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[54] **AUTOMATIC START CIRCUIT FOR LAMP**

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

[58] **Field of Search** .... 315/86, 101, 102, 107, 315/160, 171, 174–176, 205, DIG. 7

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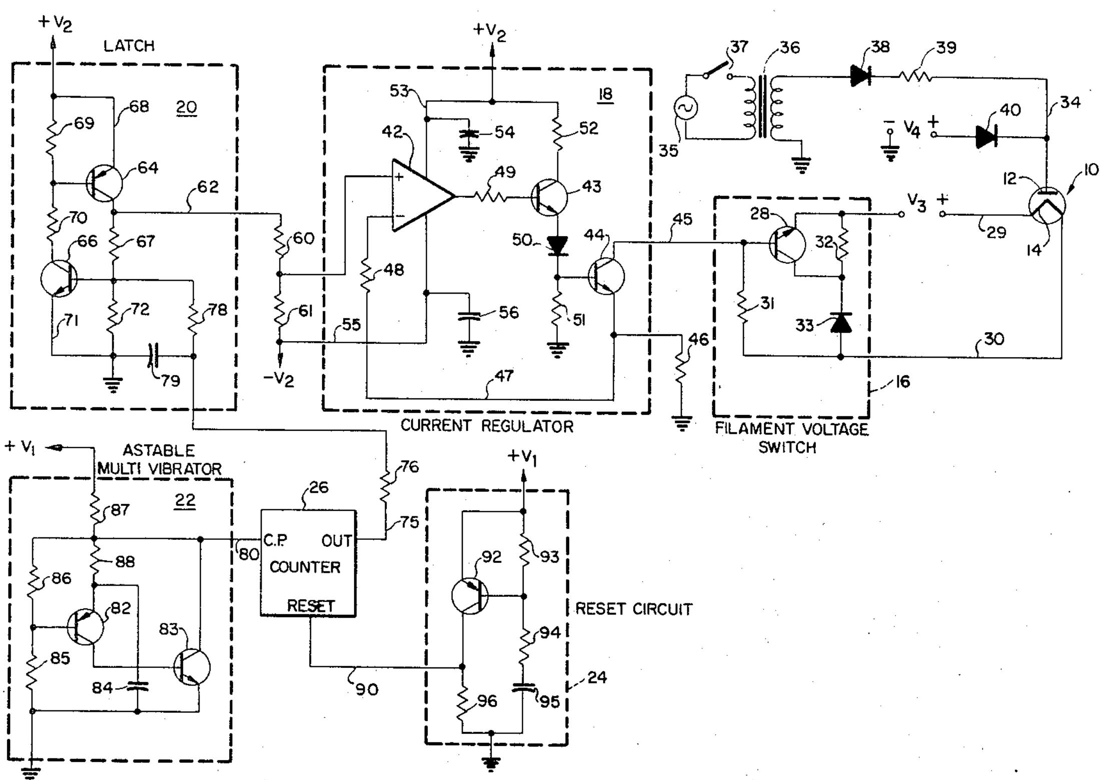
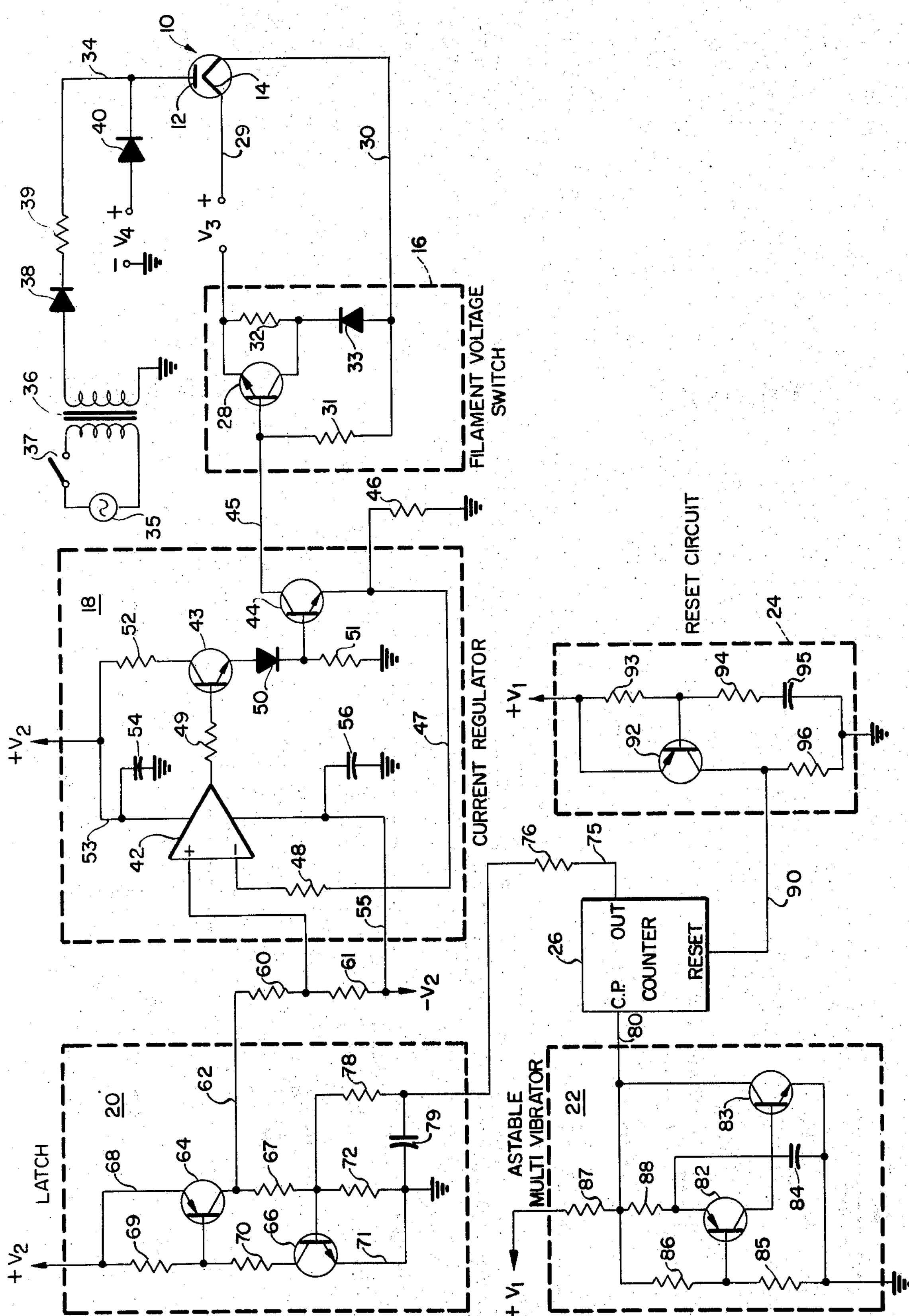
[57] **ABSTRACT**

An automatic start circuit for a gas-filled tube having an anode and a cathode, such as a deuterium lamp, the anode thereof being connected to both a voltage source for providing a firing voltage and a current source for providing the operating current after firing. The filament of the tube has a first voltage thereacross upon application of power to the circuit. A time delay circuit is provided having a time delay consistent with the warm-up time required for the tube, the termination of the predetermined time delay actuating a current regulator for regulating the anode to cathode current flowing through the tube. After the tube fires, the flow of such current energizes a filament voltage switch to apply across the filament a second voltage lower than the first voltage to compensate for power dissipation in the filament by virtue of the current flow. The time delay means includes an astable multivibrator providing pulses to a counter, which, after a preset count initiates a pulse to actuate the current regulator. The counter is reset by a reset circuit immediately upon application of power.

12 Claims, 1 Drawing Figure




FILAMENT VOLTAGE SWITCH
CURRENT REGULATOR
LATCH
ASTABLE MULTI VIBRATOR
RESET CIRCUIT
COUNTER
C.P.
OUT
RESET

AUTOMATIC START CIRCUIT FOR LAMP

BACKGROUND OF THE INVENTION

This invention relates to a start circuit for a gas filled lamp and more particularly to an automatic start circuit for a gas filled lamp having an anode and a cathode such as a deuterium lamp.

In typical gas filled lamps or tubes such as deuterium lamps a time delay is required for cathode warm-up, during which time it is desirable to apply to the filament a certain voltage which is higher than that necessary for continuous operation. Similarly with respect to such lamps the firing voltage, i.e. the voltage at which the lamp conducts between anode and cathode, can vary over a wide spread due to the characteristics of the lamp. For example, in a deuterium lamp the firing voltage may vary from 125 to 350 volts while the on voltage at 300 milliamps varies between 40 and 100 volts. Another characteristic of a deuterium lamp is that the current required to lower the anode to cathode voltage below 125 volts is one to 10 milliamps. Furthermore, start circuits for such lamp must have the capability to continuously reapply the firing voltage until the lamp fires. Due to the wide range of operating parameters of a gas filled lamp, start circuits that provide a firing voltage equal to the highest possible voltage to ensure that all lamps thereafter used fire, can result in excessive power and heat dissipation from the lamp after the lamp has fired. Similarly if an excess voltage is used on the filament to shorten the cathode warm-up time of a gas filled lamp, the excess voltage can shorten the lamp life as well as create excess heat.

SUMMARY OF THE INVENTION

Accordingly it is an object of the invention to provide a new and improved automatic start circuit for gas filled lamps or the like having an anode and a cathode.

It is another object of this invention to provide an automatic start circuit having time delay means for cathode warm-up of the gas filled lamp.

It is a further object of this invention to provide a regulated current through the lamp after the lamp has fired from a voltage lower than that necessary for lamp firing.

It is still another object of this invention to provide an automatic lowering of the filament power to compensate for the dissipation caused by the anode current.

It is a still further object of this invention to provide an automatic retiming of the time delay means to reinstitute application of the firing voltage after a power failure.

The foregoing and other objects of the invention are accomplished by providing a gas filled lamp having the filament or cathode thereof connected to a voltage source switchable between a first warm-up voltage and a second operating voltage, less than the first. The anode of the gas filled lamp is coupled to a voltage source for applying a firing voltage and then applying a current regulated low voltage after the lamp has fired. The current regulator is switched on after a predetermined time delay generally equal to the time required for cathode warm-up, the time delay being provided by the output of a counter to a latch after the count reaches a predetermined count. The clock pulses to the

counter are generated by means of an astable multivibrator having a predetermined time constant so that the total number of pulses from the multivibrator to the counter provide an output from the counter equal to the time required for cathode warm-up. Reset means are provided to reset the counter immediately upon initiation of power to the circuit so that the predetermined time delay remains constant for each application of power.

Other objects, features and advantages of the invention will become apparent from the following specification taken in conjunction with the accompanying drawing.

BRIEF DESCRIPTION OF THE DRAWING

The sole FIGURE is a schematic diagram of an automatic start circuit for a gas filled lamp in accordance with the invention.

DESCRIPTION OF THE PREFERRED EMBODIMENT

Circuit Description

Referring to the FIGURE there is shown an automatic start circuit for a gas filled lamp **10** having an anode **12** and a cathode or filament **14.** Gas filled lamps such as deuterium lamps have particular application where a light source having a known light spectrum is desired, such as in spectrophotometry. However, one of the basic problems relating to such gas filled lamps, is that the operating parameters for such lamps vary from lamp to lamp within a given lot of lamps. For example the firing voltage can be anywhere within a range from 125 volts to 350 volts while the operating voltage to maintain conduction once the lamp has fired can be anywhere within the range from 40 volts to 100 volts at 300 milliamps of operating current. Furthermore the current required to lower the anode to cathode voltage below 125 volts can range anywhere between one and 10 milliamps. Gas filled lamps of this type further require a cathode warm-up time of 2.5 to 3 minutes to provide proper conduction once fired.

In the following discussion representative values of the following components will be given with respect to the operation of a deuterium lamp. Furthermore, major functional portions of the circuit have been enclosed in dotted lines and labeled with appropriate descriptions of the function for ease of explanation. These major functional elements include a filament voltage switch **16**, a current regulator **18**, a latch **20**, an astable multivibrator **22**, a reset circuit **24** and a counter **26**.

The filament voltage switch **16** includes a NPN transistor **28** having the emitter thereof coupled to the negative side of a d.c. source V_3 which may be for example 13 volts d.c. The positive side of voltage source V_3 is coupled to the filament **14** by means of lead **29**, with the other side of filament **14** being connected by means of lead **30** through a resistor **31** (20 ohms) to the base of transistor **28.** The emitter of transistor **28** is connected to the collector thereof through resistor **32** (3 ohms), while the collector is also connected to the cathode of biasing diode **33**, having the anode thereof connected to lead **30** intermediate resistor **31** and filament **14.**

The anode **12** of lamp **10** is connected by means of lead **34** to first and second voltage sources. An alternating current source **35** (350 VAC) is applied through isolating transformer **36** when switch **37** is actuated to close the circuit between alternating current source **35** and the primary winding of transformer **36.** The secondary winding of transformer **36** has one end thereof coupled to ground while the other end thereof is connected to the anode of diode **38,** the cathode thereof being coupled through resistor **39** (15 K ohms) to lead **34.** This provides a half wave rectified voltage through resistor **39.** The second voltage source V_4 (150 V.D.C.) has the positive side thereof coupled through diode **40** to lead **34.**

The current regulator **18** includes an operational amplifier **42** and first and second NPN transistors **43** and **44,** with the collector of transistor **44** being coupled by means of lead **45** to the base of transistor **28** of the filament voltage switch **16.** The emitter of transistor **44** is connected to ground through resistor **46** (10 ohms), the emitter also being connected by means of lead **47** through feedback resistor **48** (10 K ohms) to the negative input of operational amplifier **42.** The output of operational amplifier **42** is coupled through resistor **49** (100 ohms) to the base of transistor **43,** while the emitter thereof is connected to the anode of diode **50,** the cathode of which is connected to the base of transistor **44,** and also through resistor **51** (1 K ohms) to ground. The collector of transistor **43** is connected through bias resistor **52** (470 ohms) to a voltage source $+V_2$ (15 V.D.C.), this voltage source also providing the bias for operational amplifier **42** over lead **53.** Lead **53** is coupled through power supply bypass capacitor **54** (0.01 microfarads) to ground. A negative source of bias $-V_2$ (−15 V.D.C.) is also applied to operational amplifier **42** by means of lead **55,** which is similarly coupled to ground through power supply bypass capacitor **56** (0.1 microfarads).

Intermediate current regulator **18** and latch **20** is a voltage divider including resistors **60** (11.8 K ohms) and **61** (18.2 K ohms) connected in series between voltage source $-V_2$ and lead **62** providing the output of latch **20.** The point intermediate resistors **60** and **61** is connected to the positive input of operational amplifier **42.**

The latch **20** includes PNP transistor **64** and NPN transistor **66,** transistor **64** having the collector thereof coupled to lead **62** to provide the latch output. Lead **62** is also coupled to the base of transistor **66** through resistor **67** (3 K ohms). The emitter of transistor **64** is connected by means of lead **68** to a positive source of voltage $+V_2$, the voltage source also being coupled to the collector of transistor **66** through series resistors **69** (1 K ohms) and **70** (3 K ohms). The point intermediate resistors **69** and **70** is coupled to the base of transistor **64.** The emitter of transistor **66** is connected to ground by means of lead **71,** while the base of transistor **66** is connected to ground through resistor **72** (1 K ohms). The latch **20** is set by means of a pulse appearing at the output of counter **26,** this pulse appearing on lead **75** through resistor **76** (1 K ohms) through resistor **78** (1 K ohms) to the base of transistor **66.** The point intermediate resistors **76** and **78** is coupled through smoothing capacitor **79** (10 microfarads) to ground.

The input to counter **26** is provided by clock pulses appearing on lead **80** which is the output of astable multivibrator **22.** The multivibrator **22** includes PNP transistor **82** and an NPN transistor **83,** the collector of transistor **82** being coupled to the base of transistor **83.** A capacitor **84** (100 microfarads) is connected between the emitter of transistor **82** and the emitter of transistor **83,** the emitter of transistor **83** being connected to ground. The base of transistor **82** is connected to ground through resistor **85** (5.1 K ohms), while the base is also coupled to a voltage source $+V_1$ (+5 V.D.C.) through series resistors **86** (1.6 K ohms) and **87** (1 K ohms). The point intermediate resistors **86** and **87** is connected through resistor **88** to the emitter of transistor **82.** This point is also connected to lead **80** and the collector of transistor **83.**

A reset circuit **24** provides a reset pulse on lead **90** to reset counter **26** to zero. Reset circuit **24** includes a PNP transistor **92** having the emitter thereof coupled to a voltage source $+V_1$ and the base thereof coupled to the same voltage source through resistor **93** (10 K ohms). The base of transistor **92** is connected through resistor **94** (1 K ohms) in series with capacitor **95** (10 microfarads) to ground. The collector of transistor **92** is coupled to lead **90** and also coupled through resistor **96** (220 ohms) to ground.

Circuit Operation

When power is applied to the circuit all voltages are energized simultaneously along with the simultaneous actuation of switch **37** to connect alternating current source **35** to the primary of transformer **36.** The voltage sources then remain energized during the operation of the circuit.

Briefly, the operation of the circuit is as follows. With the initial application of voltage the reset circuit **24** provides a pulse on lead **90** to reset the counter **26.** The astable multivibrator **22** and counter **26** form a time delay circuit which provides a pulse output on lead **75** at the expiration of a predetermined time period. During this predetermined time period the anode **12** of gas filled tube **10** receives its firing voltage on lead **34** from a combination of the half wave rectified alternating current voltage and the d.c. voltage source $+V_4$ (approximately 400 volts peak). Current to the filament **14** is being applied from a voltage potential of approximately 12 volts across the filament from the voltage source V_3 through the filament **14,** through lead **30,** through resistor **31,** through the base emitter path of transistor **28** to the negative side of voltage source V_3. After the counter **26** achieves its preset count indicative of the predetermined time delay the pulse appearing on lead **75** sets latch **20,** which, as will hereinafter be explained, remains "set" so long as the voltage sources are energized. With latch **20** set, a potential appears across voltage divider resistors **60** and **61** thereby providing a reference voltage to operational amplifier **42** of current regulator **18.** After the current regulator **18** turns on, current flows from the anode **12** to the cathode or filament **14** of the gas filled tube **10.** This current (approximately 300 milliamps) flows from the filament **14** through lead **30** through resistor **31,** over lead **45** from the collector to emitter of transistor **44** through resistor **46** to ground. This current flow through resistor **31** provides a voltage drop sufficient to back-bias transistor **28,** thereby rendering it nonconductive. Consequently, filament current must now flow through resistor **32,** thereby lowering the filament voltage to the operating level of approximately 10 volts. Inasmuch as this sequence is controlled by the current through the lamp **10** rather than by the time delay means, the power to filament **14** will stay high until the lamp fires. Once the lamp **10** fires, the operating current (approximately 300 milliamps) is supplied from the low voltage power supply $+V_4$ (approximately 150 volts) through diode **40** with a minimal amount of current being supplied from alternating current source **35** due to the high resistive value of current limiting resistor 39 (15 K ohms).

Referring now to the reset circuit **24**, the purpose of the reset circuit is to ensure that the counter **26** starts in the "zero" state, inasmuch as in the event of power failure counter **26** can be in any state when power is applied if it is not reset. When voltage source $+V_1$ is initially applied, capacitor **95** is discharged. Current then flows through the emitter to base junction of transistor **92** through resistor **94** to charge capacitor **95.** This current turns on transistor **92,** applying voltage to lead **90.** This voltage sets the counter **26** to the zero state. As capacitor **95** charges, the voltage across it increases. When the voltage increases to the point that sufficient current can be supplied through resistor **93** to finish the charge and hold it, transistor **92** turns off. Resistor **96** then pulls the voltage on lead **90** down below the threshold of the reset input of counter **26.** Resistor **96** must be small enough to hold the voltage thereacross below 0.7 volts.

With the counter **26** reset, the time delay means then proceeds for a predetermined time period equivalent to the desired warm-up time of the lamp **10.** For a deuterium lamp **10** the desired warm-up time is 2.50 to 3 minutes or approximately 200 seconds. Due to the difficulty of building circuits with long time constants, pulse counting from an astable multivibrator is provided. In this manner no gating is required, and although the counter **26** is shown as a single counter, two decade counters can be used with the 8-binary output of the second decade counter being utilized to provide the output on lead **75.** This would result in 80 counts of the multivibrator **22,** which would effectively give a repetition rate of 2.5 seconds for the multivibrator **22** to achieve the 200 second time delay desired. In the astable multivibrator **22** resistors **86** and **85** supply the bias voltage for the base of transistor **82.** Resistor **88** and capacitor **84** form the RC time constant that determines the frequency. Resistor **87** is the load resistor for transistor **83,** and with the circuit off, very little current flows through resistor **87** thereby causing the voltage on lead **80** (the collector of transistor **83**) to be approximately equal to the voltage source $+V_1$. Current flows through resistor **88** to thereby charge capacitor **84.** When the voltage on capacitor **84** rises to about 0.7 volts above the bias voltage supplied by resistors **85** and **86,** transistor **82** conducts, thereby causing current flowing through transistor **82** to flow into the base of transistor **83,** thereby turning on transistor **83.** At such time as transistor **83** conducts, the voltage on lead **80** will be approximately equal to ground potential (with negligible voltage drop across the collector to emitter junction of transistor **83**). Additional feedback through resistor **86** to the base of transistor **82** will hold transistor **82** in conduction until capacitor **84** is discharged through the emitter of transistor **82.** As the capacitor **84** discharges the base potential of transistor **82** will drop below that necessary to sustain conduction, at which point transistor **82** will turn off thereby causing transistor **83** to turn off, letting lead **80** go back to its initial state of approximately the same potential as the voltage source $+V_1$.

The pulses from astable multivibrator **22** continue until counter **26** reaches the predetermined count (**80** counts) at which point lead **75** goes "high."

Latch **20,** immediately upon the application of power, is in the "off" condition with resistor **69** preventing transistor **64** from conducting while resistor **72** prevents transistor **66** from conducting. When the pulse appears on lead **75** current flows through resistors **76, 78** and **72** to ground. Resistor **76** and capacitor **79** form a transient filter to prevent premature firing when the power is applied or by noise spikes that could appear in the system. With the flow of this current a voltage appears across resistor **72,** and when this voltage is greater than the base to emitter voltage drop of transistor **66,** transistor **66** conducts, causing current to flow through resistors **69** and **70.** The current flow through resistor **69** is sufficient to cause a voltage drop thereacross, thereby rendering transistor **64** conductive. The current flowing from the voltage source $+V_2$ through the emitter to collector junction of transistor **64** through series resistors **67** and **72** to ground supplies a sufficient signal to maintain the conductive state of transistor **66** after the pulse appearing on lead **75** ends. Latch **20** remains latched until the power is subsequently removed.

Current flowing through the emitter to collector junction of transistor **64** from the voltage $+V_2$ also flows through lead **62** and through series resistors **60** and **61** to a negative source of potential $-V_2$. The voltage divider consisting of resistors **60** and **61** is utilized to provide a reference voltage from the intermediate point between the resistors to the positive input of operational amplifier **42.**

With respect to the current regulator **18,** the basic circuit is a voltage follower, that is, the voltage at the emitter of transistor **44** will approximately equal the voltage at the junction of resistors **60** and **61.** Resistor **49** is a current limiting resistor to limit the current output from operational amplifier **42** to the base of transistor **43.** Transistor **43** functions as an emitter follower to give current amplification to the current flowing through resistor **49.** Diode **50** is a protection diode to prevent high voltage from being applied back through resistor **43** into the voltage source $+V_2$ in the event transistor **44** should fail. Resistor **52** is a current limiting resistor to protect transistor **43,** with resistor **51** being a base bias resistor for transistor **44.** When a positive voltage is applied from the junction of resistors **60** and **61** to the amplifier **42,** the output of amplifier **42** goes positive, thereby applying a positive voltage to the base of transistor **43** rendering transistor **43** conductive, permitting current flow from voltage source $+V_2$ through resistor **52,** through the collector to the emitter junction of transistor **43,** through diode **50,** through resistor **51** to ground. This current flow will cause a voltage drop across resistor **51** sufficient to render transistor **44** conductive. At this point the anode to cathode current is flowing through gas filled lamp **10,** the current flowing through lead **30,** through resistor **31,** through lead **45,** through the collector to emitter junction of transistor **44** and through resistor **46** to ground. The current from amplifier **42** through resistor **49** will increase until the voltage drop across resistor **46** is approximately equal to the voltage applied to the positive input of amplifier **42.** The voltage appearing at the emitter of transistor **44** is applied through current limiting resistor **48** to the inverted input of amplifier **42** to provide negative feedback thereby regulating the current through current regulator **18.**

With reference to the filament voltage switch **16**, as transistor **44** conducts and current flows through gas filled lamp **10** from the anode **12** to cathode **14**, transistor **28** which was initially conductive now becomes nonconductive by the back-bias resulting from the current flowing through resistor **31** through transistor **34**, through resistor **46** to ground. Transistor **28** then becomes nonconductive resulting in the flow of current to the filament from the positive side of voltage source V_3 through lead **29**, through filament **14**, through lead **30**, through biasing diode **33**, through resistor **32** to the negative side of voltage source V_3. In this manner the filament voltage switch **16**, upon initial application of power, provides a first current path for filament **14** through transistor **28**, and upon energization of current regulator **18** after the predetermined time delay resulting from multivibrator **22** and counter **26**, provides a second current path through resistor **32** when transistor **28** becomes nonconductive. The net effect is approximately 12 volts initially applied to filament **14**, with approximately 10 volts being applied across filament **14** after the lamp has fired.

Consequently it can be seen by the utilization of the circuitry shown in conjunction with a gas filled lamp, the following functions are performed. A time delay is provided consistent with the required cathode warm-up time for gas filled lamps. By the utilization of a half-wave rectified alternating current voltage source in conjunction with a low voltage current regulated current source, two effects are achieved — the firing voltage is continuously reapplied until the lamp fires, and the anode to cathode current of the gas filled lamp **10** is regulated from a low voltage power source after the lamp has fired. Furthermore with respect to the filament power, by providing two discrete levels of current therethrough, the filament power is automatically lowered after the lamp has fired to compensate for the dissipation caused by the anode to cathode current through the gas filled lamp **10**. With the utilization of the reset circuit **24** the time delay means are automatically reset to zero in the event of a power failure.

While there has been shown and described a preferred embodiment, it is to be understood that various other adaptations and modifications may be made within the spirit and scope of the invention.

I claim:

1. In a circuit for starting and operating a gas-filled tube or the like having an anode and a cathode with a predetermined warm-up time, the combination comprising:

a voltage source connected to the anode for providing a firing voltage for said tube;

a current source connected to the anode for providing an operating current for said tube after conduction at approximately the operating voltage of said tube;

means for providing a first filament voltage to the filament of said tube;

current control means for controlling the current through said tube after firing;

time delay means for providing a predetermined time delay approximately equal to the warm-up time of said tube;

means responsive to the termination of said time delay for energizing said current control means; and

means responsive to the flow of current through said tube after firing for applying a second filament voltage lower than said first filament voltage during conduction of said tube.

2. The combination according to claim **1** wherein said time delay means includes a counter receiving timed pulses, a predetermined count initiating a pulse indicative of the termination of said predetermined time delay.

3. The combination according to claim **2** wherein said timed pulses are provided to said counter from an astable multivibrator.

4. The combination according to claim **3** wherein said time delay means further includes a reset circuit operable in response to the initiation of power to the automatic start circuit for providing a reset pulse to said counter.

5. The combination according to claim **4** wherein said means responsive to the termination of said time delay includes a latch circuit operative in response to the pulse output of said counter after the predetermined count, said latch circuit remaining set so long as power is supplied to the automatic start circuit.

6. The combination according to claim **5** wherein said current control means is a current regulator.

7. The combination according to claim **6** wherein the setting of said latch circuit supplies a reference potential to said current regulator.

8. The combination according to claim **7** wherein said means responsive to the flow of current through said tube for applying a second filament voltage includes a voltage source switchable between said first and second filament voltages.

9. The combination according to claim **8** wherein said switchable voltage source includes a normally conductive switch in series therewith and a voltage dropping resistor in parallel with said switch.

10. The combination according to claim **9** wherein said switch is a transistor which becomes reverse biased and nonconductive upon conduction of current through said tube.

11. The combination according to claim **1** wherein said means responsive to the flow of current through said tube for applying a second filament voltage includes a voltage source in series with said filament and further in series with a normally conductive switch, said switch having a voltage dropping resistor in parallel therewith.

12. The combination according to claim **11** wherein said switch is a transistor, said transistor becoming reverse biased to render it nonconductive in response to the flow of current through said tube only after said tube fires.

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