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[31] 43/12053

[54] **IGNITION DEVICE FOR INTERNAL COMBUSTION ENGINE**
4 Claims, 1 Drawing Fig.

[52] U.S. Cl. 123/148
[51] Int. Cl. F02p 3/06
[50] Field of Search .... 123/148 (E), 179 (B); 315/209, 209 (CD), 214

[56] **References Cited**

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3,352,295	11/1967	Miki	123/179B
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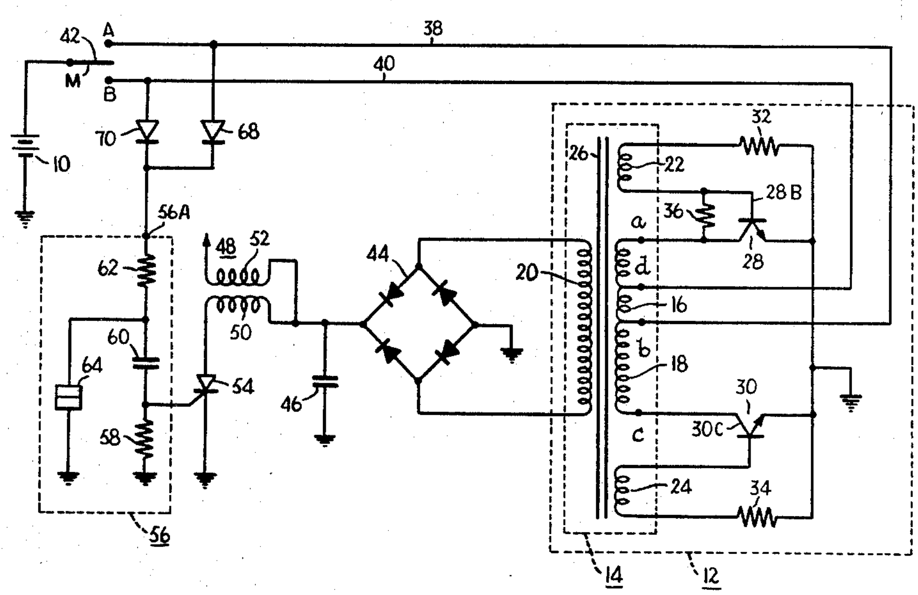
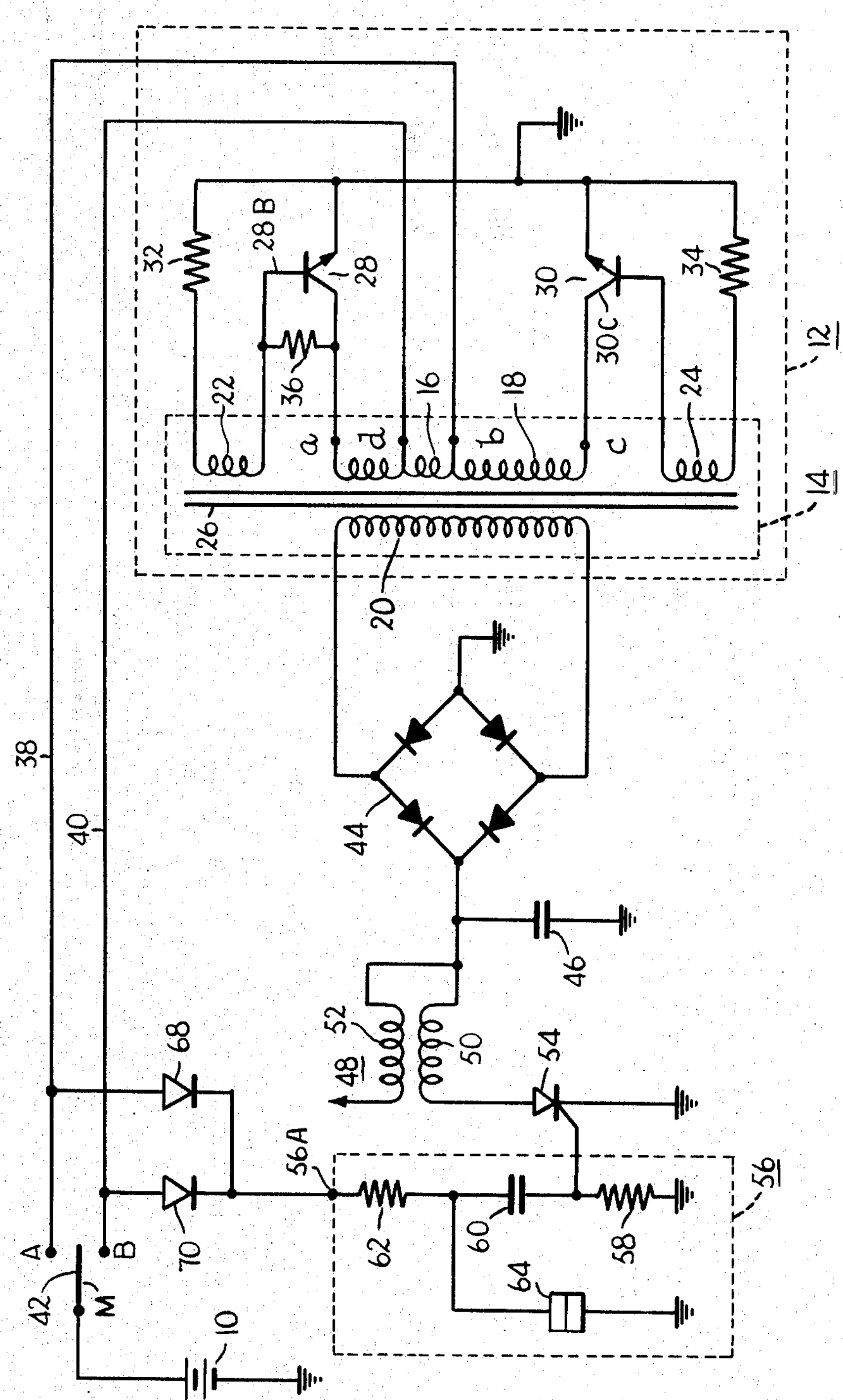
ABSTRACT: A low DC voltage boosted by an inverter and a rectifier charges a capacitor a charge on which is, in turn, discharged into an ignition coil under control of a thyristor. Upon starting the engine, the DC voltage is applied to an intermediate terminal of a primary transformer winding in the inverter. Diodes are connected in a circuit for gating the thyristor to prevent the circuit from partly short-circuiting the primary winding through the intermediate terminal.





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IGNITION DEVICE FOR INTERNAL COMBUSTION ENGINE

BACKGROUND OF THE INVENTION

This invention relates to an ignition device for use with an internal combustion engine equipped on a motor vehicle or the like and more particularly to improvements in such a device of capacitor discharge type.

The capacitor discharge type of ignition devices for use with internal combustion engines comprises generally a source of direct current, an inverter for converting a power of direct current provided by the source to a power of alternating current and increasing the voltage of the converted power, a rectifier for rectifying the power of alternating current from the inverter to provide a power of direct current, a capacitor charged with the power of direct current from the rectifier and a switch connected in a discharge circuit for the capacitor and operative in its closed position to discharge the charge on the capacitor into the associated ignition coil to produce an ignition voltage across the latter.

It has been commonly practiced that a source of electrical power for the ignition device referred to, that is, the source of direct current as above described is additionally used as a source of electrical power for an electric device for starting an internal combustion engine which is ignited by the ignition device. In most of motor vehicles the source of direct current is composed of a storage battery having a rating voltage of either 12 or 24 volts and the starting electric device is a starting electric motor through which a high load current is required to flow in operation. This flow of high load current through the motor causes a great decrease in voltage across the source of direct current. For example, with a storage battery having a rating voltage of 12 volts, the voltage thereacross will range from approximately 8 to 12 volts prior to starting the associated engine or after it has been started and it may decrease down to a minimum possible magnitude of approximately 67 percent of the rating voltage particularly when an electric device for starting the associated engine has a very high current flowing therethrough as in starting the engine in a cold district. Although the voltage across the source for the ignition device is ideally maintained always constant this leads to the necessity of providing separate sources of electrical power for the ignition and starting devices. However this measure is difficult to be realized in view of the standpoint of economy. Therefore it is highly desirable to provide an ignition device including means for compensating for any decrease in voltage applied thereto upon starting the associated engine whereby the engine is ignited with a sufficient ignition energy even under voltage decrease state.

An ignition device for an internal combustion engine meeting such requirements is described and claimed in U.S. Pat. No. 3,352,295 issued Nov. 14, 1967 to Takas Miki and assigned to the same assignee as the present application. Like the present invention the cited patent discloses in FIGS. 1 and 2 ignition devices for internal combustion engines including a capacitor. The capacitor has its discharge circuit adapted to be open and closed directly by a set of mechanical contacts. The contacts have then directly applied thereacross a high voltage, usually of from 300 to 600 volts from the capacitor. As a result, an electric arc is formed thereacross upon the opening thereof leading to a disadvantage that the contacts are brought into unusable state within a short period of time.

In order to eliminate that disadvantage, it is considered to dispose a thyristor in the discharge circuit for the capacitor. Because of no electric arc appearing in thyristors the use of a thyristor sufficiently high in dielectric strength makes it possible to form an ignition device longer in useful life than the mechanical contacts as above described. If a set of mechanical contacts such as above described is connected in a circuit for gating the particular thyristor, the contacts have only applied thereacross a voltage decreased by a factor of several tens as compared with the voltage directly provided by the capacitor as above described with the result that the occurrence of an electric arc across the contacts is scarcely called in question while insuring a long useful life of the resulting ignition device.

What is now called in question in the relationship between a circuit configuration for compensating for a decrease in direct current voltage applied to the associated inverter upon starting the engine and a circuit for gating the thyristor. According to Miki patent as above cited, an inverter includes a transformer provided on its input or primary winding with an intermediate terminal separated from its end terminals to present a higher turn ratio associated with the intermediate terminal to the output winding of the transformer. Then the primary winding have selectively supplied thereto an electrical energy through the intermediate terminal upon starting the engine and through one of the end terminals after the engine has been started.

On the other hand, the circuit for gating the thyristor is required to have an electrical energy supplied by the associated source of direct current during and after the operation of starting the engine while such supply of the electrical energy to the gating circuit must be terminated during the suspension of operation of the engine for the purpose of preventing the source from wastefully consuming the electrical energy. To this end, one conductor can be connected to the source of direct current through a switch adapted to be closed upon starting the engine thereby to supply an electrical energy to the input winding of the said transformer through the intermediate terminal while the other conductor can be connected to the source through another switch adapted to be closed after the completion of the operation of starting the engine thereby to supply an electrical energy to the input transformer winding through the one end terminal with both the conductors connected to a terminal on the source side of the gating circuit. In this case it is to be noted that means for connecting both the conductors to the said terminal of the gating circuit be prevented from short-circuiting that portion disposed between the intermediate and end terminal of the input transformer winding. This is because if such short-circuiting occurs then the magnetic core of the transformer is impeded from changing in magnetic flux resulting in a zero output from the transformer and therefore from the inverter.

SUMMARY OF THE INVENTION

Accordingly it is an object of the invention to provide a new and improved ignition device for use with an internal combustion engine having a long useful life and including means for compensating for a decrease in voltage applied to the device upon starting the engine and free from any short-circuiting fault while ensuring that the engine is ignited during the operation thereof without any waste of electrical energy during the suspension of operation of the engine.

With this object in view, the invention resides in an ignition device of capacitor discharge type for use with an internal combustion engine including an ignition capacitor charged with a rectified output from an inverter, and a thyristor connected in a circuit for discharging the capacitor and a pair of conductors for supplying electrical energies of direct current to an intermediate terminal and an end terminal of an input transformer winding in the inverter respectively, and a pair of semiconductor diodes connected to both the conductors respectively to cause an electrical energy to be selectively supplied from the conductors therethrough to a circuit for gating the thyristor, the diodes being so poled that a voltage of either polarity is prevented from causing a short-circuiting current to flow through that portion disposed between the intermediate and end terminals of the primary transformer winding.

BRIEF DESCRIPTION OF THE DRAWING

The invention will become more readily apparent from the following detailed description taken in conjunction with the accompanying drawing in which a single FIG. is a schematic circuit diagram of an ignition device for an internal combustion engine constructed in accordance with the principles of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to the drawing, it is seen that an arrangement disclosed herein comprises a source of direct current **10** such as a 12 v. storage battery equipped on a motor vehicle and an inverter generally designated by the reference numeral **12**. The inverter **12** comprises transformer generally designated by the reference numeral **14** including a pair of primary or input windings **16** and **18** connected in series circuit relationship, a single secondary or output winding **20** and a pair of tertiary windings **22** and **24** with all the windings inductively disposed on a saturable magnetic core **26**. The primary winding **16** includes a pair of end terminals *a* and *b* and an intermediate terminal *d* while the primary winding **18** includes one end terminal *c* and the other end terminal *b* common to the primary winding **16**. The conventional dot is used to indicate the polarity of each of the primary and tertiary windings.

A transistor **28** shown as being of the NPN type includes a collector electrode connected directly to the end terminal *a* of the primary winding **16**, a base electrode connected directly to one terminal of the tertiary winding **22** and an emitter electrode connected directly to the ground such a vehicle's chassis (not shown). Another transistor **30** shown as being also of NPN type includes similarly a collector electrode connected directly to the end terminal *c* of the primary winding **18**, a base electrode connected directly to one terminal of the tertiary winding **24** and an emitter electrode connected directly to the ground. The emitter electrodes of both the transistors **28** and **30** are connected to the other terminals of the tertiary windings **22** and **24** through resistors **32** and **34** respectively. Another resistor **36** is connected across the collector and base electrodes of the transistor **28** for the purpose of first flowing a forward base current through the transistor **28** upon starting the inverter **12**.

A pair of conductors **38** and **40** are connected at one end to the end and intermediate terminals *b* and *d* of the primary winding **16** and at the other ends to a pair of stationary contacts A and B of a transfer switch **42** including a movable arm M connected to one terminal, in this case, the positive terminal of the source **10** having the negative terminal connected to the ground. Thus it will be appreciated that the inverter **12** is operative to convert a direct current voltage supplied by the source **10** to an alternating current voltage and increase the latter voltage.

While the inverter **12** is shown as including the primary windings, the tertiary windings and the transistors in pairs to form a push-pull configuration it is to be understood that the inverter may be not necessarily of the push-pull type, if desired. In the latter case, the primary winding **18**, the tertiary winding **24** and the transistor **30** are omitted.

The secondary or output winding **20** of the transformer **12** has connected thereacross a single phase full wave rectifier **44** having a pair of alternating current input terminals connected to both ends of the winding **20**. The full wave rectifier **44** has one direct current output terminal connected to the ground and the other direct current output terminal connected to the ground through an ignition capacitor **46**.

An ignition coil of auto transformer type generally designated by the reference numeral **48** includes a primary winding **50** and a secondary winding **52** with the junction of both the windings connected to the junction of the rectifier **44** and the capacitor **46**. The secondary winding **52** has the other end connected to an ignition plug (not shown) and the primary winding **50** has the other end connected to a thyristor **54**. The thyristor **54** includes an anode electrode connected to the other end of the primary ignition winding **50**, a cathode electrode connected to the ground and a gate electrode **54**. The thyristor **54** along with the primary ignition winding **50** serially connected thereto forms a discharge circuit for the capacitor **46**.

In order to gate the thyristor **54**, a gating circuit enclosed with a dashed block **56** is operatively associated with the thyristor. The gating circuit **56** includes a resistor **58** connecting the gate electrode of the thyristor **54** to ground, a gating capacitor **60** connected to the junction of that cathode electrode and the resistor **58**, a resistor **62** connected to the capacitor **60** and a contact breaker **64** connected between the junction of the capacitor and resistor **60** and **62** respectively and the ground. The contact breaker **64** is arranged to be open and closed by a cam rotating in synchronization with the rotation of the associated engine in the well-known manner. The cam, and engine are well known in the art and therefore they are not illustrated. The breaker **64** is put in its open position at each ignition time of the engine.

The resistor **62** is connected to an input terminal **56A** to the gating circuit **56** which is, in turn, connected to the conductors **38** and **40** through the respective semiconductor diodes **68** and **70** each poled so as to permit a current to flow from the associated conductor **38** or **40** to the gating circuit **56** therethrough.

The transfer switch **42** as previously described has its movable arm M adapted to engage the contact B upon starting the engine and to engage the contact A after the completion of the starting operation and when the engine is put in operation. However it is noted that when the engine is out of operation the movable arm M assumes its neutral position as illustrated in the drawing. This is, none of the contacts A and B are in contact with the movable arm M.

In order to start the engine, a starting electric motor is connected to the source **10** through an on-off switch adapted to be closed when the movable arm M engages the contact B, although the motor and the on-off switch are not illustrated.

The arrangement thus far described is operated as follows:

The inverter **12** is a Royer circuit well known in the art and its operation will be briefly described. Upon applying a DC voltage from the source **10** to the inverter **12** through either one of the contacts A and B of the switch **42** as the case may be, the transistor **28** is first fired to permit a base current to flow therethrough. Then the transistor **28** is increasingly conducting through the feedback action of the tertiary winding **22** until the magnetic core **26** of the transformer **14** is driven to saturation. When the saturation of the magnetic core **26** has reached a point of contraflexure, the primary winding **18** has a low voltage induced in the reverse direction thereacross whereupon the transistor **30** is now fired, while the transistor **28** becomes nonconducting. Thereafter the process as above described is repeated with the conducting transistor **30**. In this way the transistors **28** and **30** are alternately conducting to produce across the secondary or output winding **20** an output of square waveform having a pulse recurrence frequency corresponding to the voltage across the source **10** and increased in magnitude or voltage by the particular turn ratio between the energized portion of the primary winding and the secondary winding. The output from the transformer **14** and therefore the inverter **12** is rectified by the full wave rectifier **44** and charges the ignition capacitor **46**.

Each time the thyristor **54** is conducting as will be described hereinafter, the charge on the capacitor **44** is discharged through the discharge circuit comprising the primary ignition winding **50** and the now conducting thyristor **54** whereupon a high voltage is induced across the secondary ignition winding **52** to ignite the engine in the well-known manner.

Under these circumstances, the thyristor **54** is controlled by the gating circuit **56**. More specifically, with the contact breaker **64** closed, a voltage across the gate and cathode electrodes of the thyristor **54** is of zero magnitude maintaining it nonconducting. Then if the contact breaker **64** is open, a charging current flows from the source **10** into the capacitor **60** through the switch **42** and the conductor **38** or **40** as the case may be. This charging current also flows through the resistor **58** to provide a voltage drop thereacross sufficient to gate the thyristor **54** whereupon the charge on the capacitor **44** is discharged as above described, when discharged the capacitor **46** cooperates with the primary ignition winding **50** to generate an oscillatory voltage at the instant this oscillatory voltage is reversely applied to the anode and cathode electrodes of the thyristor **54** the latter is brought into its open state ready for the succeeding ignition operation.

As previously described, the voltage across the source **10** is different in magnitude in the normal operation of the engine from the operation of starting engine resulting in a difference between ignition voltages available in both the operations. The invention contemplates to compensate for this difference between ignition voltages.

According to the principles of the invention, the movable arm M of the transfer switch **42** is in engagement with the contact A thereof during the normal operation of the engine. Then the source **10** is connected to the common terminal *b* of the primary transformer windings **16** and **18** through the movable arm and contact M and A respectively of the switch **42** and the conductor **38** while at the same time, it is connected to the input terminal **56A** to the gating circuit **56** through the movable arm M and contact A of the switch **42**, the conductor **38** and the diode **68**.

Under these circumstances, an output voltage V_o from the secondary or output winding **20** of the transformer **14** is expressed by

$$V_0=\frac{N_2}{Nab}V_B \qquad (1)$$

where:

N_2 = number of turns of secondary winding **20**;

N_{ab} = number of turns between terminals *a* and *b* of primary winding **16**, assuming that N_{ab} equals the number of turns N_{bc} between terminals *b* and *c* of primary winding **18**; and

V_B = voltage across source **10**.

Upon starting the engine the movable arm M is in engagement with the contact B of the switch **42** as previously described. The source **10** is electrically coupled to the intermediate terminal *d* of the primary winding **16** of the transformer **14** through the conductor **40** and also to the input terminal **56A** to the gating circuit **56** through the diode **70**.

Under these circumstances, an output voltage from the secondary transformer winding **20** is expressed by

$$V_0'=\frac{N_2}{N_{ab}-n}V_B' \qquad (2)$$

or

$$V_0''=\frac{N_2}{N_{bc}+n}V_B' \qquad (2')$$

V'_o = output voltage due to primary winding portion between terminals *a* and *d*;

V''_o = output voltage due to primary winding portion between terminals *d* and *c*; and

n = number of turns between terminals *d* and *b* of primary winding **16**. It is also assumed that the primary windings **16** and **18** are equal in the number of turns to each other. From the above equations (2) and (2') it is seen that V'_o is higher than V''_o. However it will be appreciated that the number of turns n between the terminals *d* and *b* of the primary winding **16** can be selected so as to render both the output voltages V'_o and V''_o approximately equal to each other in order to compensate for a difference between output voltages in the normal and starting operations of the engine.

In order to discuss the effect of the diodes **68** and **70**, it is now assumed that the conductors **38** and **40** have been connected directly to the input terminal **56A** to the gating circuit **56** with the diodes **68** and **70** omitted. Under the assumed conditions, that portion disposed between the terminals *b* and *d* of the primary transformer winding **16** is short-circuited by the conductors **38** and **40**. Thus in the operation of the inverter **12**, a short-circuiting current flows through that portion disposed between the terminals *b* and *d* of the primary winding **16** resulting in a decrease in output voltage from the secondary winding **20** of the transformer **14**. The purpose of the diodes **68** and **70** is to prevent this flow of short-circuiting current.

I claim:

1. An ignition device for use with an internal combustion engine, comprising, in combination:

1. a source of direct current;
2. inverter means including a transformer comprising a saturable magnetic core, an input winding, an output winding and a feedback winding, all said windings being inductively disposed around said magnetic core and a transistor connected to both said input winding and said feedback winding;
3. said primary winding having an end terminal and an intermediate terminal presenting to said output winding a turn ratio higher than does said end terminal;
4. a first conductor connected to said end terminal of said primary transformer winding and capable of being energized by said source;
5. a second conductor connected to said intermediate terminal of said primary transformer winding and capable of being energized by said source;
6. a transfer switch connected between said source and said first and second conductors such that, the same connects said source to said second conductor upon starting the engine and to said first conductor after the engine has been started and when it is in operation;
7. a rectifier for rectifying the output of the output winding of said transformer and an ignition capacitor charged with the rectified output of the output winding of said transformer of said inverter means;
8. an ignition coil including a primary winding and a secondary winding inductively coupled to each other, said primary winding having one end connected to said ignition capacitor;
9. a thyristor for controlling said ignition capacitor and operative in its closed state to permit said ignition capacitor to be discharged into said primary ignition coil winding to produce an ignition voltage across said secondary coil ignition winding, said thyristor having a control terminal;
10. a gating circuit controlling said thyristor and having an input terminal, means operable in synchronism with the rotation of the engine to produce a gating signal and an output terminal connected with the control terminal of said thyristor; and
11. a pair of semiconductor diodes having input and output terminals, means connecting the output terminals of both of said diodes to the input terminal of said gating circuit, means connecting the input terminal of one of said diodes with said first conductor, and means connecting the input terminal of the other of said diodes with said second conductor.

2. An ignition device as claimed in claim **1**, wherein said transformer of said inverter means includes additionally another of said inverter means includes additionally another input winding and a separate feedback winding inductively disposed around said magnetic core, and wherein another transistor is connected to both said another input winding and said separate feedback winding, said transistors being alternately turned on and off.

3. An ignition device as claimed in claim **1**, wherein said primary ignition winding is serially connected to said thyristor, the series arrangement of said primary ignition winding and thyristor being connected in parallel circuit relationship to said ignition capacitor.

4. An ignition device as claimed in claim **1**, wherein said gating circuit includes a set of contacts capable of being open and closed in synchronization with the rotation of the engine, a gating capacitor charged by said source upon the opening of said set of contacts, and a resistor connected to said gating capacitor to be traversed by a charging current for the latter to produce a voltage applied as a gating signal to said thyristor.