition circuit of the type described does not reduce the efficiency of the ignition circuit to any substantial degree as compared to conventional ignition systems wherein the circuit to the primary coil is controlled by mechanically actuated breaker points. This is due to the fact that the transistor is an inherently efficient device, in that the transistor has a very low voltage drop when conducting current and is capable of carrying high

currents. Moreover, the transistor does not consume filament power that must be supplied to vacuum tubes. The transistor thus is ideally suited for use in controlling the current to the primary coil of an ignition system from the efficiency standpoint, and has other important advantages which have been described above.

While the form of embodiment of the invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted, as may come within the scope of the claims which follow.

What is claimed is as follows:

1. An electrical ignition system comprising, a direct current voltage source, an ignition coil having a primary winding and a secondary winding, means including a transistor connected in circuit with said primary winding and said voltage source for controlling the current flow in said primary winding from said source, and a unidirectional current conducting circuit element connected between said transistor and said primary winding for preventing the flow of current in a direction from said primary winding toward said transistor whereby energy stored in said primary winding is prevented from being dissipated in said transistor by current flow therethrough in one direction.

2. The system set forth in claim 1 wherein said unidirectional current conducting circuit element is a silicon diode.

3. An electrical ignition system comprising, a direct current voltage source, an ignition coil having a coil winding, a transistor having a base, emitter and collector, a biasing resistor connected across said voltage source, a circuit interrupter, means connecting said transistor emitter to one side of said voltage source and to one side of said resistor, means connecting said interrupter between said transistor base and an opposite side of said resistor, means connecting one side of said ignition coil to an opposite side of said voltage source, and a unidirectional current conducting element connected between the opposite side of said ignition coil and said transistor collector, said element being connected in the circuit in a direction to pass current from said collector to said coil and to block current in an opposite direction whereby energy stored in said coil winding is prevented from being dissipated in said transistor by current flow therethrough in said opposite direction.

4. An electrical ignition system comprising, a voltage source, an ignition coil having a coil winding, a transistor connected in circuit with said voltage source and coil winding for controlling the flow of current to said coil winding, and means in circuit with said transistor and coil winding for preventing current flow in a direction from said coil winding toward said transistor whereby energy stored in said coil winding is prevented from being dissipated in said transistor by current flow therethrough in one direction.

5. An electrical ignition system comprising, a voltage source, a first power lead connected to a first side of said voltage source, a second power lead connected to the second side of said voltage source, a transistor, an ignition coil having a coil winding, means connecting said transistor and coil winding in series circuit relationship across said power leads, a biasing circuit for said transistor rendering said transistor conductive at certain times for passing current from said first lead to said second lead through said transistor and coil winding, and means for preventing flow of current through said transistor in a direction toward said first lead whereby energy stored in said coil winding is prevented from being dissipated in said transistor by current flow therethrough in a direction toward said first lead.

6. An electrical ignition system comprising a direct current voltage source, an ignition coil having a primary winding, semi-conductor means connected in series with said voltage source and said primary winding for controlling the flow of current therebetween, a biasing

circuit for said semi-conductor means for controlling the conduction thereof including a circuit interrupter, and a diode connected between said semi-conductor means and said primary winding in such a direction as to prevent flow of current in a direction from said primary winding toward said semi-conductor means whereby energy stored in said primary winding is prevented from being dissipated in said semi-conductor means by current flow there-through in one direction.

5

References Cited in the file of this patent

UNITED STATES PATENTS

2,306,229	Somerville	Dec. 22, 1942
2,622,213	Harris	Dec. 16, 1952
2,698,416	Sherr	Dec. 28, 1954
2,722,649	Immel	Nov. 1, 1955
2,769,021	Crosby	Oct. 30, 1956
2,806,963	Woll	Sept. 17, 1957
2,884,545	Houck	Apr. 28, 1959