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Leskin

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[54] **LAMP FLASHING CIRCUIT**

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[51] **Int. Cl.** **H05b 37/00**

[58] **Field of Search** ..... 315/223, 200 A, 241 S, 315/242

[56] **References Cited**

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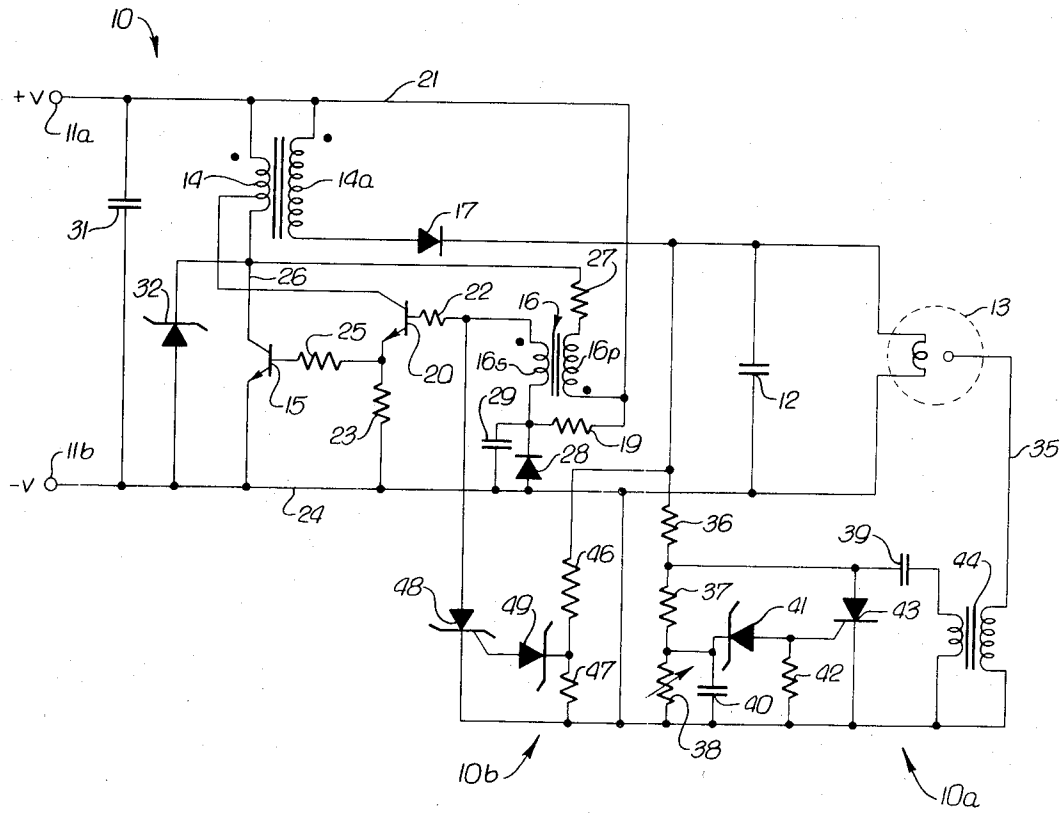
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Assistant Examiner—Lawrence J. Dahl
Attorney—Fred Flam et al.

[57] **ABSTRACT**

A circuit for flashing a xenon or other high power flash lamp employs a capacitor incrementally charged from a non-saturating inductor storing energy supplied at a low dc voltage. A transistor switches current to the inductor. The transistor is controlled by a transformer having a primary connected across the inductor. At the beginning of each capacitor charging cycle the transistor is turned on by regenerative action through the transformer. Current is supplied to the inductor until the transformer saturates, causing transistor turn-off. Energy stored in the inductor then is transferred to the capacitor via a diode. A reverse current coupled through the transformer maintains the transistor off until substantially all energy stored in the inductor has been transferred to the capacitor. The charging cycle repeats until the voltage across the capacitor is sufficient to fire the lamp.

14 Claims, 2 Drawing Figures



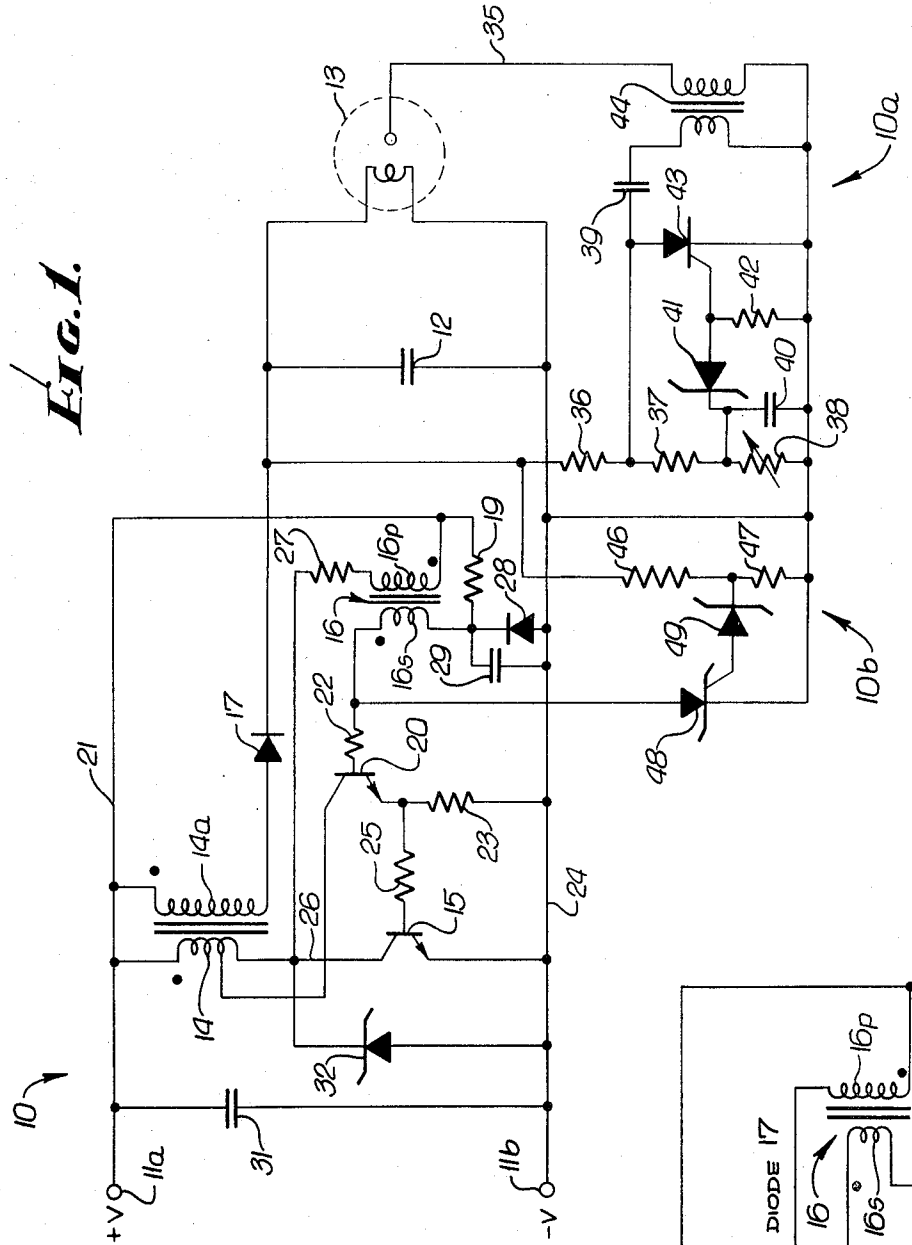

10
11a
+V
-V
11b
12
13
14
14a
15
16
16p
16s
17
19
20
21
22
23
24
25
26
27
28
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48
49
10a
10b

FIG. 1.

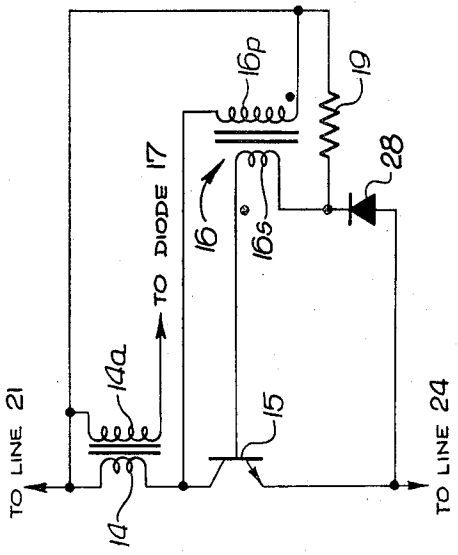

TO LINE 21
TO DIODE 17
TO LINE 24
14
14a
15
16
16p
16s
19
28

FIG. 2.

LAMP FLASHING CIRCUIT

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to a lamp flashing circuit, and particularly to a high efficiency circuit for incrementally charging a capacitor to a high voltage.

2. Description of the Prior Art

For many applications it is desirable to operate a xenon or other high power flash lamp from a low voltage dc supply. One such use is in a building security system having a burglar alarm connected to a police station or a private security agency. A high power flash lamp is mounted atop the building and connected to flash when the burglar alarm is tripped. The flashing light, visible at some distance, allows a police helicopter or patrol car to spot the building readily at night. Chances of apprehending the thief are improved. Battery operation is desirable to insure lamp flashing even if the thief should disable ac power to the building.

High intensity xenon flash lamps operate at a relatively high voltage, usually above 200 volts. Circuitry must be provided to convert a low dc supply to a voltage sufficient to fire the lamp. Typically this is done by repetitively, inductively storing energy at battery voltage, then transferring the energy from the inductor to the capacitor. In this way, the capacitor is charged incrementally to a level sufficient to fire the flash lamp. The problem is one of efficiency in the energy transfer operation. In prior art circuits efficiencies below 50 percent are the rule. Much of the energy not transferred to the capacitor is lost as heat, so that thermal dissipation from the circuit package becomes a serious consideration. More important, the low efficiency severly shortens the time period during which flashing can be powered with a certain battery. For example, if 19 watts are required to flash the lamp once per second, a 24 volt, 6 ampere hour battery will flash the lamp once per second for a period of only 1.5 hours at 40 percent efficiency. One object of the present invention is to provide a lamp flashing circuit having higher efficiency, typically greater than 75 percent, with concomitant lower heat loss and longer flashing time for a particular battery than has been possible in the past.

Other prior art problems relate to the manner of incrementally charging the capacitor. In one type of circuit the battery is connected to the inductor by an electronic switch. The capacitor and a diode are connected across the switch. With the switch closed, current is stored in the inductor. At the instant when the current reaches a preselected value, the switch is opened. As the magnetic field of the inductor collapses, the stored energy is conducted via the diode to the capacitor. Although simple in concept, the circuit is difficult to implement since the switch must be operated at a precise instant, requiring special circuitry to sense current through the inductor. Furthermore, a diode having very fast turn-off speed is required. If the diode does not turn off rapidly when energy transfer to the capacitor is completed, current may flow back through the diode and appear across the switch, which may be closing for the next cycle. Efficiency is reduced, and catastrophic damage to a semiconductor switch may result.

Another prior art approach involves the use of a blocking oscillator having a transformer which functions both as a feedback element and for energy storage. The oscillator cycle is established by saturation of

the transformer. However, the energy stored in an inductor is proportional to LI^2 where L is the inductance and I is the current. At saturation the inductance L is minimum. Accordingly, with the blocking oscillator transformer operating near saturation, less than maximum energy storage is achieved and significant loss results.

In inverter-type capacitor charting circuits, the efficiency is limited by compliance voltage considerations to less than about 50 percent.

Thus it is another object of the present invention to provide a capacitor charging circuit which does not require a diode having fast turn-off time, and wherein the inductor used for energy storage is operated at a non-saturating level to achieve optimum energy transfer efficiency.

SUMMARY OF THE INVENTION

These and other objects are achieved by providing a lamp flashing circuit wherein current to an energy storage inductor is switched by a transistor. Conduction of the transistor is controlled by a transformer having a primary connected across the inductor. At the beginning of each capacitor charging cycle the transistor is turned on by regenerative action through the transformer. The transistor remains on until the transformer saturates. During this on time, current is supplied to the inductor, which does not saturate. When the transistor switches off, the inductively stored energy is coupled via a diode to the capacitor. A reverse current coupled through the transformer maintains the transistor off until the inductor has completely discharged, completing the charging cycle. The action repeats until the voltage across the capacitor is sufficient to fire the lamp.

BRIEF DESCRIPTION OF THE DRAWINGS

A detailed dscription of the invention will be made with reference to the accompanying drawings, wherein:

FIG. 1 is an electrical schematic diagram of a preferred embodiment of the inventive lamp flashing circuit.

FIG. 2 is a fragmentary electrical schematic diagram of a simplified version of the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENTS

The following detailed description is of the best presently contemplated modes of carrying out the invention. This description is not to be taken in a limiting sense, but is made merely for the purpose of illustrating the general principles of the invention since the scope of the invention best is defined by the appended claims.

Operational characteristics attributed to forms of the invention first described also shall be attributed to forms later described, unless such characteristics obviously are inapplicable or unless specific exception is made.

Referring now to FIG. 1, the inventive lamp flashing circuit **10** is powered by a battery or other dc supply connected across the terminals **11a**, **11b**. Energy from this supply is used to charge a capacitor **12** to a voltage sufficient to fire a xenon or other flash lamp **13**. Such charging is accomplished incrementally by storing energy in a non-saturating inductor **14** during an interval when a transistor **15** is biased on by circuitry including a transformer **16**. The energy stored in the inductor **14**

then is transferred via a diode 17 to the capacitor 12. The transistor 15 is held off during the entire energy transfer duration, as described below, so that the diode 17 need not exhibit fast turn-off characteristics.

At the beginning of each capacitor 12 charging cycle no energy is stored in the inductor 14 and the transformer 16 is not saturated. Turn-on of the transistor 15 is achieved by regenerative action involving feedback through the transformer 16. To this end, a starting voltage is supplied by a resistor 19 to the base of a low power transistor 20 via a path including the supply terminal 11*a*, a line 21, the resistor 19, the secondary 16*s* of the transformer 16 and a current limiting resistor 22.

The collector of the transistor 20 is connected directly to a tap on the inductor 14. The transistor 20 emitter is connected via a resistor 23 and a line 24 to the other supply terminal 11*b*, and via a resistor 25 to the base of the transistor 15. Thus the voltage supplied via the resistor 19 causes the transistor 20 to begin conduction, driving the base of the transistor 15 positive. The transistor 15 itself starts to go on, tending to clamp the collector and the line 26 toward the negative potential of the terminal 11*b*.

Accordingly, a current path is provided from the positive terminal 11*a* via the line 21 the primary 16*p* of the transformer 16, a current limiting resistor 27 and the collector-emitter of the transistor 15 to the negative terminal 11*b*. The resultant current flow through the transformer primary 16*p* induces in the secondary 16*s* a signal which enhances the positive starting voltage at the transistor 20 base. Thus the transistor 20, and hence the transistor 15 both are driven further into conduction. This regenerative action causes the transistor 15 rapidly to reach the condition of maximum conduction.

When the transistor 15 conducts, current is supplied to the inductor 14 from the dc supply via the collector-emitter path of the transistor 15. This current causes energy to be stored in the form of a magnetic field in the inductor 14. Current flow through the transistor 15, and concomitant energy storage in the inductor 14, continues until the transformer 16 saturates. The parameters of the transformer 16 and the inductor 14 are selected so that such transformer 16 saturation occurs while the inductor 14 is still unsaturated.

When the transformer 16 saturates, transformer action ceases and a positive voltage no longer is induced in the secondary 16*s*. The transistor 20 base voltage decreases correspondingly, and the bias supplied via the resistor 19 is insufficient by itself to keep the transistor 20 on. As a result, the transistor 20 turns off, causing the transistor 15 base to go negative and the transistor 15 to turn off. This opens the current path through the transformer primary 16*p*, inducing in the secondary 16*s* a negative going pulse which reinforces turn-off of the transistors 20 and 15.

As soon as the transistor 15 turns off, current no longer is supplied to the inductor 14. The magnetic field in the inductor 14 starts to collapse, and the energy stored therein is inductively coupled to a winding 14*a* and thence via the diode 17 to the capacitor 12. Substantially all the energy stored in the inductor 14 is transferred to the capacitor 12.

As the inductor 14 magnetic field collapses, a reverse current appears across the inductor 14. This current also flows through the transformer primary 16*p* to induce in the secondary 16*s* a voltage which is negative at the base of the transistor 20. The secondary 16*s* current flow is through the path including the resistor 22, the base-emitter path of the transistor 20, the resistor 23, the line 24 and a diode 28 shunted by a capacitor 29. As a result, the transistor 20, and hence the transistor 15, is clamped off so long as the inductor 14 is discharging. The transistor 15 will not turn on until substantially all of the energy stored in the inductor 14 has been transferred to the capacitor 12. The diode 17 need not exhibit fast turn-off time, since it is the discharge of the inductor 14 which determines how long the transistor 15 is clamped off irrespective of the diode 17 characteristics.

When the inductor 14 has discharged completely, current flow momentarily will cease through the transformer 16. This completes the charting cycle and returns the circuit 10 to the initial condition for the next capacitor charging cycle, now initiated by the starting signal supplied via the resistor 19. Note that the diode 28 polarity prevents flow therethrough of this turn-on signal.

A capacitor 31 filters the supply voltage, and a Zener diode 32 protects the transistor 15 from damage by high voltage spikes which may occur in the circuit 10.

Eventually the voltage across the capacitor 12 will become sufficient to fire the flash lamp 13. A circuit 10a detects when this voltage level has been reached and provides a pulse on a line 35 to ignite the flash lamp 13. To this end, a voltage divider including three resistors 36, 37, 38 is connected across the capacitor 12. As the capacitor 12 charges, the voltage developed across the resistors 37, 38 is used to charge a capacitor 39 and another capacitor 40 is charged by the voltage across the resistor 38.

When the voltage across the capacitor 12 reaches a lamp flashing level, the capacitor 40 will be charged sufficiently to actuate a trigger diode 41 and discharge via a resistor 42. The resultant current will trigger a silicon controlled rectifier (SCR) 43. As a result, the capacitor 39 rapidly will discharge through the SCR 43 and the primary of an ignition transformer 44. The current pulse induced in the transformer 44 secondary is supplied via the line 35 to ignite the flash lamp 13, which flashes as the capacitor 12 discharges. The next flashing cycle then begins.

If for some reason the lamp 13 should not flash, the charge on the capacitor 12 might continue to increase to the level of capacitor destruction. To prevent this, a protector circuit 10*b* inhibits charging operation when the voltage across that capacitor exceeds the level at which the lamp 13 is set to flash.

The circuit 10*b* uses a voltage divider comprising two resistors 46, 47 connected across the capacitor 12. Should the charge on the capacitor 12 exceed the lamp firing level, the voltage at the junction of the resistors 46, 47 will be sufficient to gate on an SCR 48 via a trigger diode 49. Conduction of the SCR 48 effectively clamps the base of the transistor 20 to the negative supply terminal 11b, thereby preventing turn-on of the transistor 20. This clamps off the transistor 15 inhibiting further energy storage by the inductor 14, thereby terminating the capacitor 12 charging operation.

In the simplified circuit of FIG. 2 the transformer secondary 16s is connected directly (or via a current limiting resistor not shown) to the transistor 15 base. The transistor 20 is eliminated. The transistor 15 must be capable of switching the relatively high current to the

inductor **14** and have relatively high gain. In the FIG. **1** embodiment, the control signals are effectively amplified by the low power transistor **20**, so that the transistor **15** need not exhibit high gain.

The circuit of FIG. **1** exhibits high efficiency, typically on the order of 80 percent. Thus with a **12** volt battery supplying **24** watts (**2** amperes) to the terminals **11***a*, **11***b*, the capacitor **12** may be charged once per second to 19 watts. Using a flash lamp **13** rated at 19 joules, the circuit **10** thus could flash the lamp once per second. With a 6 ampere-hour battery, such flashing could continue for three hours.

By way of example only, the inductor **14** may comprise a coil of nineteen turns, with a tap at sixteen turns, wound on a toroidal core of molybdenum alloy powder material. The secondary winding **14**a may comprise a coil of about 235 turns wound on the same core. The transformer **16** may have a primary of 100 turns wound on a ferrite toroidal core also containing a secondary of about 50 turns.

As an alternative to using the secondary winding **14**a for coupling energy to the capacitor **12**, the diode **17** may be connected directly to the inductor **14.** However with such arrangement, the transistor **15** should be capable of withstanding a voltage equal to that developed across the capacitor **12.** Using the secondary winding **14***a* as shown, the transistor **15** need only withstand a voltage equal to that across the capacitor **12** times the secondary **14***a*-to-inductor **14** turns ratio.

Intending to claim all novel, useful and unobvious features shown or described, the applicant claims:

1. A lamp flashing circuit powered by a dc supply and including a capacitor charged incrementally during successive charging cycles to a level sufficiently high to flash said lamp, comprising:

a semiconductor switching device,

an inductor connected in series with said device across said supply,

means for coupling energy stored in said inductor to said capacitor as the field of said inductor collapses,

a control transformer having a primary connected in parallel with said inductor and a secondary operatively connected to control said switching device,

circuit means including said transformer secondary for regeneratively turning on said switching device at the beginning of each charging cycle to permit current flow to said inductor for energy storage therein,

said control transformer saturating before saturation of said inductor, saturation of said transformer causing turn-off of said switch device to terminate said current flow to said inductor, the resultant collapse of said inductive field inducing a reverse polarity signal in said transformer secondary which maintains said switching device off until substantially all energy stored in said inductor has been coupled to said capacitor.

2. A lamp flashing circuit according to claim **1** wherein said power switching device comprises a first transistor and where said circuit means comprises:

a circuit connecting one terminal of said transformer secondary to the base of said first transistor,

a first diode connecting the other terminal of said transformer secondary to a terminal of said supply, and

a resistor connected between said transformer secondary other terminal and the other terminal of said supply to provide, in conjunction with the output of said transformer, a signal regeneratively initiating turn-on of said first transistor.

3. A lamp flashing circuit according to claim **2** wherein said circuit connecting comprises:

a second transistor having a base connected to said transformer secondary one terminal and operatively connected to turn on said first transistor when said second transistor is on.

4. A lamp flashing circuit according to claim **3** wherein one non-control element of said second transistor is connected to a tap on said inductor and wherein the other non-control element is resistor connected to a terminal of said supply and to the base of said first transistor.

5. A lamp flashing circuit according to claim **1** wherein said means for coupling comprises:

a secondary winding inductively coupled to said inductor, and

unidirectional current flow means connecting said secondary winding to said capacitor.

6. A lamp flashing circuit according to claim **5** further comprising:

voltage divider means for sensing when the voltage across said capacitor is sufficient to flash said lamp, and

ignitor means cooperating with said voltage divider means for igniting said lamp when sufficient capacitor voltage is sensed.

7. A lamp flashing circuit according to claim **6** further comprising:

means for inhibiting the incremental charging of said capacitor should the voltage across said capacitor substantially exceed said sufficient voltage.

8. A circuit powered by a low voltage dc source for incrementally charging a capacitor during successive charging cycles to a high voltage, comprising:

an inductor,

a transistor connected in series with said inductor across said source to provide current from said source to said inductor when said transistor is on,

a transformer having a primary connected across said inductor and a secondary, said transformer saturating prior to said inductor,

circuit means connecting one terminal of said transformer secondary to the control electrode of said transistor,

bias supply means cooperating with current induced in said transistor secondary regeneratively to drive said transistor into conduction at the beginning of each charging cycle, conduction of said transistor causing current flow to said inductor with concomitant inductive energy storage therein, until saturation of said transformer causes said transistor to turn off, thereby terminating current flow to said inductor,

energy transfer means for transferring the stored energy from said inductor to said capacitor as the magnetic field in said inductor collapses subsequent to turn-off of said transistor,

reverse current induced in said transformer secondary as said inductor field collapses maintaining said transistor off while substantially all of the energy stored in said inductor is transferred to said capacitor.

9. A circuit according to claim 8 together with a winding inductively coupled to said inductor and a diode connecting said winding to said capacitor, collapse of the magnetic field in said inductor resulting in energy transfer via said winding and said diode to said capacitor.

10. A circuit according to claim 9 wherein the reverse current resultant as said inductor field collapses produces via said transformer a signal maintaining said transistor off, said circuit including a second diode operatively connected to permit flow of said signal.

11. A circuit according to claim 10 wherein said second diode and the secondary of said transformer are connected in series between one terminal of said source and a transistor base, and wherein said bias supply means comprises a resistor connected from the other terminal of said source to the junction of said second diode and said transformer secondary, and wherein said transformer produces prior to saturation a signal enhancing conduction of the transistor providing current to said inductor.

12. A circuit according to claim 11 wherein said transformer secondary is connected to the base of the transistor providing current to said inductor.

13. A circuit according to claim 11 together with a second transistor connected to control conduction of said transistor providing current to said inductor, and wherein said transformer secondary is connected to the base of said second transistor.

14. A circuit according to claim 8 together with a flash lamp connected to be powered by the energy stored in said capacitor, and means for igniting said lamp when the voltage across said capacitor reaches a value sufficient to flash said lamp.

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