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3,087,090

## IGNITION SYSTEM

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Filed Mar. 13, 1961, Ser. No. 95,162  
15 Claims. (Cl. 315-205)

This invention relates to ignition systems for internal combustion engines wherein a semiconductor such as a transistor controls current flow to the primary winding of an ignition coil.

One of the objects of this invention is to provide an ignition system wherein a semiconductor such as a transistor controls current flow to the primary winding of an ignition coil and wherein the conduction of the semiconductor is controlled by voltage generating means driven in synchronism with the engine.

Another object of this invention is to provide an ignition system wherein a semiconductor such as a transistor controls an ignition circuit and wherein the turning off of the semiconductor is accomplished by a voltage developed across a capacitor.

Still another object of this invention is to provide an ignition system wherein a transistor controls current flow to the primary winding of an ignition coil, the transistor being biased normally conductive and being turned off at a periodic rate by a voltage developed on a capacitor which is connected with the transistor at the right time in the engine cycle through a circuit that includes another transistor whose conduction is varied in synchronism with operation of the engine.

A further object of this invention is to provide an ignition system wherein a transistor controls current flow to the primary winding of an ignition coil, the transistor being normally biased on and being turned off by an RC timing circuit which is in turn controlled by means driven in synchronism with an engine.

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:

The single FIGURE drawing is a schematic circuit illustration of an ignition system made in accordance with this invention.

Referring now to the drawing, the reference numeral 10 designates an internal combustion engine having eight spark plugs each designated by reference numeral 12 for firing the combustible mixture of the engine. It can be seen that one side of the spark plugs is connected directly to ground whereas the opposite side of the spark plugs is connected with contacts 16 on a distributor cap 14. The distributor rotor contact is designated by reference numeral 18 and this contact is driven in synchronism with the engine to connect the lead wire 20 with each of the contacts 16 as the rotor contact 18 rotates. The lead wire 20 is connected with the secondary winding 22 of an ignition coil which is generally designated by reference numeral 24. The ignition coil has a primary winding 26, and it is seen that the primary and secondary windings are connected at junction 28. The junction 28 is connected to one side of a resistor 30, the opposite side of this resistor being connected directly to ground.

The primary winding 26 of ignition coil 24 is connected with a lead wire 31. The lead wire 31 is connected to one side of a semiconductor switch means which in this case takes the form of a PNP transistor designated by reference numeral 32. It can be seen that the collector electrode of transistor 32 is connected with lead wire 31 whereas the emitter electrode of transistor 32 is connected

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with the lead wire 34. The base electrode of transistor 32 is connected with a junction 36 and a resistor 38 is connected between junction 36 and ground. The junction 36 is connected to one side of capacitors 40 and 42. The opposite side of capacitor 40 is connected with the junction 44. The opposite side of capacitor 42 is connected to ground as shown. The junction 44 is connected with the collector electrode of a PNP transistor 46. This junction 44 is also connected to one side of resistor 48, the opposite side of this resistor being grounded. The emitter electrode of transistor 46 is connected with junction 50 and the base electrode of transistor 46 is connected with junction 52. A resistor 54 is connected between junctions 52 and 56.

The ignition system of this invention includes a transistor 58 of the NPN type having base, collector and emitter electrodes. It is seen that the emitter electrode of transistor 58 is connected directly to ground whereas the collector electrode is connected to one side of resistor 60. The base electrode of transistor 58 is connected with junction 62 and it is seen that this junction is connected to one side of capacitor 64 and diode 66. The opposite side of diode 66 is connected directly to ground.

The capacitor 64 has one side thereof connected with resistor 68, the opposite side of this resistor being connected with junction 70. The junction 70 is connected to the collector electrode of a PNP transistor 72 and is also connected to one side of resistor 74. The opposite side of resistor 74 is connected directly to ground. The emitter electrode of transistor 72 is connected with the junction 76 whereas the base electrode of transistor 72 is connected with a coil winding 78 which forms a part of a magnetic pick-up device.

The coil winding 78 has voltage pulses induced therein whenever the toothed rotor 80 rotates relative to the core member 82 upon which the coil winding 78 is wound. This magnetic device may take many forms, and as an example, the magnetic flux may be produced by a permanent magnet and the flux passes through the rotor 80 and into the core 82 and then returns back to an opposite side of the permanent magnet. The details of construction of this device are not important to this invention, it only being necessary that pulses of voltage are generated in the coil winding 78 as the rotor 80 rotates. The rotor 80 is driven by the engine 10 so that there will be eight pulses of voltage induced in the coil winding 78 for every revolution of the rotor 80. It is pointed out here that other devices could be used for controlling this ignition circuit, it only being necessary that some device be operated in synchronism with the engine 10 for varying the conductivity of transistor 72.

It is seen that the coil winding 78 is connected between the base and emitter electrodes of transistor 72. It is also seen that one side of the coil winding 78 is connected with the lead wire 34 which forms a common connection for the junctions 50, 56, 84, and 76. The junction 84 is connected to one side of an ignition switch 86, the opposite side of this switch being connected to a voltage source 88 which in this particular case is a battery. The opposite side of the D.C. voltage source 88 is grounded as shown.

In describing the operation of the ignition system, let it first be assumed that the teeth in rotor 80 are not in alignment with core 82 so that there is no voltage induced in the coil winding 78. When there is no voltage generated in the coil winding 78, the transistor 72 will be substantially fully nonconductive between its emitter and collector since its emitter and base electrodes will be at substantially the same potential due to their connection through the coil winding 78. Since there is no emitter to collector current flow in transistor 72, there

will be no voltage developed across resistor 74 and the base electrode of transistor 58 will therefore be essentially at the same potential as the emitter of this transistor and no current will therefore flow in the emitter-collector path of the transistor 58. Transistor 58 is therefore shut off. With no current flowing between the collector and emitter electrodes of transistor 58, there will be no current flow through resistors 54 and 60 and there will be no base circuit for the transistor 46. As a result of this, the transistor 46 will be substantially fully nonconductive between its emitter and collector electrodes. The emitter and base electrodes of transistor 46 are at substantially the same potential since they are connected by the resistor 54.

Since transistor 46 is now substantially fully nonconductive between emitter and collector, it can be seen that junction 44 will be substantially at ground potential. It is also seen that one side of resistor 38 is always connected to ground. Under these conditions, it can be seen that there is a path for emitter to base current for transistor 32 via the emitter electrode of this transistor, through junction 36 and through resistor 38 to ground. As a result of this base current flow, there will be a much larger emitter to collector current through transistor 32, and transistor 32 will therefore be turned substantially fully on. With transistor 32 on between emitter and collector, it can be seen that a large current flow will exist in the primary winding 26 of the ignition coil 24. This circuit is from the positive side of battery 88, to junction 84, through lead wire 34, through the emitter-collector circuit of transistor 32, through lead wire 31, through the primary winding 26 and thence through the resistor 30 to ground. The magnetic field in the ignition transformer 24 will therefore build up.

It is pointed out that when the transistor 32 is conducting between the emitter and collector, the capacitor 40 is being charged by the emitter to base current flow. The capacitor 40 will be charged from lead wire 34, through the emitter to base circuit of transistor 32, through capacitor 40, and through resistor 48 to ground. The time that it takes to fully charge the capacitor 40 is determined by the RC time constant of the resistor 48 and capacitor 40.

In summarizing the conductive conditions of the transistors when there is no voltage generated in the coil winding 78, it is seen that transistors 72, 58 and 46 are nonconductive in their emitter-collector circuits. Transistor 32, on the other hand, is conductive between emitter and collector and also serves to charge the capacitor 40 through the emitter to base circuit of transistor 32. It is also apparent that the magnetic field is now building up in the ignition coil 24 and if the transistor 32 were now suddenly made nonconductive, a large voltage would be induced in the secondary winding 22 which would be applied to a spark plug 12 through the rotor contact 18 and one of the distributor contacts 16.

As the rotor 80 continues to rotate, the time will come when one of its teeth will be aligned with the core 82 and a voltage will therefore be induced in the coil winding 78. The voltage that is induced in the coil winding 78 is of such a polarity as to drive the base of transistor 72 negative with respect to the emitter. This will, of course, cause an emitter to base current in transistor 72 which will turn transistor 72 fully on between its emitter and collector electrodes. As a result of this, transistor 72 turns fully on and the junction 70 will now be substantially at positive battery potential since it is connected directly to junction 84 via the turned on transistor 72. With junction 70 at a positive potential, the transistor 58 will be turned on between its collector and emitter circuit. This is due to the fact that the positive potential of junction 70 causes a base current to flow in transistor 58 that charges the capacitor 64. The time that this base current will flow is determined by the RC time constant of

resistor 68 and capacitor 64. Transistor 58 will therefore be turned on between collector and emitter until the capacitor 64 has been fully charged. When the capacitor 64 has been fully charged, the transistor 58 is switched off.

When transistor 58 conducts between collector and emitter, it can be seen that there will be a base circuit for transistor 46 via resistor 60, and the collector to emitter circuit of transistor 58. With base current flow in transistor 46, the transistor is turned fully on between emitter and collector so that the junction 44 is now changed from ground potential to the positive potential of the battery 88. With the junction 44 substantially at positive battery potential, a discharge path for capacitor 40 is set up via the emitter to collector circuit of transistor 46. This capacitor will discharge via a circuit that includes the resistor 38, battery 88, lead wire 34, and the emitter-collector circuit of transistor 46. It can be seen that the voltage that appears across the capacitor 40 will now be impressed across the emitter and base electrodes of transistor 32 through the emitter to collector circuit of transistor 46. The polarity of the voltage on capacitor 40 is such that the base electrode of transistor 32 suddenly becomes positive with respect to the emitter. This will cause the transistor 32 to shut off between emitter and collector and therefore cuts off the current flow to primary winding 26.

The sudden turning off of the current flow between the emitter and collector electrodes of transistor 32 and the stopping of current flow through the primary winding 26 causes a large voltage to be induced in the secondary winding 22 which is applied to a given spark plug 12 via the rotor contact 18 and one of the distributor cap contacts 16. This causes a given spark plug 12 to fire. The time that the transistor 32 is turned off depends upon the RC time constant of resistor 38 and capacitor 40 since the capacitor discharges through the resistor 38. When the capacitor 40 has completely discharged, there is no longer a reversed biased condition on the transistor 32 so that it now will be once more fully conductive between emitter and collector due to its base circuit through resistor 38.

Referring back to the part of the circuit that includes resistor 68 and capacitor 64, it is seen as has been previously described that the transistor 58 remains conductive as long as the capacitor 64 is charging. It is also seen that transistor 72 will remain fully conductive between emitter and collector as long as there is a voltage being developed in coil winding 78. When the rotor 80 rotates sufficiently so that there is no voltage generated in coil winding 78, the transistor 72 once more will be rendered nonconductive and the capacitor 64 will then discharge through a circuit that includes resistors 68 and 74 and the diode 66. The system is now ready for another voltage pulse in coil winding 78 to set into motion a series of events which will once more cut off transistor 32.

The resistor 30 is provided in the circuit to limit the current flow through the emitter to collector circuit of transistor 32 to a safe value. The capacitor 42 is intended to delay the turning off of the transistor 32 to some extent and the circuit will have a sharper cut-off characteristic if the capacitor 42 is eliminated. Its provision however results in a decreased spike in the primary voltage waveform and an improved output. The resistor 54 is provided to prevent thermal run away of transistor 46 under conditions of no base current since it acts to tie the base to the emitter of this transistor during off conditions of transistors 58 and 32.

Although a magnetic pick up device has been shown for controlling the conductivity of transistor 72, it will be apparent to those skilled in the art that other devices might be used to control the conduction of transistor 72

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in synchronism with operation of the engine without departing from the scope and spirit of this invention.

While the embodiment of the present invention as herein disclosed constitutes a preferred form, it is to be understood that other forms might be adopted.

What is claimed is as follows:

1. An electrical ignition system for an internal combustion engine, comprising, a source of voltage, a spark discharge device, an ignition coil having a primary winding and a secondary winding, means connecting said secondary winding with said spark discharge device, a first transistor having emitter, collector and base electrodes, means connecting the emitter-collector circuit of said first transistor between said voltage source and the primary winding of said ignition coil, a capacitor, a charging circuit for charging said capacitor from said voltage source including the emitter-base circuit of said first transistor and a first resistor, a second transistor having emitter, base and collector electrodes, means connecting the emitter electrodes of said transistors together, a discharging circuit for said capacitor including the emitter-collector circuit of said second transistor and a second resistor connected between one side of said source of voltage and a junction that is connected between one side of said capacitor and the base electrode of said first transistor, and means for applying a varying voltage applied to the base electrode of said second transistor in synchronism with operation of said engine.

2. An ignition system for an internal combustion engine comprising, a source of voltage, a spark discharge device for igniting the combustible mixture of said engine, a first transistor for controlling the energization of said spark discharge device having base, collector, and emitter electrodes, a second transistor having emitter, base and collector electrodes, an RC timing circuit including a series connected resistor and capacitor connected between the collector electrode of said second transistor and the base electrode of said first transistor, a pick-up coil connected across the emitter and base electrodes of said second transistor, and magnetic means driven in synchronism with said engine for causing pulses of voltage to be induced in said pick-up coil in synchronism with operation of engine.

3. An ignition system for an internal combustion engine, comprising, a source of voltage, a spark discharge device for igniting the combustible mixture of said engine, a first transistor for controlling the energization of said spark discharge device, a second transistor, an RC timing circuit including a series connected resistor and capacitor connecting the collector electrode of one of said transistors with the base electrode of the other of said transistors, means for controlling the conductivity of said second transistor in synchronism with operation of said engine, and a discharge circuit for the capacitor of said RC timing circuit including a diode.

4. A control circuit for controlling the firing of an ignition circuit comprising a first transistor, a second transistor, and RC network including a series connected resistor and capacitor connecting the base electrode of one of said transistors with the collector electrode of the other of said transistors, and a pick-up coil connected across the emitter and base electrodes of one of said transistors.

5. An ignition system for an internal combustion engine comprising, a source of voltage, an ignition coil having a primary winding and a secondary winding, a spark discharge device, means connecting the secondary winding of said ignition coil with said spark discharge device, a first transistor having its emitter-collector circuit connected between said voltage source and the primary winding of said ignition coil, a second transistor having emitter, collector and base electrodes, a capacitor connecting the collector electrode of said second transistor with the base electrode of said first transistor, a base circuit for said second transistor including the emitter-collector cir-

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cuit of a third transistor, a fourth transistor having emitter, collector and base electrodes, an RC network including a series connected resistor and capacitor connecting the collector electrode of said fourth transistor with the base electrode of said third transistor, and means connected across the emitter and base electrodes of said fourth transistor for varying its conductivity in synchronism with operation of said engine.

6. An ignition system for an internal combustion engine comprising, a source of voltage, an ignition coil having a primary winding and a secondary winding, a spark discharge device connected with said secondary winding, a first transistor having its emitter-collector circuit connected between said voltage source and the primary winding of said ignition coil, a second transistor having emitter, collector and base electrodes, a capacitor connecting the collector electrode of said second transistor with the base electrode of said first transistor, a base circuit for said second transistor including the emitter-collector circuit of a third transistor, a fourth transistor having emitter, collector and base electrodes, an RC network including a series connected resistor and capacitor coupling the collector electrode of said fourth transistor with the base electrode of said third transistor, a pick-up coil connected across the emitter and base electrodes of said fourth transistor and means driven in synchronism with said engine for causing voltage pulses to be generated in said pick-up coil.

7. An ignition system for an internal combustion system comprising, a voltage source, a spark discharge device, an ignition coil having a primary winding and a secondary winding, means connecting said secondary winding with said spark discharge device, a first transistor having emitter, collector and base electrodes, means connecting the emitter-collector circuit of said first transistor between said power source and the primary winding of said ignition coil, a second transistor having emitter, base and collector electrodes, means connecting the emitter-collector circuit of said second transistor across said voltage source, a capacitor connecting the collector electrode of said second transistor with the base electrode of said first transistor, a third transistor having its emitter-collector circuit connected between the base electrode of said second transistor and one side of said power source, a fourth transistor having emitter, collector and base electrodes, means connecting the emitter-collector circuit of said fourth transistor across said power source, an RC network connecting the collector electrode of said fourth transistor with the base electrode of said third transistor, a diode connected between the base electrode of said third transistor and one side of said power source, a pick-up coil connected across the emitter to base circuit of said fourth transistor and means driven in synchronism with said engine for causing voltage pulses to be generated in said pick-up coil.

8. An ignition system for an internal combustion engine comprising, a source of voltage, an ignition coil having a primary winding and a secondary winding, a spark discharge device for igniting the combustible mixture of said engine, means connecting said secondary winding with said spark discharge device, a transistor controlling a circuit for said primary winding, a capacitor, a charging circuit for said capacitor including the emitter-base circuit of said transistor, variable conducting means, a discharging circuit for said capacitor including said variable conducting means, a point on said discharging circuit being connected with the junction of the base electrode of said transistor and one side of said capacitor and with one side of said source of voltage, and means for operating said variable conducting means in synchronism with said engine.

9. A timing circuit for an internal combustion engine ignition system comprising, a source of voltage, a transistor having emitter, collector and base electrodes, a capacitor, a charging circuit for said capacitor including

the emitter-base circuit of said transistor, variable conducting means operated in synchronism with said engine, a discharging circuit for said capacitor including said variable conducting means and a conductive circuit that connects one side of said capacitor and the base electrode of said transistor with one side of said source of voltage.

10. A timing circuit for an internal combustion engine ignition system comprising, a source of voltage, first semiconductor switch means having a pair of current carrying terminals and a control terminal, means connecting said current carrying terminals across said source of voltage, second semiconductor switch means having a pair of current carrying terminals and a control terminal, means connecting the current carrying terminals of said second semiconductor switch means across said power source, a capacitor connecting the control terminal of said first semiconductor switch means with one of the current carrying terminals of said second semiconductor switch means, a charging circuit for said capacitor including the control terminal and one of the current carrying terminals of said first semiconductor switch means, a discharging circuit for said capacitor including the current carrying terminals of said second semiconductor switch means and a conductive circuit which connects one side of said capacitor and the control terminal of said first semiconductor switch means with one side of said source of voltage, and means driven by said engine for controlling said second semiconductor switch means.

11. The combination according to claim 10 wherein at least one of the semiconductor switch means is a transistor.

12. A timing circuit for an internal combustion engine ignition system comprising, a source of voltage, a first transistor having emitter, collector and base electrodes, a second transistor having emitter, collector and base electrodes, a capacitor connecting the base electrode of said first transistor with the collector electrode of said second transistor, a charging circuit for said capacitor including the emitter-base circuit of said first transistor, a discharging circuit for said capacitor including the emitter-collector circuit of said second transistor and a conductive circuit which connects one side of said capacitor and the base electrode of said first transistor with one side of said source of voltage, and means driven by said engine for controlling said second transistor.

13. A timing circuit for controlling an internal combustion engine ignition system comprising, a source of voltage, a first transistor having emitter, collector and base electrodes, a second transistor having emitter, collector and base electrodes, means connecting the emitter-collector circuits of both of said transistors across said source

of voltage, a capacitor connected between the base electrode of said first transistor and the collector electrode of said second transistor, a charging circuit for said capacitor including the emitter-base circuit of said first transistor and a circuit which connects the collector electrode of said second transistor with one side of said source of voltage, and a discharging circuit for said capacitor operative when said second transistor is conductive in its emitter-collector circuit, said discharging circuit including the emitter-collector circuit of said second transistor and a circuit which conductively connects the base electrode of said first transistor with one side of said source of voltage.

14. A timing circuit for an internal combustion engine ignition system comprising, a source of voltage, a first transistor having emitter, collector and base electrodes, a second transistor having emitter, collector and base electrodes, a capacitor, means connecting said capacitor between the base electrode of said first transistor and the collector electrode of said second transistor, a charging circuit for said capacitor including the emitter-base circuit of said first transistor and a conductive circuit which connects the collector electrode of said second transistor with one side of said power source, and a discharging circuit for said capacitor including the emitter-collector circuit of said second transistor and a conductive circuit connecting the base electrode of said first transistor with one side of said source of voltage.

15. A timing circuit for an internal combustion engine ignition system comprising, a first transistor having emitter, collector and base electrodes, a second transistor having emitter, collector and base electrodes, a source of voltage, a capacitor connected between the base electrode of said first transistor and the collector electrode of said second transistor, a first resistor connecting one side of said capacitor and the collector electrode of said second transistor with one side of said source of voltage, and a second resistor connecting an opposite side of said capacitor and the base electrode of said first transistor with the same side of said voltage source, said first resistor and the emitter-base circuit of said first transistor forming part of a charging circuit for said capacitor, said second resistor and the emitter-collector circuit of said second transistor forming a part of a discharging circuit for said capacitor.

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