United States Patent

Ford

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[54] **IGNITION SYSTEMS FOR INTERNAL COMBUSTION ENGINES**

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Related U.S. Application Data

[63] Continuation-in-part of Ser. No. 801,721, Feb. 24, 1969.

[52] **U.S. Cl.**.....**123/148 E,** 315/209 T

[51] **Int. Cl.**.....**F02p 3/02**

[58] **Field of Search**.....123/148

[56] **References Cited**

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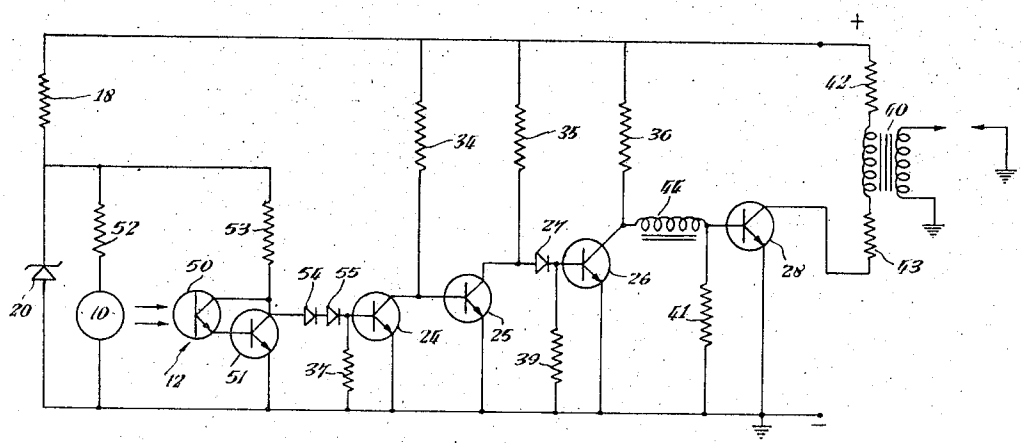
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[57] **ABSTRACT**

In an ignition system for an internal combustion engine the provision of a device for fast switching the primary circuit having a solid state radiation source, a radiation sensitive element, the radiation path being interrupted in timed relation to the engine revolutions, and a transistorized ignition circuit including an amplifier whose transistors are arranged in cascade to switch in inverse relation to one another, a power transistor connected to the output of the amplifier to fast switch the primary circuit of the ignition coil so as to produce the ignition spark every time the radiation is cut off, and energy storage means associated with the power transistor to reduce voltage spikes induced in the primary circuit.

4 Claims, 3 Drawing Figures



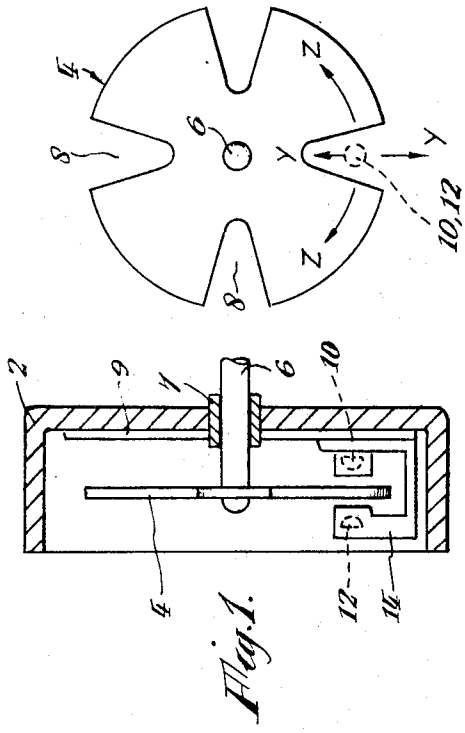


Fig. 1.

Fig. 2.

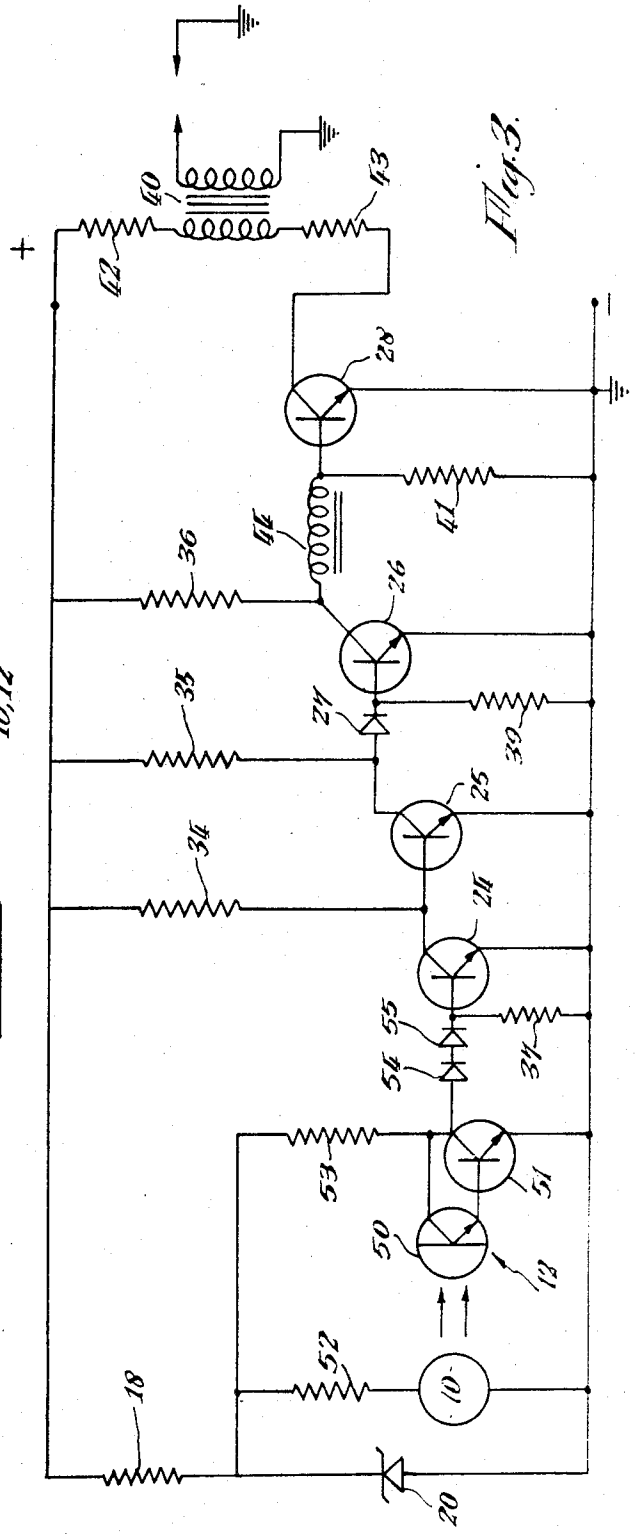


Fig. 3.

IGNITION SYSTEMS FOR INTERNAL COMBUSTION ENGINES

CROSS REFERENCE

This application is a continuation-in-part application of my U.S. application Ser. No. 801,721 and relates in particular to certain improvements in the transistorized ignition circuit disclosed therein.

FIELD OF INVENTION

The present invention relates to improvements in ignition systems for internal combustion engines.

The usual form of ignition system for an internal combustion engine, such as petrol engine relies on a contact breaker to interrupt the current and thus generate in the ignition coil a sufficient voltage pulse to pass across the gap between the contacts of the sparking plug in order to fire the combustible mixture compressed in the cylinder, the pulse being fed to the appropriate sparking plugs in timed sequence by a distributor. Such an ignition system relies on moving mechanical parts in circuit with the current to the primary winding of the ignition coil and these are liable to wear or to become out of correct adjustment.

DESCRIPTION OF THE PRIOR ART

It is well known that voltage pulses for use with an ignition system of an internal combustion engine can be generated by using a light source, a photo-sensitive device such as a photo-electric cell or photo-transistor, and a disc or drum with holes in it or an obscuring device rotated in synchronism with the engine revolutions. This principle is disclosed in U.S. Pat. Nos. 2,084,267; 2,787,649 and 2,791,724. The circuits disclosed in these patents incorporate filament light bulbs as the source of radiation and thyratrons or thermionic tubes in the amplifier. It will be appreciated that filament light bulbs and thermionic tubes will be very subject to vibration and are thus likely to have a very short life indeed if mounted in an internal combustion engine.

In later developments the thyratrons and thermionic tubes were replaced by transistors, but there was no replacement of the filament light bulbs by a solid state device. U.S. Pat. Nos. 3,235,742; 3,368,539 and 3,422,804 show various transistorized ignition circuits for switching the current through the primary winding of the ignition coil. However, all these systems suffer from the same drawback, namely that they are unable to switch fast enough at high engine revolutions. Not only must the radiation sensitive device be capable of determining the precise point at which the radiation is either turned on or cut off, but the transistorized ignition circuit must be able to switch this very fast indeed if there is to be any hope of the system working at high speeds.

SUMMARY OF INVENTION

It is an object of the present invention to obviate partially or wholly the above mentioned disadvantages in the known transistorized circuits of ignition systems for internal combustion engines.

In particular it is an object of the invention to provide inverse switching of the transistors of the amplifier to increase the speed of the switching action of the circuit, and also to protect the individual transistors from being damaged due to the presence of any unwanted high voltage pulses on the line to the positive terminal of the battery.

According to the present invention there is provided a device for fast switching the primary circuit of an ignition coil of an internal combustion engine to thereby induce a desired voltage in the secondary circuit including a radiation sensitive element which will switch on or conduct when exposed to radiation and switch off when the radiation is cut off; a solid state infra-red radiation source; a disc having as many substantially V-shaped slots cut therein in equi-spaced relation around the circumference as there are cylinders in the engine, said disc being positioned between the radiation source and the radiation sensitive element; means for rotating the disc in timed relation to the engine revolutions; means for moving the line of sight between the radiation source and the radiation sensitive element in relation to the slotted disc so as to achieve an advance or retard of the ignition timing; a transistorized ignition circuit including an amplifier having a plurality of transistors arranged in cascade and fed from the output of the radiation sensitive element so as to fast switch in inverse relation to one another; a power transistor fed from the output of the amplifier means and feeding the ignition coil; and energy storage means connected to the base electrode of the power transistor, whereby every time a slot permits a beam of infra-red radiation to fall onto and be cut off from the radiation sensitive element, the transistorized ignition circuit causes a switching action to effect the sequential magnetic build up and collapse of the field in the primary winding of the ignition coil, the latter event resulting in the production of the desired voltage in the secondary circuit.

Preferably the energy storage means is an inductance which is so connected in the base circuit of the power transistor thus slowing down the switch off of the power transistor to prevent any primary voltage spike being generated.

BRIEF DESCRIPTION OF THE DRAWINGS

The present invention will now be described in greater detail by way of examples with reference to the accompanying drawings, wherein

FIG. 1 is an elevation view of one form of device for fast switching the primary circuit of an ignition system of an internal combustion engine in order to produce a high voltage discharge at the required firing point of the engine;

FIG. 2 shows the disc having V-shaped slots of the device shown in FIG. 1; and

FIG. 3 is a circuit diagram showing one preferred form of transistorized ignition system which responds to the output from the photo-transistor of the device shown in FIG. 1.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to FIGS. 1 and 2 of the drawings, the device includes a cup-shaped housing 2, an opaque disc 4 mounted on a shaft 6 which is driven by the cam shaft of the engine. The shaft 6 is supported within the housing 2 by means of a bearing 7. The disc 4 is provided

with four V-shaped slots 8 which are cut therein in equi-spaced relation around the circumference of the disc. It should be noted that the sides of the V-shaped slots are not radial with respect to the center of the disc but slightly inclined thereto so that the base of the V-shaped slots which are slightly curved terminate well before the center of the disc. Mounted for rotation within the cup-shaped housing a is a disc 9. A solid state infra-red radiation source 10 such as a Gallium Arsenide lamp and a radiation sensitive semi-conductor device 12 such as a photo-transistor are located on opposite ends of a square C-shaped member 14 which is keyed into and radially slidable on the disc 9.

As the disc 4 is rotated by the cam shaft of the engine the radiation sensitive element 12 is exposed to infra-red radiation from the solid state source 10 every time it is uncovered by one of the V-shaped slots. When the infra-red radiation falls onto the radiation sensitive element 12 it is energized to initiate operation of the transistorized ignition circuit described more fully in FIG. 3. As will be explained more fully hereinafter it is at the actual moment that the infra-red radiation is cut off that the spark is produced to fire the charged cylinder in question. The slotted disc 4 has four slots and is therefore applicable to a four cylinder internal combustion engine, but it will be appreciated that the disc would have N equi-spaced slots 4 for a N cylinder engine, the firing order of the cylinders being arranged according to conventional practice.

In order to achieve an advance or retard of the ignition to allow for different engine speeds and/or loads, the square C-shaped member 14 can be moved either radially with respect to the disc 9, i.e. within keyed slot referred to above, or it can be moved circumferentially by rotating the disc 9 relative to the housing 2. In the former case the apparent positions of the infra-red source 10 and radiation sensitive element 12 are displaced along the lines Y—Y relative to the disc 4. In the latter case the apparent positions of the infra-red source 10 and radiation sensitive element 12 are displaced along the lines Z—Z relative to the disc 4.

The transistorized ignition circuit shown in FIG. 3 includes the solid state infra-red radiation source 10; the radiation sensitive element 12 in the form of a darlington pair consisting of a photo-transistor 50 and a transistor 51; three transistors 24, 25 and 26 each having respective collector load resistors 34, 35 and 36; a power transistor 28 and the ignition coil 40. The 12 volt battery of the automobile is connected across the points marked + and −, the negative terminal being grounded as is now conventional. The battery feeds the solid state infra-red source 10 and the photo-transistor 50 with current through respective resistors 52 and 53 and a common supply resistor 18. A zener diode 20 is provided across the solid state source 10 and the photo-transistor 50 to ensure a stabilized voltage thereacross in the event of fluctuations in battery voltage. The darlington pair 50–51 is connected in conventional manner such that the collector electrodes are common and the emitter electrode of the photo-transistor 50 is connected to the base electrode of the transistor 51. The collector electrodes of the darlington pair 50–51 are connected in common to the base electrode of the transistor 24 through a pair of diodes 54 and 55. These diodes are provided to raise the voltage across the darlington pair 50–51.

A resistor 37 is connected between the base electrode of the transistor 24 and ground. A diode 27 is connected between the collector electrode of the transistor 25 and the base electrode of the transistor 26 which is itself connected to ground through a resistor 39. The output form the transistor 26 is connected to the base electrode of the power transistor 28 through an iron-core inductance 44 as indicated in FIG. 3, the base electrode being grounded through a resistor 41. The emitter-collector path of the power transistor 28 is in series with the primary winding of the ignition coil 40 and resistors 42 and 43. One side of the secondary winding of the ignition coil is grounded whilst the other is connected to the spark plugs of the individual cylinders through a conventional distributor (not shown).

It will be noted that the ignition coil 40 is of the type having a primary electrically separated from the secondary. The collector of the power transistor 28 is connected via the resistor 43 to the primary of the coil 40 which also has the resistor 42 in series with it. The use of this type of coil prevents secondary surges damaging the transistorized circuit supplying the primary.

The inductance 44 stores energy in the form of a magnetic field when the transistor 26 is off and the base of the power transistor 28 is being supplied with current through the inductance 44. When the radiation is cut off from the darlington pair 50–51, the pair switches off, transistor 24 switches on, transistor 25 switches off, the transistor 26 switches on and the power transistor 28 switches off to effect the magnetic collapse of the field in the primary winding of the coil. The voltage across the inductance 44 is reduced to zero instantaneously. However as is well know, by Lenz's law, the current through the inductance 44 cannot be reduced to zero instantaneously due to collapse of the magnetic field associated with the inductance. The energy stored in this field is dissipated as current supply to the base of the power transistor 28 so slowing down the switch-off of the power transistor. Thus any primary voltage "spike" is prevented or at least controlled. In this regard, it is noted that the trigger described above actually switches too fast for normal ignition coils, and, hence, when the power transistor 28 is switched to the "off" condition by the trigger, the current flowing in the primary winding of coil 40 represents considerable energy which must be dissipated somewhere. Although, of course, this current serves in inducing the voltage in the secondary winding for producing the spark, the energy levels are such that some of the energy is also dissipated as radiation. This is very undesirable because of the resultant radio frequency interference and hence the need for control of the switching of the power transistor 28.

From the above description, it will be appreciated that every time the darlington pair 50–51 is energized by radiation and cut off from the radiation there is inverse switching of all the transistors.

	50–51	24	25	26	28
Radiation ON	ON	OFF	ON	OFF	ON
Radiation OFF	OFF	ON	OFF	ON	OFF

The values of resistance of the resistors 34, 35 and 36 are such that:

$$R35 = n\,R36$$

$$R34 = n^2\,R36$$

where n is an integer between 15 and 20. The preferred value for the resistance of resistor **36** is 22 ohms.

With the above described ignition system, it will be appreciated that very fast switching of the action of the transistorized circuit causes the sequential magnetic build up and collapse of the field in the primary winding of the coil, the latter event resulting in the production of the desired voltage in the secondary circuit. Moreover, due to the inverse switching action, the transistors are fully protected from any high voltage transients. Finally, the provision of the inductance slightly slows down the very fast switching action of the power transistor and so avoids the generation of voltage spikes in the primary circuit.

What I claim and desire to secure by Letters Patent is:

1. A device for fast switching the primary circuit of an ignition coil of an internal combustion engine to thereby induce a desired voltage in the secondary circuit including a radiation sensitive element which will switch on or conduct when exposed to radiation and switch off when the radiation is cut off; a solid state infra-red radiation source; a disc including a plurality of substantially V-shaped slots therein located in equispaced relationship around the circumference thereof, the number of said slots being equal to the number of cylinders in the engine and the disc being positioned between the radiation source and the radiation sensitive element; means for rotating the disc in timed relation to the engine revolutions; means for moving the line of sight between the radiation source and the radiation sensitive element in relation to the slotted disc so as to achieve an advance or retard of the ignition timing; a transistorized ignition circuit including an amplifier having a plurality of transistors arranged in cascade and fed from the output of the radiation sensitive element so as to fast switch in inverse relation to one another; a power transistor, fed from the output of the amplifier and connected to the ignition coil, for, responsive to a slot permitting a beam of infra-red radiation to fall onto and be cut off from the radiation sensitive element, causing a sequential magnetic build up and collapse of the field in the primary winding of the ignition coil so as to produce a desired voltage in the secondary circuit; and an iron core inductance connected between the base electrode of the power transistor and the output of the last transistor of the said amplifier for slowing down the switching off of the power transistor so as to control the primary voltage level.

2. A device according to claim **1**, wherein the solid state infra-red radiation source comprises a Gallium Arsenide lamp and the radiation sensitive element is a darlington pair consisting of a photo-transistor and a transistor.

3. A device according to claim **1**, wherein the transistor comprises three transistor stages, and each stage has a resistor connected in the collector circuit the value of resistance of the resistor associated with the first stage being n^2R, and the value of the resistor associated with the second stage being nR, where n is an integer between 15 and 20 and R is the resistance of the resistor associated with the third stage.

4. A device according to claim **1**, wherein the solid state infra-red radiation source, the radiation sensitive element and a zener diode are connected in parallel to provide a substantially constant current through these elements irrespective of the battery voltage.

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