(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) Publication number: 0 481 609 A2

(12) **EUROPEAN PATENT APPLICATION**

(21) Application number: **91308654.2**

(51) Int. Cl.^{5}: **F02P 15/00**, F02C 7/26

(22) Date of filing: **24.09.91**

(30) Priority: **21.06.91 GB 9113489**
19.10.90 GB 9022734

(43) Date of publication of application:
22.04.92 Bulletin 92/17

(84) Designated Contracting States:
DE FR GB IT

(71) Applicant: **LUCAS INDUSTRIES PUBLIC LIMITED COMPANY**
Brueton House, New Road
Solihull, West Midlands B91 3TX(GB)

(72) Inventor: **Khan, Mohammad Gulistan**
75, Clipston Road
AlumRock, Birmingham, B8 3HH(GB)
Inventor: **Livings, Rodney**
12, Stirling Avenue
Waterlooville, Portsmouth, PO7 7NH(GB)

(74) Representative: **Robinson, John Stuart et al**
Marks & Clerk Alpha Tower Suffolk Street
Oueensway
Birmingham, B1 1TT(GB)

(54) **HT exciter for turbine ignition system.**

(57) A high tension exciter for use in a gas turbine ignition system. The exciter comprises a power supply for charging an energy store (12). The energy store (12) is periodically discharged, via a solid state switch (13), into a pulse transformer (15). The pulse transformer (15) has a step-up action, and transforms the voltage from the energy store (12) into a voltage suitable for operating an ignition plug of a gas turbine engine.

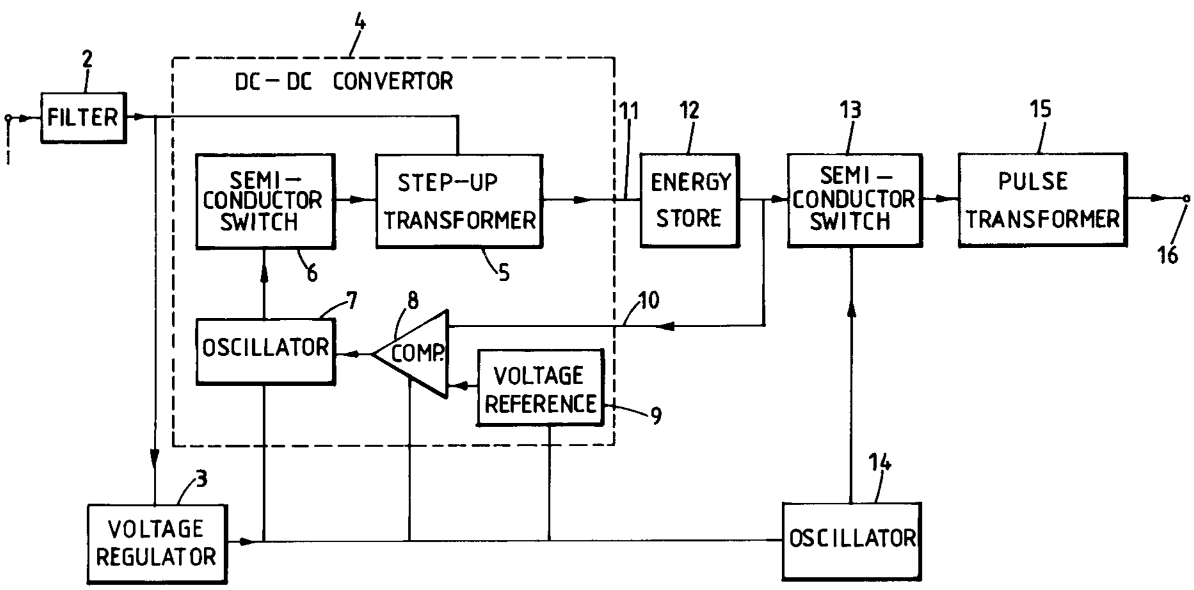

FIG. 1.

EP 0 481 609 A2

The present invention relates to an HT exciter for a turbine ignition system. Such an exciter may be used in ignition systems for gas turbines, such as jet engines in aircraft.

Conventional ignition systems for gas turbines used mechanical means, such as tremblers, to allow the high tension required by a sparking plug to be derived from a low tension source, such as a battery. However, more recently, such systems have been replaced by electronic "solid state" systems in which the relatively low voltage is converted into a suitable voltage for actuating a sparking plug in several stages. An example of such a system is disclosed in EP-0 369 236. In the first stage, a direct current to direct current (DC-DC) converter increases the voltage, for instance lying between a few volts and a few tens of volts, to a high voltage, typically a few thousand volts. The high voltage charges an energy storage device, such as a capacitor, in readiness for an ignition actuation signal. When this signal is received, the energy storage device is discharged into an inductor which is connected in series with the ignition plug.

In order to improve the ignition characteristics, it is known to use a saturable inductor in series with the ignition plug. Such an inductor has a relatively high inductance while it passes a current below a threshold level such that the core of the inductor is not magnetically saturated. However, once the current increases above this level, the inductance falls to a lower value as the core saturates. Thus, the current through the ignition plug rises relatively slowly and is of prolonged duration. The rate of ageing of the ignition plug is thus reduced and better ignition characteristics are obtained. Also, the rate of increase of current through a solid state switch is reduced during the initial switching on of the switch so as to reduce stress on the switch and prolong its life expectancy.

Switching of such high voltages requires careful selection of suitable switching means. Solid state switches, such as thyristors, are preferable in order to provide accurate control of ignition timing. However, single thyristors are unsuitable for operation at several kilovolts. In order to overcome this problem, EP-0 382 907 proposes the use of a plurality of thyristors connected in series and triggered simultaneously. However, an individual gate drive circuit has to be provided for each thyristor. Also, a voltage sharing circuit has to be provided so as to ensure that the HT voltage is shared evenly among the thyristors so that the maximum voltage rating of each thyristor is not exceeded. The cost and complexity of exciters of this type are thus increased.

According to a first aspect of the invention, there is provided an HT exciter for a turbine ignition system, comprising an energy store, a power supply for charging the energy store, a voltage step-up pulse transformer, and discharging means for discharging the energy store into the pulse transformer.

Preferably the exciter is arranged to reduce the HT voltage as the output current increases. The pulse transformer may be arranged to saturate as the output current increases so as to reduce and/or remove the voltage step-up action of the transformer. The pulse transformer may be arranged as an autotransformer. The autotransformer may have a winding with a step-up portion which is arranged to be substantially short-circuited automatically after discharging or after an initial phase of discharging of the energy store into the pulse transformer, for instance by at least one diode connected across the step-up portion and arranged to be reverse-biased during discharge or an initial discharge phase and forward-biased thereafter or during a succeeding phase.

The energy store is preferably a capacitor, and the power supply is preferably a DC-DC converter arranged to charge the capacitor to a predetermined voltage.

The discharging means is preferably a solid state switch, such as silicon controlled rectifier or thyristor.

The exciter preferably includes an oscillator for actuating the discharging means at a predetermined repetition rate.

It is thus possible to provide an HT exciter of the solid state type which is capable of providing excellent performance using, for instance, a single solid state switch. Such an exciter is less complex and less expensive than known types, while providing desirable output voltage and current waveforms for ignition and for reducing stress on the solid state switch.

According to a second aspect of the invention, there is provided an ignition system including an exciter according to the first aspect of the invention.

It is thus possible to provide an exciter and a turbine ignition system which are relatively easy and less expensive to design and manufacture, and whose performance is subject to lower tolerances.

The invention will be further described, by way of example, with reference to the accompanying drawings, in which:

Figure 1 is a block schematic diagram of an exciter constituting an embodiment of the invention;

Figure 2 is a circuit diagram of the exciter of Figure 1; and

Figure 3 is a circuit diagram of an exciter constituting a further embodiment of the invention.

The same reference numerals refer to corresponding parts in the drawings.

The exciter of Figure 1 receives low voltage DC power, for instance from the normal power supply system of an aircraft, at an input terminal 1. Power is supplied, for instance, from an engine switch-on control system actuated automatically or manually whenever ignition of the engine is required. The power supply typically provides a nominal voltage of 28 volts, but this can vary substantially during normal operation.

The power supply is filtered by a filter 2 and supplied to a voltage regulator 3 and a DC-DC converter 4. The converter 4 comprises a step-up transformer 5 connected to receive filtered power from the filter 2 and controlled by a semi-conductor switch 6. The semi-conductor switch 6 is controlled by an oscillator 7 which is in turn controlled by a comparator 8. The comparator has a first input connected to a voltage reference 9 and a second input which forms a voltage controlling input 10 of the converter 4. The oscillator 7, the comparator 8, and the voltage reference 9 receive power from the voltage regulator 3.

The output 11 of the converter 4 is connected to an energy store 12 whose output is connected to a semi-conductor switch 13 and to the input 10 of the converter 4. The semi-conductor switch 13 is controlled by an oscillator 14 which receives power from the voltage regulator 3. The semi-conductor switch 13 controls the discharge of energy from the energy store 12 to a saturable voltage step-up pulse transformer 15 which is connected to an output terminal 16 of the exciter.

In use, the converter 4 converts the relatively low voltage received at the input terminal 1 and filtered by the filter 2 to a relatively high voltage, for instance of the order of a kilovolt, at its output terminal 11. The semi-conductor switch 6 chops the primary current of the transformer 5 at a rate determined by the oscillator 7 whenever the oscillator is enabled by the comparator 8. The comparator 8 compares the voltage of the energy store 12 with the voltage supplied by the reference 9, and disables the oscillator 7, and hence the converter 4, when the voltage of the energy store reaches the reference voltage. The voltage regulator 3 prevents the operation of the converter 4 from being substantially affected by variations in the aircraft supply.

The semi-conductor switch 13 is periodically actuated by the oscillator 14, which receives its power supply from the voltage regulator 3 so as to eliminate or reduce the effects of variations in power supply to the exciter. Whenever the semi-conductor switch 13 is actuated, it discharges the energy store 12 into the pulse transformer 15. The pulse transformer 15 increases the voltage to an HT value, for instance of several kilovolts, which is supplied from the output terminal 16 via a suitable HT lead to an ignition plug in a turbine engine such as an aircraft jet engine. The pulse transformer 15 includes means for adapting the current waveform supplied to the ignition plug, as will be described with reference to Figure 2.

As shown in Figure 2, the filter 2 comprises a diode 20, a choke 21, capacitors 22 and 23, and a resistor 24. The output of the filter is supplied to the transformer 5 and via a resistor 25 to the gate of a power MOSFET which constitutes the semi-conductor switch 6.

The voltage regulator 3 comprises a Zener diode 26, a resistor 27, an integrated circuit voltage regulator device 28, and capacitors 29 to 32. The Zener diode 26 provides a pre-regulated voltage directly to some parts of the circuit and to the regulator device 28, whose output provides a stable low noise source of power.

The MOSFET 6 has a source connected via a resistor 33 to a common supply line connected to another input terminal 34 of the exciter. The drain of the MOSFET 6 is connected to one end of the primary winding of the transformer 5, the other end of the winding being connected to the filter 2. The drain of the transistor 6 is also connected to the common supply line via a network comprising a diode 34, a resistor 35, and a capacitor 36.

The gate of the transistor 6 is connected to the oscillator 7, which comprises an operational amplifier 37, a capacitor 38, a transistor 39, a diode 40, and resistors 41 to 46. The oscillator 7 is controlled by a gating arrangement comprising a transistor 48 and resistors 49 to 52. One input of this gating arrangement is connected to the comparator 8, which comprises an integrated circuit operational amplifier or comparator 53, a diode 54, and resistors 55 and 56. The voltage reference 9 is provided by a potential divider comprising resistors 57 and 58.

The oscillator 14 comprises an operational amplifier 59, a capacitor 60, resistors 61 to 65, and a diode 66.

The output of the oscillator 14 is connected to the gating arrangement between the comparator 8 and the oscillator 7 so as to ensure that the converter 4 is switched off whenever the thyristor 13 is actuated. The gate of thyristor 13 is actuated by means of a drive circuit comprising transistors 47 and 67, a diode 68, capacitors 69 and 70, and resistors 71 to 75. This arrangement provides sufficient drive current and suitable level shifting for the gate of the thyristor 13, the thyristor gate drive current being supplied by the pre-regulated supply provided by the Zener diode 26 and the resistor 27 so as not to disturb the power supply provided by regulator device 28.

The secondary winding of the transformer 5 is connected via a diode 80 to the capacitor 12 which forms the energy store. The voltage across the capacitor 12 is fed back via a resistor 81 to the comparator 8. Filtering components are provided in the form of a diode 82, a capacitor 83, and a resistor 84.

The pulse transformer 15 comprises a first winding connected between the capacitor 12 and the common supply line via a resistor 85 and a capacitor 86. A free-wheel diode 87 is connected from the capacitor 12 to the common supply line.

The pulse transformer 15 has a second winding connected between the capacitor 12 and an inductor 88, the inductor being connected in series with the output terminal 16. Two normally reverse-biased diodes 89 and 90 are connected across the second winding of the transformer 15.

The exciter operates whenever power is supplied to the terminal 1 as described hereinbefore. Whenever the thyristor 13 is switched off by the oscillator 14, and whenever the voltage across the capacitor 12 is less than a predetermined voltage represented by the reference voltage supplied by the reference 9, the gating arrangement permits the oscillator 7 to operate. The power MOSFET 6 thus chops the direct current flowing through the primary winding of the transformer 5, and the stepped-up voltage pulses produced at the secondary winding of the transformer 5 charge up the capacitor 12. Whenever the voltage across the capacitor 12 reaches, for instance, 1.5 Kv corresponding to the voltage of the reference 9, the output of the comparator 8 changes state and, via the gating arrangement, disables the oscillator 7. Likewise, whenever the oscillator 14 actuates the thyristor 13, the oscillator 7 is disabled.

The oscillator 14 actuates the thyristor 13 at a predetermined repetition rate. When the thyristor 13 is actuated, it discharges the capacitor 12 into the pulse transformer 15, which supplies an HT voltage through the inductor 88 to the ignition plug.

During the initial discharge phase, the capacitor 12 is discharged into the pulse transformer 15. The diodes 89 and 90 are reverse-biased and the pulse transformer therefore operates as a voltage step-up autotransformer. The duration of this initial phase is largely determined by the inductance of the "primary" winding of the transformer 15 together with the values of the resistor 85 and the capacitor 86, whose value is much less than that of the capacitor 12. Thus, a narrow pulse of several kilovolts is produced.

Once the spark gap of the ignition plug has broken down, current flows through the plug via the inductor 88 and the diodes 89 and 90. The rate of change of current is limited by the inductor 88. The core of the transformer 15 saturates as the current increases so that the transformer ceases to operate, the resistance of the "secondary" winding being short-circuited by the diodes 89 and 90. The capacitor 12 is thus effectively connected (via the inductor 88) directly to the ignition plug through which it discharges to maintain the spark. The exciter thus provides a narrow high energy pulse during the initial phase and an extended low energy pulse during the succeeding phase. The rate of change of current is limited by the inductor 88 but is greater than during the initial phase. Thus, the initial rate of increase of current through the thyristor 13 is limited to a safe value within its rating and the spark created by the ignition plug is prolonged. The voltages to which the thyristor 13 is subjected are well within the voltage ratings of a single thyristor. This improves the ignition performance and prolongs the life of the ignition plug and the thyristor 13.

When drive to the gate of the thyristor 13 is removed by the oscillator 14, the oscillator 7 is re-enabled and begins to charge the capacitor 12 for the next ignition pulse. The above-described process is repeated for as long as power is supplied to the input terminal 1.

Figure 3 shows a second embodiment of the present invention.

Power for the solid state ignition system is derived from an aircraft power supply. First and second power lines 101 and 102 are connected to a ground terminal 103 via tranzorbs 104 and 105. A tranzorb 106 is connected between the first power line 101 and the second power line 102. The first power line 101 includes a series inductor 107 and the second power line 102 includes a series inductor 108.

Following the inductors 107 and 108, a capacitor 109 interconnects the first and second power lines 101 and 102. Capacitors 110 and 111 connect the first and second power lines 101 and 102 to a ground terminal 112 respectively. A reverse polarity protection diode 113 and a fuse 114 are connected in series between the first power line 101 and a filtered and protected power supply line 201. Reservoir capacitors 115 and 116 are connected between the power supply line 201 and the power supply line 102.

A first terminal of a resistor 117 is connected to the power supply line 201. A second terminal of the resistor 117 is connected to the cathode of a zener diode 118. The anode of the zener diode 118 is connected to the second supply line 102. The collector of a first transistor 119 is connected to the power supply line 201. The base of the first transistor 119 is connected to the second terminal of resistor 117. The emitter of the first transistor 119 is connected to a first terminal of a resistor 120, to a first terminal of a resistor 125, to a first terminal of a resistor 130 and to the "+Vin" pin of a pulse width modulator integrated circuit 136 type No.SG1526J available from SGS-Thomson Microelectronics Srl.

A second terminal of the resistor 120 is connected to a first terminal of a capacitor 121, a first terminal of the primary winding 122 of a first transformer, and a cathode of a diode 124. A second terminal of the capacitor 121 is connected to the second supply line 102. The drain terminal of a first MOSFET 123 is connected to a second terminal of the primary winding 122 of the first transformer. The drain terminal of the first MOSFET 123 is also connected to the anode of the diode 124 and the cathode of a diode 132. The source terminal of the first MOSFET 123 is connected to the second supply line 102. The gate terminal of the first MOSFET 123 is connected to a second terminal of the resistor 125 and to the anodes of diodes 126, 127 and 128. The cathode of the diode 126 is connected to pin 15 of a CMOS counter integrated circuit 129 type No.4020. Pin 1 of the counter 129 is connected to the cathode of the diode 127, pin 2 to the cathode of the diode 128, and pins 8 and 11 to the second power supply 102. Pins 10 and 16 are connected to pins 12 and 18, respectively, of the pulse width modulator 136.

Pin 18 of the pulse width modulator 136 is also connected to a first terminal of a resistor 134, the first terminal of a resistor 133 and the first terminal of a capacitor 131. A second terminal of the capacitor 131 is connected to the second supply line 102. Pin 14 of the pulse width modulator 136 is connected to a second terminal of the resistor 130, pin 5 is connected to the anode of the diode 132, and pins 9 and 10 are connected to the second supply line 102 via a resistor 135 and a capacitor 139, respectively.

Pin 2 of the pulse width modulator 136 is connected to a second terminal of the resistor 133, a first terminal of a resistor 137 and a first terminal of a resistor 141. Pin 1 of the pulse width modulator 136 is connected to a second terminal of the resistor 134, a first terminal of a resistor 138 and a first terminal of a resistor 142. Pins 6, 11 and 15 of the pulse width modulator 136 are connected to the second supply line 102, as are a second terminal of the resistor 138 and a second terminal of the resistor 137.

A first terminal of the primary winding of a step up transformer 143 is connected to the collector of the first transistor 119. A second terminal of the primary winding of transformer 143 is connected to the drain terminal of a second MOSFET 144. The gate terminal of the second MOSFET 144 is connected to pin 13 of the pulse width modulator 136. A current sensing resistor 146 is connected at a first end to the source terminal of the second MOSFET 144 and at a second end to the second power line 102. A resistor 145 is connected between pin 7 of the pulse width modulator 136 and the first end of the current sensing resistor 146. A capacitor 140 is connected between pin 7 of the pulse width modulator and the second power line 102.

A first terminal of the secondary winding of the step up transformer 143 is connected to the anode of a fly back diode 147. The cathode of the diode 147 is connected to the cathode of a diode 148, a second terminal of the resistor 141, a first terminal of a capacitor 149, the anode of a thyristor 151 and a first terminal of a storage capacitor 154. The anode of the diode 148 is connected to a ground terminal 163. A second terminal of the capacitor 149 is connected to the ground terminal 163 via a resistor 150. The cathode of the thyristor 151 is connected to the ground terminal 163. A gate terminal of the thyristor 151 is connected via a resistor 152 to a first terminal of a secondary winding 153 of the first transformer. A second terminal of the secondary winding 153 of the first transformer is connected to the ground terminal 163, as is a second terminal of the secondary winding of the step up transformer 143.

A second terminal of the storage capacitor 154 is connected to the anode of a diode 155, a first terminal of a resistor 157, a second terminal of resistor 142 and a second terminal of an autotransformer 158. The cathode of the diode 155 is connected to the anode of a diode 156. The cathode of the diode 156 is connected to the ground terminal 163. A second terminal of the resistor 157 is connected to the ground terminal 163. A first terminal of the autotransformer 158 is connected via series capacitors 159 and 160 to the ground terminal 163. A third terminal of the autotransformer 158 is connected to a first terminal of an igniter 162. The second terminal of the igniter 162 is connected to the ground terminal 163.

The tranzorbs 104, 105 and 106 are arranged to remove high voltage spikes on the power lines 101 and 102. The inductors 107 and 108 in combination with the capacitors 109, 110 and 111 are arranged to filter the power supply. The reverse polarity protection diode protects the electronic components if the supply polarity becomes reversed.

The zener diode 118, in conjunction with the resistor 117 and the first transistor 119, forms a regulated power supply for the pulse width modulator 136. The pulse width modulator has a repetition rate set by the resistor 135 and the capacitor 139.

The storage capacitor 154 is charged to and maintained at 800V by the action of the pulse width modulator 136, the second MOSFET 144, and the transformer 143, with voltage feedback provided by the voltage monitoring network formed by the resistors 133, 134, 137, 138, 141 and 142. The resistor 146 measures the current through the second MOSFET 144 and, when the required current is reached, the drive signal to the gate of the second MOSFET 144 is removed. The current through the primary of the step up transformer 143 falls rapidly and, by virtue of the transformer action, a high voltage pulse is formed at the secondary of the step up transformer 143. The storage capacitor is charged by the pulses from the secondary of the step up transformer 143.

The counter 129 receives its power from pin 18 of the pulse width modulator 136. The counter 129 counts the number of charging cycles and, when a predetermined number is reached (as set by the diodes 126, 127 and 128), the first MOSFET 123 discharges the capacitor 121 through the primary winding 122 so as to fire the thyristor 151. The energy stored in the storage capacitor 154 is transferred to the igniter 162 when the thyristor 151 is fired. The action of the autotransformer 158 steps up the voltage from the capacitor 154 from around 800V to about 3000V to cause a spark. The thyristor 151 is protected against excessive rates of change of voltage by the resistor 150 and the capacitor 149, and against excessive rates of change of current by the secondary of the autotransformer 158.

While the thyristor 151 is conducting, the pulse width modulator 136 is disabled via the diode 132 so as to prevent charging of the storage capacitor. After the thyristor 151 has fired, the whole operation is repeated.

Thus, when the voltage across the storage capacitor 154 is below the required voltage, for instance following its discharge, the storage capacitor 154 is rapidly recharged by a series of constant frequency pulses. Although the pulses are of nominally constant width, the actual pulse width may vary in accordance with the time taken for the current through the MOSFET 144 to reach the required value. For instance, this time may be affected by power supply variations. The pulses then cease. However, any charge leakage is detected by the voltage monitoring network 133, 134, 137, 138, 141, 142 and the modulator 136 causes the charge to be "topped-up" as necessary by causing occasional narrow charging pulses to be supplied. The ignition system is thus always ready for the next actuation, which occurs after a number of clock pulses from the modulator 136 determined by the counter 129 and the gate formed by the diodes 126 to 128 and the resistor 125.

In one possible modification of the embodiment of Figure 3, the counter 129 is replaced by an oscillator controlling the ignition firing rate. The firing rate may thus be made independent of the repetition rate of the modulator 136.

Claims

1. A high tension exciter for a gas turbine ignition system, comprising an energy store (12,154) and a power supply (4) for charging the energy store (12,154), characterised by a voltage step-up pulse transformer (15,158), and discharging means (13,151) for discharging the energy store (12,154) into the pulse transformer (15,158).

2. An exciter as claimed in claim 1, characterised by means for reducing the high tension as the output current increases.

3. An exciter as claimed in claim 1 or 2, characterised in that the pulse transformer (15,158) has a saturable core arranged to saturate at a predetermined output current.

4. An exciter as claimed in any one of the preceding claims, characterised in that the pulse transformer (15,158) is an autotransformer.

5. An exciter as claimed in any one of the preceding claims, characterised by means (89,90) for short-circuiting at least part of a secondary winding of the pulse transformer (15,158) after an initial phase of discharging of the energy store (12,154) into the pulse transformer (15,158).

6. An exciter as claimed in claim 5, characterised in that the short circuiting means is at least one diode (89,90).

7. An exciter as claimed in any one of the preceding claims, characterised in that the power supply (4) is a direct current to direct current converter.

8. An exciter as claimed in any one of the preceding claims, characterised in that the power supply (4) is arranged to charge the energy store (12,154) to a predetermined voltage, and thereafter maintain the energy store (12,154) substantially at the predetermined voltage before discharge.

9. An exciter as claimed in any one of the preceding claims, characterised in that the energy store is a capacitor (12,154).

10. An exciter as claimed in any on of the preceding claims, characterised in that the discharging means (13,151) is a solid state switch.

11. An exciter as claimed in claim 10, charac-

terised in that the discharging means (13,151) is a silicon controlled rectifier.

12. An exciter as claimed in any one of the preceding claims, characterised in that the discharging means (13,151) is arranged to discharge the energy store (12,154) into the pulse transformer (15,158) at a predetermined repetition rate.

13. An exciter as claimed in any one of the preceding claims, characterised by means (88) for limiting the rate of change of current through the discharge means (13,151).

14. An exciter as claimed in any one of the preceding claims, characterised by means for temporarily disabling the power supply (4) from charging the energy store (12,154) during the discharging of the energy store (12,154).

15. An ignition system including an exciter as claimed in any one of the preceding claims.

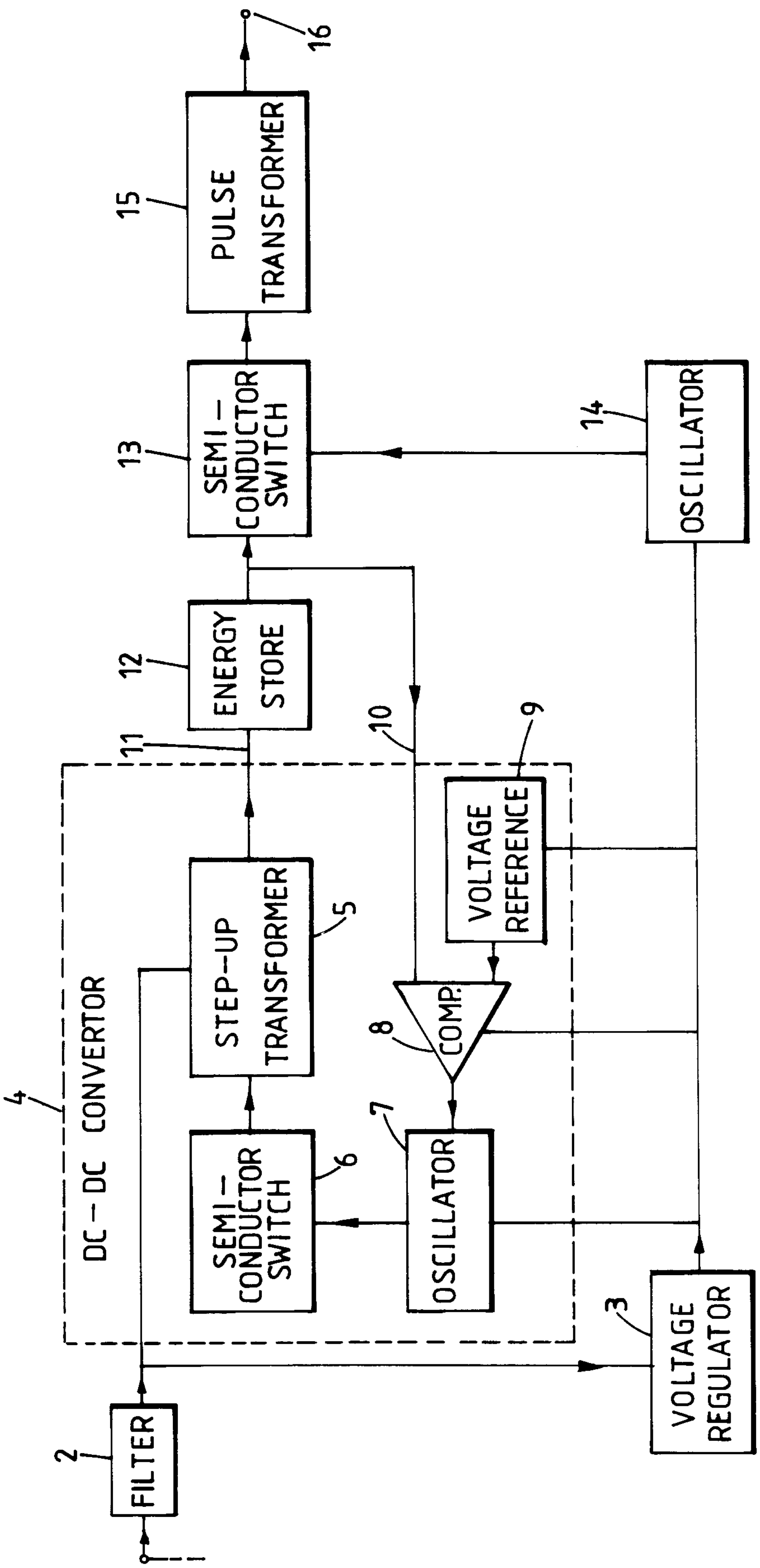
FILTER
2
VOLTAGE REGULATOR
3
DC - DC CONVERTOR
4
STEP-UP TRANSFORMER
5
SEMI-CONDUCTOR SWITCH
6
OSCILLATOR
7
COMP.
8
VOLTAGE REFERENCE
9
10
11
ENERGY STORE
12
SEMI-CONDUCTOR SWITCH
13
OSCILLATOR
14
PULSE TRANSFORMER
15
16

FIG. 1.

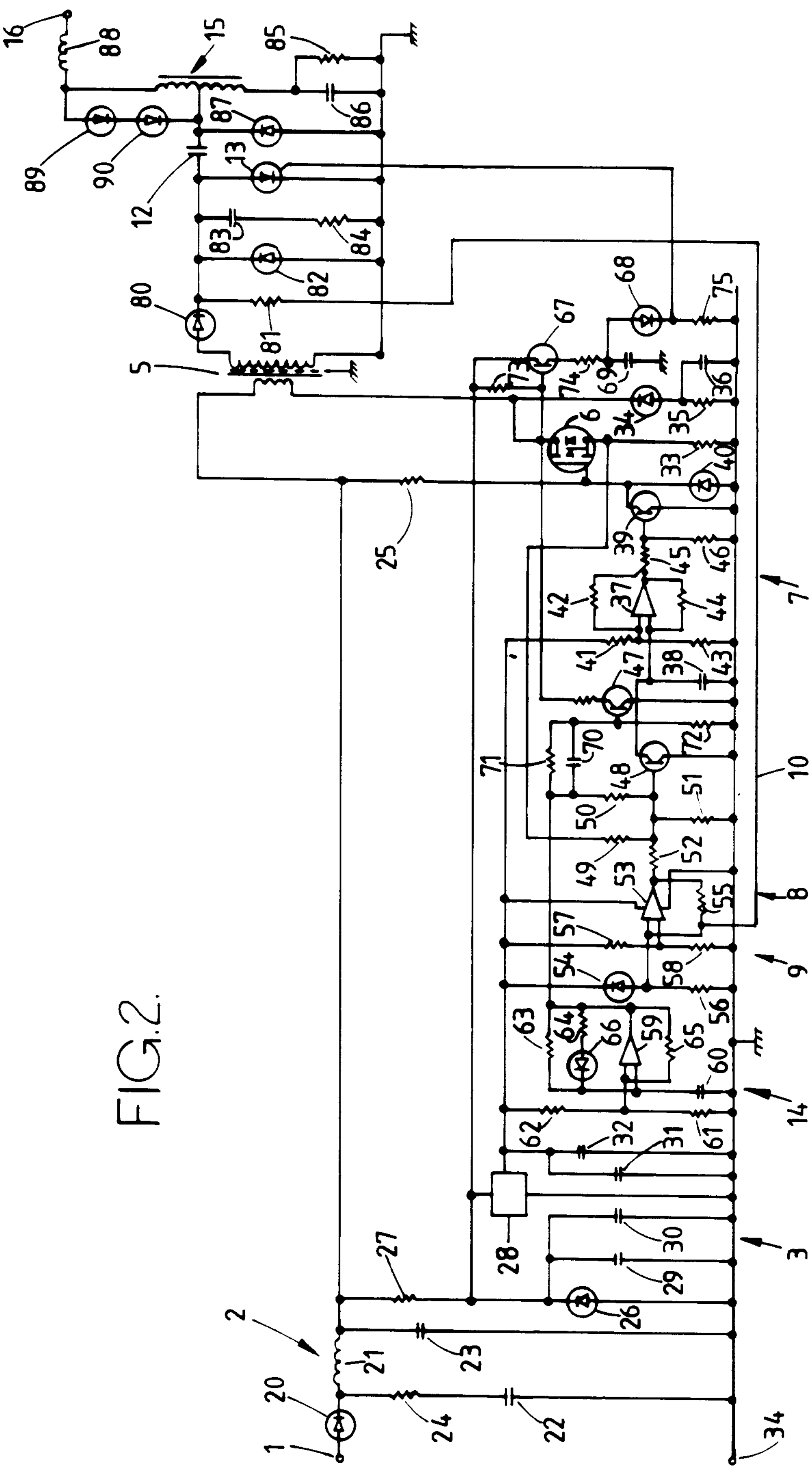

FIG.2.

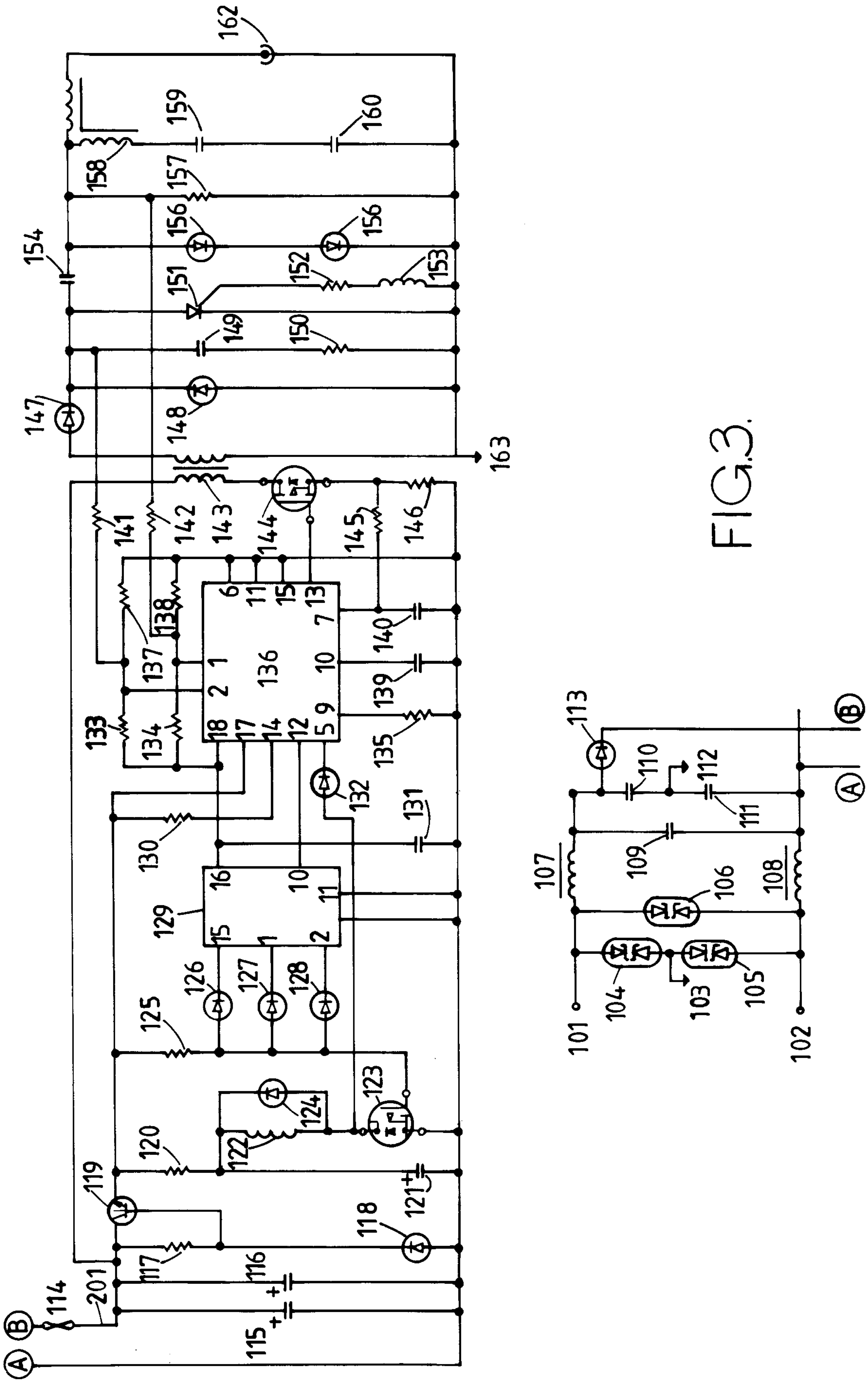
A
B
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
156
157
158
159
160
162
163
201

FIG.3.