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SEMICONDUCTOR IGNITION SYSTEM

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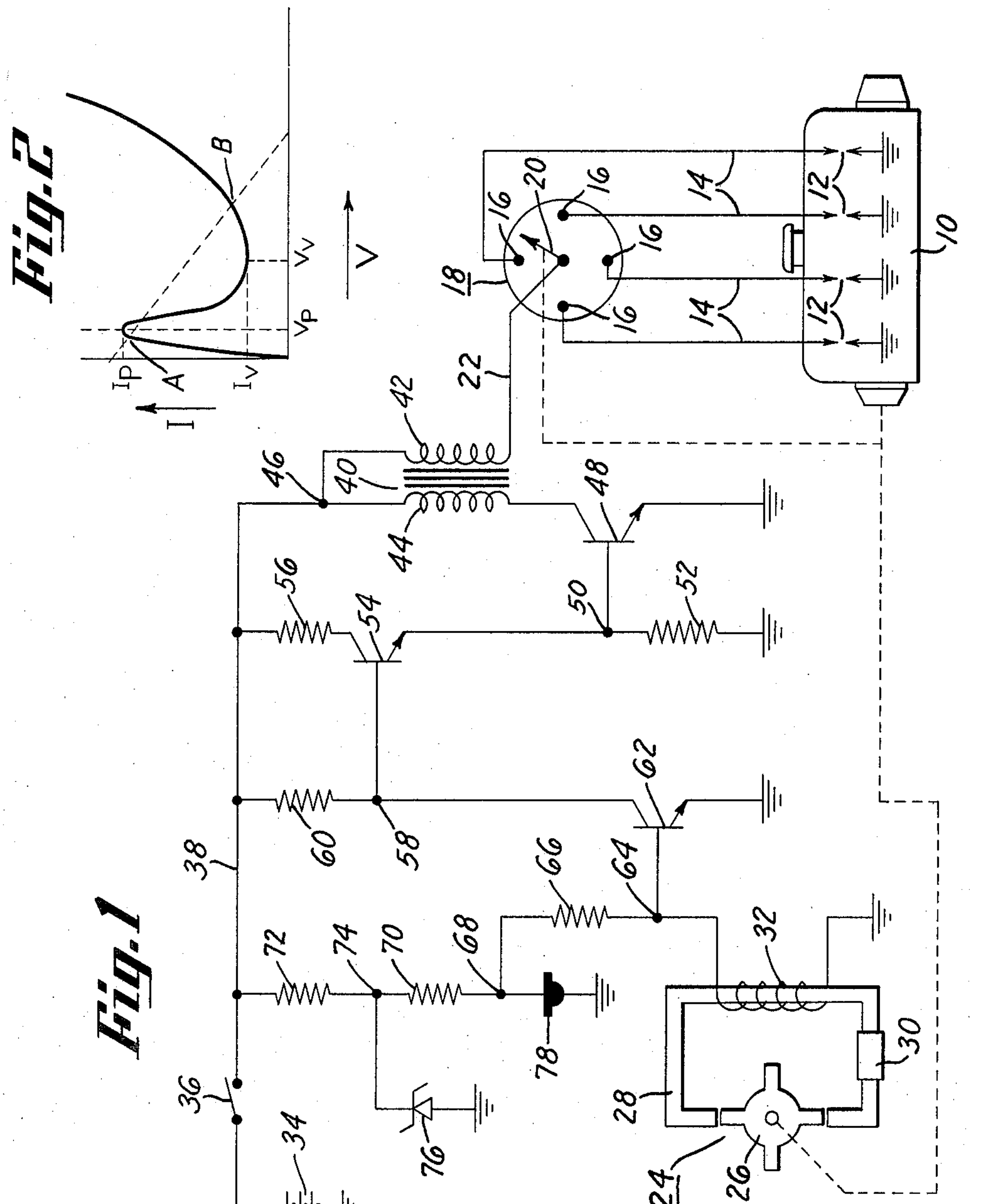

Fig. 2

Fig. 1

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SEMICONDUCTOR IGNITION SYSTEM

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This invention relates to semiconductor ignition systems and more particularly to an ignition system that utilizes transistors and a tunnel diode.

The ignition system of this invention is in some respects similar to the ignition systems illustrated in the Konopa Patent 3,087,090, and in the Short et al. Patent 3,087,001, in that in these patents, a breakerless transistor ignition system is disclosed.

One of the objects of this invention is to provide a transistor ignition system which has an improved low speed performance as compared to systems that use resistor-capacitor coupling as in the above-mentioned Konopa and Short et al. patents.

Another object of this invention is to provide a transistor ignition system which requires less output voltage from a pick-up coil to insure proper triggering of the ignition system as compared to known systems.

Still another object of this invention is to provide a transistor ignition system wherein a tunnel diode is used as the active switching element in the system.

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

In the drawings:

FIGURE 1 is a schematic circuit diagram of an ignition system made in accordance with this invention.

FIGURE 2 is a curve illustrating the voltage-current characteristic of a tunnel diode which is used in the system of FIGURE 1.

Referring now to FIGURE 1, the reference numeral **10** designates an internal combustion engine which has a plurality of spark plugs **12** for firing the combustile mixture of the engine.

The spark plugs **12** are connected with spark plug conductors **14** which are connected with the conductive inserts or electrodes **16** on a conventional distributor cap **18**. The inserts or electrodes **16** cooperate with a rotatable rotor contact **20** which distributes spark firing energy to the spark plugs **12** from a high voltage conductor **22**. The rotor contact **20** is driven in synchronism with the engine **10** as is depicted by the dotted lines of FIGURE 1.

The timing device for the ignition system shown in FIGURE 1 takes the form of a magnetic pick-up or voltage pulse generator generally designated by reference numeral **24**. This voltage pulse generator has a rotor **26** which is formed of magnetic material and this rotor cooperates with a magnetic circuit shown as a U-shaped magnetic part **28**. A permanent magnet **30** or other flux source provides magnetic flux for the U-shaped part **28**. An output coil **32** is wound on the U-shaped part **28** and pulses of voltage are induced in this output coil as the rotor **26** rotates. When the rotor **26** rotates, the magnetic flux through part **28** is maintained and interrupted so that a train of pulses of voltage are induced in the output winding **32** which go positive and negative with increments of no output voltage between the series of positive and negative pulses. The voltage induced in pick-up coil **32** is a result of flux flow increasing through the magnetic circuit and then decreasing when the pole tips of the rotor **26** are out of alignment with the ends of U-shaped member **28**. The frequency of the pulses of voltage generated in the pick-up coil **32** depend upon the speed of rotation of the rotor **26**. The rotor **26** is driven by the engine **10** and is also mechanically coupled to the rotor contact **20** as is depicted by the dotted lines of FIGURE 1.

Although a specific type of magnetic pick-up **24** has been illustrated, it will be appreciated that other types of voltage pole generating devices could be used with the system to be described.

The source of direct current power for the ignition system takes the form of a battery designated by reference numeral **34**. One end of this battery is grounded and the opposite end is connected to one side of an ignition switch **36**. When the ignition switch **36** is closed, the voltage of the direct current source **34** is applied between the power conductor **38** and ground. In a motor vehicle electrical system, the voltage applied between conductor **38** and ground can come from a generator which is used to charge the battery **34**.

An ignition coil generally designated by reference numeral **40** is provided which has a secondary winding **42** and a primary winding **44**. The secondary winding **42** is connected to one side of the primary winding at junction **46** and this junction is connected with conductor **38**. The opposite side of the secondary winding **42** is connected with the high voltage conductor **22** which can feed the spark plugs **12** via rotor contact **20**, one of the conductive inserts **16** and then through one of the spark plug wires **14**.

The primary winding **44** is connected with the collector electrode of an NPN transistor **48**. The emitter of transistor **48** is grounded. The base of transistor **48** is connected with a junction **50**.

A resistor **52** is connected between junction **50** and ground and is also connected with the emitter of another NPN transistor **54**. The collector of transistor **54** is connected with power conductor **38** through a resistor **56**. The base of transistor **54** is connected with junction **58**.

A resistor **60** is connected between junction **58** and conductor **38**. The junction **58** is also connected with the collector of an NPN transistor **62**. The emitter of transistor **62** is grounded while the base of transistor **62** is connected with a junction **64**.

The junction **64** is located between the output winding **32** of the magnetic pick-up **24** and a resistor **66**. The opposite side of the output coil **32** is grounded as shown. The opposite side of resistor **66** is connected with junction **68**. A pair of resistors **70** and **72** connect the junction **68** and the power conductor **38** and these resistors have a junction **74**. A Zener diode **76** is connected between junction **74** and ground while a tunnel diode **78** is connected between junction **68** and ground.

The Zener dode as is well known to those skilled in the art, prevents current flow in a reverse direction, that is from junction **74** to ground, until the voltage impressed across it exceeds a predetermined break down voltage. When this voltage is exceeded, the Zener diode will break down and conduct in a reverse direction and it then operates as a constant voltage device.

The voltage-current characteristic of the tunnel diode **78** is depicted in FIGURE 2 together with a load line which is shown dotted. The load line intersects the characterstic curve of the tunnel diode at points A and B. These are the two stable operating points for the tunnel diode. The peak forward current for the tunnel diode is designated as I_p and this occurs at a voltage V_p. The valley current I_v for the tunnel diode occurs at the valley voltage V_v.

When the ignition switch **36** is closed, the voltage of the direct current source is impressed between conductor 38 and ground and if the rotor 26 is now rotating as when the engine 10 is being cranked or when the engine is running, the ignition system will be operative. The operation of this system will be described during the time when no voltage is induced in pick-up coil 32 and during the time when positive and negative voltages are induced in pick-up coil 32.

When no voltage is induced in the pick-up coil 32, the tunnel diode is biased to point A on the characteristic curve shown in FIGURE 2. The voltage appearing between the base and emitter of transistor 62 is not sufficient to turn on transistor 62 and this voltage is approximately V_p. Since transistor 62 is not biased to a conductive state, the voltage of junction 58 is such as to apply a forward bias to transistor 54 and base current can flow into the base of transistor 54 causing it to switch on in its collector-emitter circuit.

When transistor 54 switches on in its collector-emitter circuit, the junction 50 is at such a voltage as to bias the transistor 48 to a conductive condition and base current will flow into the base of transistor 48 causing it to conduct in its collector-emitter circuit. With transistor 48 switched on, current can flow from conductor 38, through primary winding 44 and through the collector-emitter circuit of transistor 48 back to the grounded side of battery 34.

To summarize the operation of the system when no voltage is induced in the pick-up coil 32, the transistors 54 and 48 are conductive and transistor 62 is nonconductive. The tunnel diode 78 is now operating at point A on the characteristic curve shown in FIGURE 2.

When a positive pulse is now induced in pick-up coil 32 which is caused by further rotation of rotor 26, the junction 64 is driven more positive. This will drive the junction 68 positive and will cause the tunnel diode to go into its negative resistance region and it will switch operation from point A to point B on the curve shown in FIGURE 2. This will raise the voltage of the base of transistor 62 to a point where the transistor 62 is switched from a nonconductive condition to a conductive condition. With transistor 62 conductive, the voltage of junction 58 is lowered to a point where the transistor 54 is now biased to a non-conductive condition. When transistor 54 turns off in its collector-emitter circuit, the base current to transistor 48 is interrupted and transistor 48 therefore turns off in its collector-emitter circuit.

When transistor 48 turns off, the circuit for the primary winding 44 is interrupted, and a large voltage is induced in the secondary winding 42 which is applied to one of the spark plugs by conductor 22, rotor contact 20, one of the inserts or electrodes 16 and one of the spark plug wires 14. The transistor 48 will remain switched off until a negative pulse is applied to the base of transistor 62 from pick-up coil 32. This occurs after further rotation of the rotor 26.

When a negative voltage pulse is applied to the base of transistor 62 via junction 64, the current flow through the tunnel diode 78 is decreased below the valley point I_v and the tunnel diode and switches back to point A on the load line. The system is now ready for another cycle of operation.

The Zener diode 76 which parallels resistor 70 and the tunnel diode 78 is used to provide a constant bias on the tunnel diode regardless of the value of supply voltage of source 34.

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

What is claimed is as follows:

1. An ignition system for an internal combustion engine comprising, an ignition coil having a primary winding and a secondary winding, a source of direct current, a transistor having emitter, collector and base electrodes, means connecting said primary winding of said ignition coil and the emitter and collector electrodes of said transistor across said source of direct current, a tunnel diode, means connecting said tunnel diode across said source of direct current, a control junction, means connecting said control junction with one side of said tunnel diode, means for varying the potential of said control junction in timed relationship with operation of said engine, and a circuit connecting said control junction and the base electrode of said transistor.

2. The ignition system according to claim 1 wherein the circuit that connects the junction and the base electrode of the transistor includes at least one other transistor.

3. The ignition system according to claim 1 wherein the means for varying the voltage of the junction is a voltage generating device having a rotor and a pick-up coil.

4. A transistor switching circuit comprising, a source of variable signal voltage, a source of direct current, a transistor having emitter, collector and base electrodes, a circuit connecting said tunnel diode across said source of direct current, means connecting said tunnel diode across the base and emitter of said transistor, means connecting the collector and emitter electrodes of said transistor across said source of direct current, means connecting said source of variable voltage across the emitter and base electrodes of said transistor, and a constant voltage device connected between said circuit and one side of said source of direct current, said constant voltage device shunting said tunnel diode.

5. The system according to claim 4 wherein the constant voltage device is a Zener diode.

6. An ignition system for an internal combustion engine comprising, a source of direct current, an ignition coil having a primary winding and a secondary winding, a semiconductor switching device, means connecting said semiconductor switching device and said primary winding in series across said source of direct current, a transistor, means connecting said transistor across said source of direct current, means connecting said transistor and said semiconductor switching device whereby said transistor controls the conduction of said semiconductor switching device, a junction connected with the base electrode of said transistor, a circuit connected across said source of direct current including said junction and a tunnel diode connected between said junction and one side of said source of direct current, means for developing a control voltage in synchronism with operation of said engine, and means for applying said control voltage between said junction and said one side of said source of direct current.

7. An ignition system for an internal combustion engine comprising, an ignition coil having a primary winding and a secondary winding, a source of direct current, a switching device, means connecting said switching device and said primary winding in series across said source of direct current, a transistor connected across said source of direct current, a voltage pulse generating means having an output coil driven in synchronism with said engine, a circuit connected across said source of direct current including a junction and said output coil, means connecting said junction with the base of said transistor, a tunnel diode, means connecting said tunnel diode between said junction and one side of said source of direct current, said tunnel diode forming part of a circuit which is connected in parallel with said output coil, and means connecting said transistor in controlling relationship with said switching device.

8. An ignition system for an internal combustion engine comprising, a source of direct current, an ignition coil having a primary winding and a secondary winding, a switching device, means connecting said primary winding and said switching device in series across said source of direct current, a transistor connected across said source of direct current, a voltage pulse generating means driven in synchronism with said engine including an output coil, a circuit connected across said source of direct current in-

cluding in a series connection first and second resistors and said output coil, a first junction connected between said resistors, a second junction connected between one of said resistors and said output coil, means connecting the base electrode of said transistor to said second junction, a tunnel diode connected between said second junction and one side of said source of direct current, a Zener diode, means connecting said Zener diode between said first junction and said one side of said source of direct current, and means connecting said transistor in controlling relationship with said switching device.

9. The ignition system according to claim **8** where a resistor is connected between said second junction and said tunnel diode.

10. An ignition system for an internal combustion engine comprising, a source of direct current, an ignition coil having a primary winding and a secondary winding, a switching device, means connecting said switching device and said primary winding in series across said source of direct current, a transistor, means coupling said transistor and said switching device whereby the conduction of said switching device is controlled by said transistor, a tunnel diode, a circuit connected across said source of direct current including said tunnel diode and at least one

resistor, means connecting the junction of said resistor and tunnel diode with the base of said transistor whereby the voltage at the base of said transistor is varied in accordance with the conductive characteristic of said tunnel diode, said tunnel diode being operative to switch between first and second conductive conditions, said transistor being biased conductive when said tunnel diode is in its first conductive condition, said transistor being biased nonconductive when said tunnel diode is in its second conductive condition, means driven in synchronism with said engine for developing a control voltage, and means connecting said control voltage with said tunnel diode whereby said tunnel diode is switched between said first and second conductive conditions in accordance with the variation of said control voltage.

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