Sept. 16, 1969 C. D. SKIRVIN 3,467,887

LIGHTING SYSTEM

Filed Aug. 28, 1967 3 Sheets-Sheet 1

Fig. 1

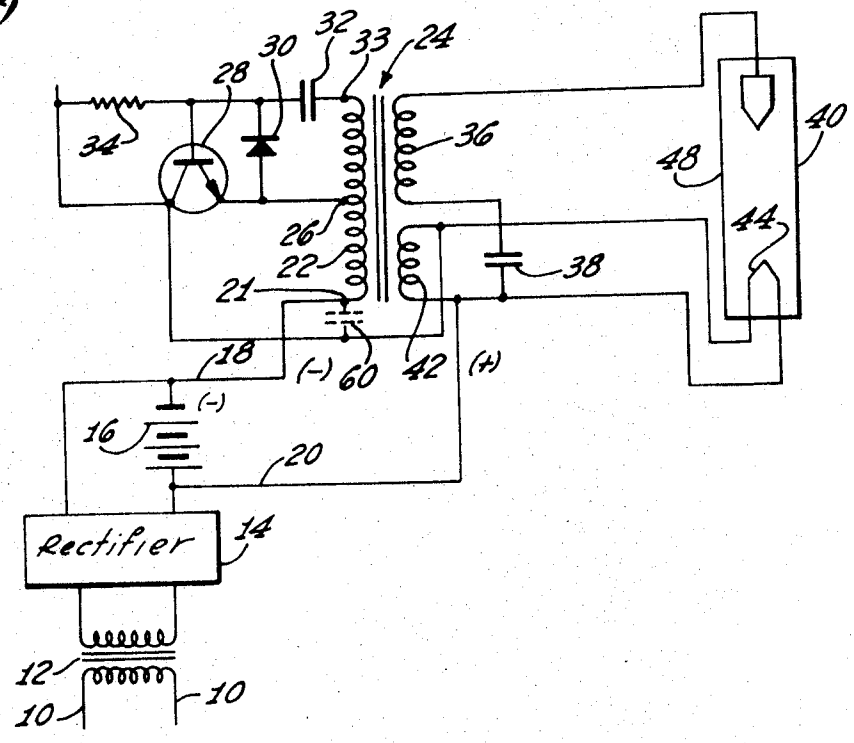
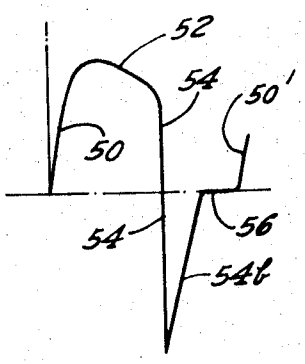


Fig. 2



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Sept. 16, 1969 C. D. SKIRVIN 3,467,887

LIGHTING SYSTEM

Filed Aug. 28, 1967 3 Sheets-Sheet 2

Fig. 3

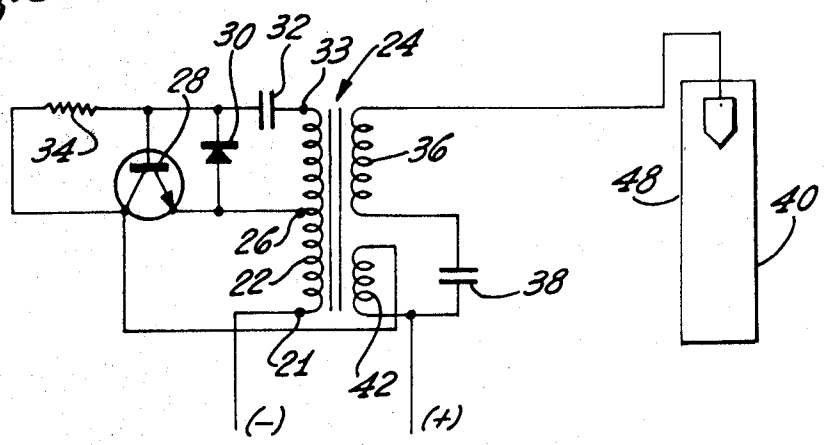
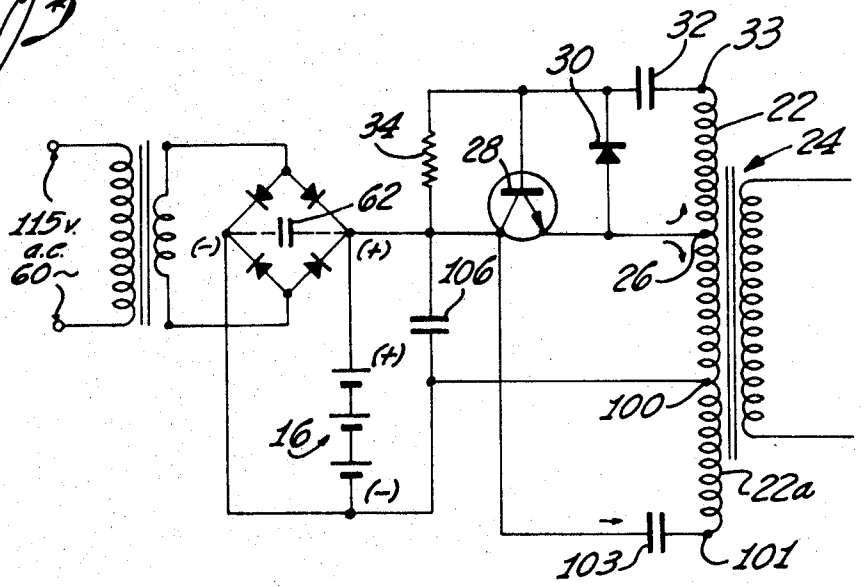


Fig. 4



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Sept. 16, 1969 C. D. SKIRVIN 3,467,887

LIGHTING SYSTEM

Filed Aug. 28, 1967 3 Sheets-Sheet 3

Fig. 5

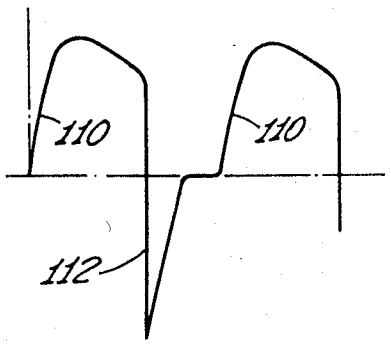
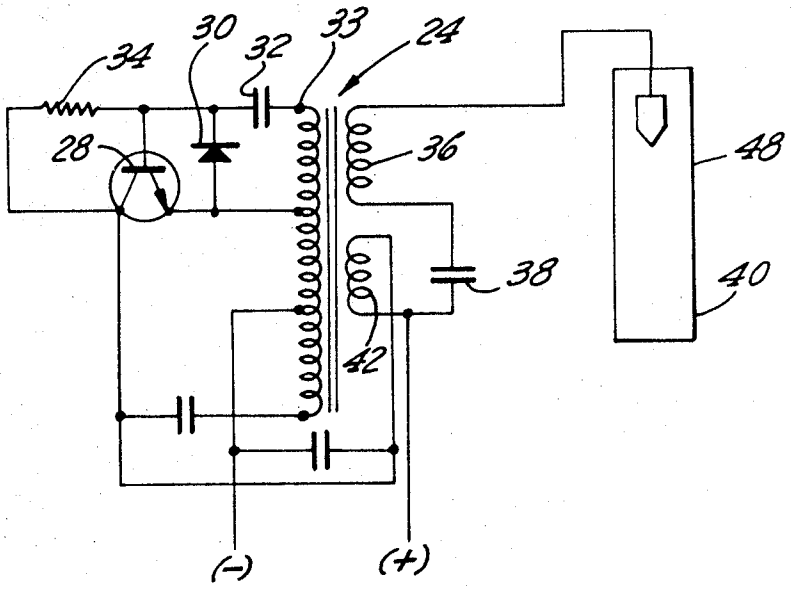


Fig. 6



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United States Patent Office 3,467,887 Patented Sept. 16, 1969

3,467,887

LIGHTING SYSTEM

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Int. Cl. H05b 37/02
U.S. Cl. 315—209 15 Claims

ABSTRACT OF THE DISCLOSURE

This invention relates to a lighting system in which a direct voltage of a relatively low value is used to illuminate a luminescent tube such as a fluorescent tube. The system includes a current control member such as a transistor which is normally biased to a state of conductivity. A first reactance such as the primary winding of a transformer is connected to the source of direct voltage and to the transistor to store energy during the time that the transistor is conductive. A second reactance such as a capacitor is also connected to the current control member and the primary winding of the transformer to store energy during the time that the transistor is conductive.

When the capacitor becomes charged to a particular value, it starts to discharge through a second current control member such as a diode which is connected to the transistor and which is connected in a circuit with the primary winding of the transformer and the capacitor. During the time that the capacitor is discharging through the diode, the transistor is biased to a state of nonconductivity.

In this way, the transistor is alternately triggered to the conductive and nonconductive states. When the transistor is triggered to the nonconductive state, the low impedance provided by the diode across the primary winding of the transformer prevents the electromotive force in the transformer from producing voltage surges which would tend to damage the transformer.

The transformer has a secondary winding which is connected across the luminescent tube to illuminate the tube. During the time that the transistor is conductive, a current flows through the secondary winding and the luminescent gas to excite the gas in the tube. When the transistor becomes nonconductive, the energy stored in the transformer discharges through the luminescent tube.

The transformer may have a third winding when the luminescent tube has a filament. This third winding is connected across the filament and in a circuit with the transistor. This causes the third winding to provide a relatively low impedance across the filament during the time that the transistor is conductive. This low impedance tends to limit the flow of current through the filament. However, when the transistor is nonconductive, the third winding provides a high impedance across the filament so that a relatively great current flows through the filament. In this way, the filament receives an alternating current so as to become heated and emit electrons for exciting the tube.

This invention relates to a lighting system employing a direct voltage of relatively low amplitude to illuminate a luminescent tube such as a fluorescent tube. The invention is especially advantageous since it provides a relatively low drain of power on the source of direct voltage so that the luminescent tube can continue to be illuminated for a relatively great period of time such as several hours without requiring that the source of direct voltage be recharged.

The safety codes of all buildings in major cities provide that exit lights be illuminated at all times to indicate to

those in the buildings where exits are located in the buildings in case of emergency. The exit lights are energized normally by the power introduced to the building from the main power lines which carry alternating current. The systems energizing such exit lights include a battery which is charged by the signals in the main power lines during the time that power is available in these lines. However, if there should be a power failure of any kind, the batteries provide energy to the exit lights to obtain an illumination of the exit lights.

Systems are also desired which can be carried by people in an office or in a home in case of a power failure. For example, even in this day of advanced technology, people have to light candles in their homes in case of a power failure. The use of candles is inefficient since the candles do not provide very much illumination. Furthermore, candles are dangerous since they involve the use of a flame open to the atmosphere.

Various attempts have been made to provide exit lights or portable lights but these attempts have not been completely successful for various reasons. One reason is that the exit lights now in use have not been able to provide an illumination for any extended length of time after a power failure has occurred. Another reason is that the systems for operating the exit lights now in use are fairly complicated. The same problems exist with respect to the portable lights now in use.

This invention provides a system for energizing an exit light or a portable light for an extended period of time such as several hours after a power failure has occurred. This results from the operation of the system constituting this invention to drain energy from a source of direct voltage such as a battery at a relatively low rate. The system is also advantageous, since it uses a minimum number of parts and since it provides certain compensating features to regulate the energizing of the luminescent tube even when the characteristics of the luminescent tube vary from one unit to the next, and even when the characteristics of each individual luminescent tube vary with age.

The system including this invention has a first current control member such as a transistor which is normally biased to maintain the transistor in the conductive state. First reactance means such as a transformer are connected to the transistor and to the source of direct voltage to introduce a voltage to the transistor for triggering the transistor to a state of conductivity from a nonconductive state. When the transistor becomes conductive, current flows through a circuit including the transistor, the transformer and the source of direct voltage. Current also flows through a circuit including the transistor, the transformer and second reactance means such as a capacitor. The flow of current through the capacitor and the transformer causes energy to be stored in the transformer and in the capacitor.

When the energy stored in the capacitor reaches a particular level, the capacitor becomes discharged through a second current control member such as a diode. The diode is connected to the transistor so as to bias the transistor to a state of nonconductivity by the forward impedance across the diode when the diode is conductive. In this way, the diode maintains the transistor nonconductive during the time that the capacitor is discharging through the transistor. Upon becoming discharged to a relatively low level, the bias normally produced in the transistor is able to become operative to trigger the transistor to a state of conductivity.

In this way, the transistor becomes alternately conductive and nonconductive at a particular frequency dependent upon the characteristics of certain elements including the value of the capacitor. The waveform pro-

duced in the transformer by the alternate production of conductive and nonconductive states in the transistor is nonsinusoidal so that the signal in the transformer has a fundamental frequency and also has harmonics. The fundamental frequency and the harmonics are instrumental in exciting the gas in the luminescent tube to produce an illumination in the tube.

Various embodiments are provided for the system constituting this invention. In one embodiment, the luminescent tube is provided with a filament constructed to emit electrons when heated. An additional winding is provided in the transformer and is connected across the filament to produce an alternating current through the filament for exciting the filament to emit electrons. The alternating current is produced in the filament because of the operation of the transistor in becoming alternately conductive and nonconductive. In a second embodiment, the additional winding may be used as a choke when the luminescent tube does not have a hot cathode which is energized upon becoming heated.

In another embodiment of the invention, an additional portion is included in the primary winding of the transformer. This portion is connected in the circuit in a relationship to minimize any flow of direct current through the circuit. As will be appreciated, a direct current is not advantageous in the circuit since it does not aid in the formation of the alternating signal in the transistor. Furthermore, the direct current tends to drain the source of direct voltage so as to minimize the time in which the luminescent tube can be illuminated by power from the source of direct voltage.

In the drawings:

FIGURE 1 is a circuit diagram of one embodiment of the invention;

FIGURE 2 illustrates the voltage waveform introduced to the luminescent tube in FIGURE 1;

FIGURE 3 is a circuit diagram of a second embodiment of the invention;

FIGURE 4 is a circuit diagram of a third embodiment of the invention;

FIGURE 5 illustrates the voltage waveforms produced at strategic terminals in the embodiment shown in FIGURE 4; and

FIGURE 6 is a circuit diagram of a fourth embodiment of the invention.

In the embodiment of the invention illustrated in FIGURE 1, alternating voltage is introduced from power lines **10** through a transformer **12** to a rectifier **14**. The transformer **12** may be adapted to reduce the voltage on the lines **10** from a value such as 115 volts RMS to a suitable value such as 5 volts RMS. The rectifier **14** may constitute a whole wave or a half wave rectifier of known construction. The output from the rectifier **14** is introduced to a source of direct voltage such as a battery **16** which may be formed from a plurality of nickel cadmium battery cells of known construction. The cells may be connected to provide a negative voltage on a line **18** and a positive voltage on a line **20**.

The line **18** is connected to a terminal **21** at one end of a primary winding **22** of a transformer generally indicated at **24**. The primary winding **22** has an intermediate tap **26** which is connected to an input electrode of a current control member. The input electrode may constitute an emitter when the current control member constitutes a transistor **28**. A connection is also made from the intermediate tap **26** to a second current control member such as a diode **30**. For example, the connection may be between the intermediate tap **26** and the plate of the diode **30**. The control electrode of the first current control member such as the base of the transistor **28** is connected to the cathode of the diode **30** and is also connected to one plate of a capacitor **32**, the second plate of which is connected to a terminal **33** at the other end of the primary winding **22**. The base of the transistor **28** is also connected to one terminal of the resistor **34**, the other terminal of which is connected to the collector of the transistor.

The transformer **24** also has a secondary winding **36** which is connected with a capacitor **38** in a circuit including the two electrodes of a luminescent tube **40**. The luminescent tube may be a fluorescent tube of conventional construction. The transformer **24** further includes a tertiary winding **42** which is connected across a filament **44** in the tube **40**. The filament **44** may be considered as one of the electrodes in the tube. The winding **42** and the filament **44** are connected between the positive line **20** of the battery **16** and the collector of the transistor **28**.

Since a negative voltage is introduced from the line **18** to the terminal **21** of the primary winding **22** in FIGURE 1 and since the terminal **33** of the primary winding is connected through the capacitor **32** and the resistor **34** and the winding **42** to the positive line **20**, the terminal **33** of the primary winding in FIGURE 1 is more positive than the terminal **21** of the winding or than the intermediate tap **26**. This causes the voltage on the base of the transistor **28** to become more positive than the voltage on the emitter of the transistor so that the transisor becomes conductive. The conductivity of the transistor **28** is facilitated by the operation of the resistor **34** in providing a bias between the base and collector of the transistor in a direction for facilitating the flow of current between the base and collector of the transistor. When the transistor **28** becomes conductive, current flows through a circuit including the battery **16** or the rectifier **14**, the line **20**, the tertiary winding **42**, the collector and emitter of the transistor **28** and the portion of the primary winding **22** between the intermediate tap **26** and the terminal **21** in FIGURE 1. This flow of current is in a direction for inducing a voltage in the primary winding **22** in a direction for obtaining a positive voltage on the terminal **33** of the primary winding relative to the voltage on the intermediate tap **26**. This voltage further biases the transistor **28** in a direction for producing a large flow of current through the transistor. Because of the voltage across the primary winding **22**, current also flows through a circuit including the portion of the primary winding between the terminal **33** and the intermediate tap **26**, the capacitor **32**, the resistor **34** and the collector and emitter of the transistor **28**. The capacitor **32** becomes charged by this flow of current such that a positive voltage is produced on its right plate and a negative voltage on its left plate.

When the capacitor **32** becomes charged to a particular value, the negative voltage on the left plate of the capacitor tends to bias the base of the transistor **28** to a voltage for producing a state of nonconductivity in the transistor. The capacitor **32** then starts to discharge through a circuit including the portion of the primary winding **22** between the terminal **33** and the tap **26** in FIGURE 1 and also including the diode **30**. Because of the flow of current through the diode **30**, a voltage drop is produced between the plate and cathode of the diode. Although this voltage drop is relatively low, it is sufficient to bias the base and emitter of the transistor **28** in a direction for maintaining the transistor nonconductive. Since the diode **30** has a relatively low impedance when conductive, it provides a low impedance across the primary winding **22** to prevent voltage surges from being produced in the primary winding **22** when the transistor **28** becomes nonconductive. In this way, the transistor **28** cannot become damaged when it changes between the conductive and nonconductive states.

The waveform of the voltage produced in the primary winding **22** is illustrated in FIGURE 2. As will be seen at **50** in FIGURE 2, the waveform initially rises steeply as the voltage is applied from the battery **16** to the primary winding. When the transistor **28** becomes conductive, the resultant charging of the capacitor **32** and the resultant storage of energy in the primary winding

22 cause the voltage in the primary winding **22** to decrease gradually, as illustrated at **52** in FIGURE 2.

A negative surge **54** is subsequently produced when the capacitor **32** has become charged to a sufficient value to make the diode **30** conductive and the transistor **28** nonconductive. The surge **54** has both a falling portion **54***a* followed by a rising portion **54***b*. The surge results from the electromotive force produced in the transformer **24** when the transistor **28** changes from a conductive to a nonconductive state.

At the end of the surge **54**, a time interval occurs during which the energy stored in the transformer **24** during the conductivity of the transistor **28** is discharged through the luminescent tube **40**. This time period is illustrated at **56** in FIGURE 2. Thereafter, a new cycle of operation is initiated by a voltage surge **50'** similar to the voltage surge **50** described above.

Since the tertiary winding **42** is magnetically coupled to the primary winding **22**, its impedance is controlled by the flow of current through the primary winding. For example, the impedance of the tertiary winding **42** is relatively low during the time that current is flowing through the transistor **28** and the primary winding. Since the low impedance provided by the winding **42** is across the filament **44**, relatively little current flows through the filament. However, when the transistor **28** becomes nonconductive so that relatively little current flows through the primary winding **22**, the impedance provided by the tertiary winding **42** is relatively high. This causes a relatively great current to flow through the filament **44** since the impedance of the filament is relatively low and since the filament is, in effect, shunted by an open circuit represented by the winding **42**. In this way, the filament **44** receives an alternating current even though it is connected to a source of direct voltage.

As will be seen, the direct voltage from the rectifier **14** or the battery **16** is converted to an alternating voltage. This alternating voltage has a fundamental frequency of a relatively high value such as in the order of 23 kilocycles. The gas in the tube **40** becomes excited when subjected to a voltage at this relatively high frequency so as to produce an ionization of the gas in the tube and a resonance of the ionized particles. The resonance is facilitated by the harmonics which occur in the signal illustrated in FIGURE 2. The harmonics are also instrumental in initially exciting the gas in the tube. Because of the excitation of the gas in the tube to produce an ionization of the gas and the resonance of the ionized particles, the tube **40** produces a relatively great illumination with the expenditure of relatively little energy.

As will be seen from the above discussion, substantially no direct current flows through the system illustrated in FIGURE 1 whether the system is energized by the rectifier **14** or the battery **16**. Furthermore, the alternating current flowing through the system has a relatively low amplitude. This results in part because of the relatively high frequencies produced in the system to energize the tube **40** and because of the harmonics produced in the system to resonate the gas in the tube **40**. Since substantially no direct direct current and an alternating current of relatively low amplitude flow through the system, the system is able to operate for extended periods of time such as several hours to energize the tube **40** even when a power failure interrupts the supply of energy from the source **10** so that energy has to be supplied to the circuit entirely by the battery **16**.

In addition to the advantages discussed above, the system illustrated in FIGURE 1 and disclosed above provides its own regulation. For example, the frequency of the alternating signal illustrated in FIGURE 2 may tend to vary as the tube **40** and the other elements in FIGURE 1 age. For example, the frequency of the signal illustrated in FIGURE 2 may increase. This would tend to produce an increased impedance in the winding **42** when the transistor **28** is triggered from the conductive state to the nonconductive state. This increased impedance in the winding **42** would tend to increase the current through the filament **44**. The current through the filament **44** might increase to such an extent that the tube **40** would become damaged or at least its life would be shortened. However, since the transformer **24** releases its stored energy by a flow of current through the secondary winding **36** and the tube **40** when the transistor **28** becomes nonconductive, any increase in such current flow tends to limit any increase in impedance across the winding **42**. This limits any tendency of the filament **44** in the lighting tube to become overheated since the impedance across the winding **42** controls the amplitude of the current through the filament.

It may sometimes occur that the filament **44** of the tube **40** may become impaired by an extended operation of the tube. The tube **40** would still tend to become illuminated at a time near the peak in each alternating cycle because of the discharge of energy in the transformer **24** through the winding **36** and the tube **40**. When the tube **40** becomes illuminated, it tends to draw a normal current through the remainder of each alternating cycle. The result would be that the tube would require a longer time in each cycle to become illuminated than with a normal filament but the tube would continue to operate in its normal manner for the remainder of the cycle.

At times, the continuous circuit between the winding **36** and the tube **40** may become interrupted because of defects in parts or in workmanship. Since the winding **36** does not now limit the flow of current through the filament **44**, the flow of current through the filament may tend to become excessive and eventually impair the filament. At such a time, both the windings **36** and **42** would experience open circuits. The resultant impedances across the windings **36** and **42** would be relatively great during the time that the transistor **28** is nonconductive. These high impedances would tend to limit the currents drawn from the rectifier **14** or the battery **16** so that the life of the battery would not be materially impaired.

Sometimes the circuit across the winding **36** or across the winding **42** or across both windings may become short circuited. For example, a short circuit may sometimes occur across the winding **42**. This would tend to increase the current in a manner similar to that described above for an increase in current through the filament **44**. However, the winding **36** would still tend to produce a current through the tube **40** during the time that the transistor **28** is nonconductive. This current would tend to limit the impedance across the winding **42** so as to limit the current drawn from the rectifier **14** or the battery **16** as described above.

At relatively low temperatures, the resistance of the filament **44** is reduced compared to that at normal temperatures. This tends to increase the current through the filament **44** so that the ease of initially exciting the tube **40** becomes enhanced. If the temperature of the filament **44** increases, the resistance of the filament accordingly increases and limits the current flowing through the filament. This tends to increase the difficulty of igniting the tube **40**. In this way, the temperature of the filament is compensated in the operation of the tube so that a regulating action is provided on this operation.

In one embodiment of the invention, the following values and elements were used to accomplish the results dsecribed above in detail:

Winding **22** (between terminal **21** and tap **26**)—16 turns of No. 24 wire.
Winding **22** (between tap **26** and terminal **33**)—22 turns of No. 24 wire.
Winding **36**—350 turns of No. 36 wire
Winding **42**—16 turns of No. 24 wire
Diode **30**—a silicon diode such as a Type SD05 manufactured by Diodes, Inc.

Transistor **28**—Type MJE520 manufactured by Motorola
Capacitor **32**—0.1 microfarad
Resistor **34**—10 kilohm
Capacitor **38**—0.01 microfarad

A capacitor **60** is illustrated in broken lines in FIGURE 2 as being connected between the terminal **21** of the primary winding **22** and the winding **42**. This capacitor is shown in broken lines since it is connected on an optional basis in the system shown in FIGURE 1. The capacitor **60** may be provided with a suitable value such as approximately 0.22 microfarad. One purpose of including the capacitor **60** is to insure that noise is suppressed in the system shown in FIGURE 1 so that the operation of adjacent radio and television receivers will not be impaired.

It will be appreciated that tubes may be provided which do not have a hot cathode or filament such as the filament **44**. Under such circumstances, the system shown in FIGURE 1 may still be used. This system is illustrated in FIGURE 3 for purposes of convenience. The tertiary winding **42** now serves as a choke during the flow of current through the transformer **24** and the transistor **28** to limit this flow of current. The winding **42** further serves as a noise suppressor to limit any surges of voltage across the transistor, thereby preventing buzzes or static in nearby electronic equipment such as radios. Although the tertiary winding **42** is shown in FIGURE 3 as being magnetically coupled to the windings **22** and **36**, it will be appreciated that the winding **42** can serve as a choke without being magnetically coupled to the other windings in the transformer **24**.

The system shown in FIGURE 4 constitutes a further modification of the systems shown in FIGURES 1 and 3. The system shown in FIGURE 4 includes a primary winding **22** and a secondary winding **36**, a transistor **28**, a diode **30** and a capacitor **32** in a manner similiar to that described above. However, the winding **42** is in effect attached to the bottom of the primary winding **22** in FIGURE 1 to form an additional portion **22*a*** at the bottom end of the winding. This portion is defined by an intermediate tap **100** and an end terminal **101** at the bottom of the winding in FIGURE 1. The connections to the additional portion **22*a*** of the primary winding **22** correspond to those shown in FIGURE 1 and described above except that a filament corresponding to the filament **44** is not connected across the portion **22*a***.

The system shown in FIGURE 4 operates in a manner similar to that shown in FIGURE 1. The voltage introduced to the winding **22** from the rectifier **14** or the battery **16** causes the transistor **28** to become conductive. The resultant flow of current through the capacitor **32** and the primary winding **22** causes the capacitor and the transformer **24** to store energy. When the energy stored in the capacitor **32** reaches a particular value, the capacitor discharges through the diode **30** to make the transistor **28** nonconductive. The transistor **28** continues to be nonconductive until the capacitor **32** has discharged somewhat. The bias then produced in the transistor then becomes predominant and the transistor becomes conductive to initiate a new cycle of operation.

The system shown in FIGURE 4 differs from the system shown in FIGURE 1 in the paths in which the currents flow at different times in each cycle of operation. For example, during the time that the transistor **28** is conductive, current flows through a circuit including the portion of the primary winding **22** between the tap **26** and the terminal **33** in FIGURE 4, the capacitor **32**, the resistor **34** and the collector and emitter of the transistor **28**. This current is in an upward direction in FIGURE 4 through the primary winding **22**. Current also flows downwardly through the primary winding between the intermediate taps **26** and **100**. This flow of current occurs through a circuit including the portion of the primary winding between the intermediate tap **26** and the terminal **101** of the primary winding in FIGURE 4, a capacitor **103** and the collector and emitter of the transistor **28**. The number of turns in the primary winding between the intermediate tap **26** and the terminal **101** of the winding in FIGURE 4 is greater than the number of turns between the intermediate tap **26** and the terminal **33** of the winding in FIGURE 4. Furthermore, the value of the capacitor **103** is less than the value of the capacitor **32**. Because of this, the current flowing downwardly through the primary winding **22** in FIGURE 4 is greater than the current flowing upwardly through the primary winding during the time that the transistor **28** is conductive. This current flow is illustrated at **110** in FIGURE 5.

The capacitor **103** becomes charged by the flow of current through it in a manner similar to that described above for the capacitor **32**. The charge is in a direction such that the right plate of the capacitor **103** is more positive than the left plate of the capacitor. Accordingly, when the transistor **28** becomes nonconductive, current flows through a circuit including the lower portion of the winding **22** in FIGURE 4, a filter capacitor **106** and the capacitor **103** to discharge the capacitor **103**. The flow of current is upwardly through the winding **22**. This is in a direction opposite to the current flowing through the lower portion of the winding **22** in FIGURE 4 when the transistor **28** is conductive. The current flowing through the capacitor **32** and the upper portion of the winding **22** to discharge the capacitor **32** is also in an upward direction in FIGURE 4.

Because of the upward flows of current through the primary winding **22** in FIGURE 4 during the time that the transistor **28** is nonconductive, a current illustrated at **112** in FIGURE 5 is produced. Since the current **112** has an opposite polarity to the current **110** which flows through the winding **22** during the time that the transistor **28** is conductive, the current **112** helps to minimize any direct current components in the transformer. This insures that the drain on the battery **16** will be minimal when the battery is supplying energy to light the lamp **40**. In effect, the Q of the transformer **24** is increased by providing the portion of the winding between the tap **100** and the terminal **101** of the winding in FIGURE 4.

By varying the values of the capacitors **32** and **103**, the duty cycle or frequency of the signal introduced to the tube **40** can be adjusted through a relatively great range such as between approximately 30 kilocycles and 250 kilocycles. If the values of the capacitors **32** and **103** are increased, the frequency of the signal is decreased since the capacitors receive an increased charge and the time required for the capacitors to discharge increases. If only the value of the capacitor **100** is increased, the frequency is decreased but the width of the signal **110** is increased. This results from the fact that the current flowing through the transistor **28** is decreased so that decreased currents flow through the capacitors **32** and **103** and require increased times to charge these capacitors to particular values. An increase in the value of the capacitor **103** also increases the amplitude of the signal **112** since the capacitor **103** in effect serves as a battery and receives an increased voltage because of its increased capacity. However, the width of the signal **112** is not affected appreciably by changing the value of the capacitor **103**.

Preferably the number of turns between the tap **26** and the terminal **33** of the primary winding **22** in FIGURE 4 is approximately equal to the number of turns between the intermediate tap **103** and the terminal **101** of the winding. One purpose of providing such a ratio is to insure that the transistor **28** will be switched properly between the conductive and nonconductive states. If the transistor **28** does not receive a sufficient voltage between its base and emitter relative to the voltage between the base and collector, the transistor will be starved from conducting. If the transistor receives too high a voltage between the base and emitter relative to the voltage between the base and collector, the transistor will become

saturated easily and will not be triggered sufficiently fast to the nonconductive state. Under such circumstances, the transistor will tend to overheat.

FIGURE 6 represents a combination of the circuits shown in FIGURES 1 and 3 or a combination of the circuits shown in FIGURES 1 and 4. The embodiment shown in FIGURE 6 is similar to that shown in FIGURE 4 but includes the winding **42** shown in FIGURES 1 and 3. When the luminescent tube **40** has a hot cathode, the winding **44** is connected as illustrated in FIGURE 4. The operation of the embodiment shown in FIGURE 6 will be understood from the description given above for the previous embodiments.

Although this application has been disclosed and illustrated with reference to particular applications, the principles involved are susceptible of numerous other applications which will be apparent to persons skilled in the art. For example, the invention may be used as an inverter into resistance loads and/or inductance loads such as incandescent lamps, vibrators and controlled frequency power devices. The invention is, therefore, to be limited only as indicated by the scope of the appended claims.

What is claimed is:

1. In combination for illuminating a luminescent tube,
a source of direct voltage,
a first current control member having conductive and nonconductive states and having control, input and output electrodes,
first reactance means coupled electrically to the source of direct voltage and to the input electrode of the first current control member for biasing the input electrode with a voltage of a particular polarity,
second reactance means constructed to store energy,
first means including the second reactance means connected in a electrical circuit with the source of voltage and the first reactance means for biasing the control electrode of the first current control member with a particular voltage relative to the voltage on the input electrode of the first current control member to product a state of conductivity in the first current control member and a storage of energy in the first and second reactance means,
a second current control member having conductive and nonconductive states,
second means connecting the second current control member in an electrical circuit with the first and second reactance means between the control and input electrodes of the first current control member for biasing the first current control member to a state of nonconductivity upon the storage of a particular amount of energy in the second reactance means and for providing a discharge of the energy in the second reactance means through the second current control member and the first reactance means upon a state of nonconductivity in the first current control member to obtain a subsequent state of conductivity in the first current control member, and
third means connecting the luminescent tube to the first reactance means to obtain a flow of current through the luminescent tube during the state of conductivity in the first current control member and to obtain a discharge through the luminescent tube, during the state of conconductivity in the first current control member, of the energy stored in the first reactance means.

2. The combination set forth in claim **1** wherein the first reactance means is inductive and the second reactance means is capacitive.

3. In combination for illuminating a luminescent tube,
a source of direct voltage,
a first current control member having conductive and nonconductive states,
a second current control member having conductive and nonconductive states,
first reactance means constructed to store energy,
second reactance means constructed to store energy,
means connected in electrical circuitry with the first and second reactance means and the source of direct voltage to bias the first current control member to the state of conductivity and to obtain a storage of energy in the first reactance means and a storage of energy in the second reactance means during the state of conductivity in the first current control member,
means conducted in electrical circuitry with the first and second reactance means and the second current control member for producing a discharge through the second current control member of the energy stored in the second reactance means upon the storage of a particular amount of energy in the second reactance means to bias the first current control member to the state of nonconductivity during the discharge of the energy in the second reactance means through the second current control member and to obtain the state of conductivity in the first current control member after such discharge, and
means connecting the luminescent tube to the first reactance means to obtain a flow of current through the first reactance means and the luminescent tube during the state of conductivity in the first current control member and to obtain a discharge through the luminescent tube of the energy stored in the first reactance means upon the state of nonconductivity in the first current control member.

4. The combination set forth in claim **3** wherein the first reactance means in inductive and includes a first winding connected in the electrical circuitry with the first and second reactance means and the source of voltage connected in the electrical circuitry with the first and second reactance means and the source of voltage and includes a second winding connected to the luminescent tube and includes a third winding connected in an electrical circuit with the first winding and the current control member and the source of direct voltage to inhibit voltage surges during the change in the operation of the current control member between the conductive and nonconductive states.

5. In combination for illuminating a luminescent tube,
a source of direct voltage,
a current control member having an input electrode, a control electrode and an output electrode,
a transformer having a primary and a secondary, the primary having first and second end terminals and an intermediate tap,
a capacitance,
a diode connected between the input and control electrodes of the current control member and connected in a series circuit with the capacitance and the primary of the transformer between the first end terminal and the intermediate tap of the primary,
a resistance connected between the control electrode and the output electrode of the current control member, means connecting the source of direct voltage between the output terminal of the current control member and the second end terminal of the primary of the transformer, and
means connecting the luminescent tube to the secondary of the transformer.

6. The combination set forth in claim **5** wherein the transformer has a third winding and wherein the luminescent tube has a filament and wherein the filament is connected across the third winding of the transformer and wherein the third winding of the transformer is connected between the output terminal of the current control member and the source of direct voltage.

7. In combination for illuminating a luminescent tube,
a source of direct voltage,

a first current control member having conductive and nonconductive states,

first reactance means constructed to store energy and connected to the first current control member and to the source of direct voltage to receive a storage of energy when the first current control member is in the conductive state,

second reactance means constructed to store energy and connected to the first reactance means and to the first current control member to store energy when the first current control member is in the conductive state,

a second current control member connected to the first current control member and connected in electrical circuitry with the first and second reactance means to provide for a discharge of the second reactance means through the second current control member upon the storage of energy in the second reactance means to a particular value and to produce the state of nonconductivity in the first current control member during the discharge of the second reactance means through the second current control member and to inhibit any transient conditions in the first reactance means upon a change of the first current control member from the conductive state to the nonconductive state,

means connected to the first current control member to bias the first current control member to the state of conductivity for obtaining the first state of conductivity in the first current control member upon the discharge of the second reactance means to a second particular value different from the first particular value, and

means connecting the first reactance means to the luminescent tube to obtain a flow of current through the first reactance means and the luminescent tube during the state of conductivity in the first reactance means and to obtain a discharge through the luminescent tube of the energy stored in the first reactance means during the state of nonconductivity in the first current control member.

8. The combination set forth in claim **7** wherein the luminescent tube has a filament and wherein the first reactance means has a portion connected across the filament.

9. The combination set forth in claim **8** wherein the first reactance means is inductive and the second reactance means is capacitive.

10. In combination for illuminating a luminescent tube having a filament,

a source of direct voltage,

a transformer having first, second and third windings,

the third winding of the transformer being connected across the filament of the luminescent tube to provide a high impedance across the filament in the absence of a current through the third winding and to provide a reduced impedance across the filament in accordance with the flow of current through the third winding,

the second winding of the transformer being connected across the tube to produce a luminescence of the tube upon the heating of the filament in the tube by the second winding,

a current control member having conductive and nonconductive states and connected in a circuit with the first and third windings of the transformer and with the source of direct voltage to produce a flow of current through the first and third windings of the transformer during the state of conductivity in the first current control member,

means for biasing the current control member of the state of conductivity, and

capacitive means connected in a circuit with the current control member and the first winding of the transformer to become charged during the state of conductivity in the current control member and to become discharged upon becoming charged to a particular value and to bias the current control member to a state of nonconductivity during the discharge of the capacitance means.

11. The combination set forth in claim **10** wherein the first winding of the transformer is provided with an intermediate tap and wherein the current control member and the capacitance means are connected in the circuit with the first winding of the transformer at the intermediate tap in the primary winding of the transformer.

12. In combination for illuminating a luminescent tube,

a source of direct voltage,

a transformer having a primary winding and a secondary winding, the primary winding having first and second terminals and first and second intermediate taps at a pair of spaced positions along the winding,

a current control member having states of conductivity and nonconductivity and connected in a circuit with the source of direct voltage and the primary winding of the transformer between the first and second taps of the primary winding,

means biasing the current control member to the state of conductivity to obtain the flow of current through the circuit including the current control member, the source of direct voltage and the primary winding of the transformer,

charge storage means connected in a circuit with the current control member and the primary winding of the transformer between the first tap and the first end terminal of the primary winding to become charged during the state of conductivity in the current control member and to become discharged upon becoming charged to a particular value and to bias the current control member to the state of nonconductivity during such discharge,

the second end terminal of the primary winding of the transformer being connected to the current control member, and

means connecting the luminescent tube to the secondary winding of the transformer.

13. The combination set forth in claim **12** wherein the charge storage means include a capacitor and a second current control member to obtain a discharge of the capacitor through the second current control member and wherein the second current control member is connected to the first current control member to bias the first current control member to the state of nonconductivity during the time that the capacitor is discharging through the second current control member.

14. In combination for illuminating a luminescent tube,

a source of direct voltage,

a first current control member having conductive and nonconductive states,

a second current control member having conductive and nonconductive states,

an inductive reactance having first and second end terminals and an intermediate tap,

a capacitance,

means connecting the source of direct voltage, the first and second end terminals of the inductance reactance and the capacitance in electrical circuitry to bias the first current control member to a conductive state for obtaining a charging of the capacitance and a storage of energy in the inductive reactance during the operation of the first current control member in the conductive state,

means connecting the capacitance, the second current control member and one of the end terminals and the intermediate tap of the inductive reactance in electrical circuitry for producing a discharge of the capacitance through the second current control member and the inductive reactance upon the charging of the capacitance to a particular value to obtain the

operation of the first current control member in the nonconductive state during the discharge of the capacitance through the second current control member, and

means connecting the luminescent tube to the inductive reactance for energizing the inductive reactance.

15. The combination set forth in claim **14** wherein means are included for inhibiting transient surges of voltage during the change in the operation of the first current control member between the conductive and nonconductive states.

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