

Aug. 19, 1958

L. W. HUSSEY

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TRANSISTOR GATING CIRCUIT

Filed Oct. 4, 1957

2 Sheets-Sheet 1

FIG. 1

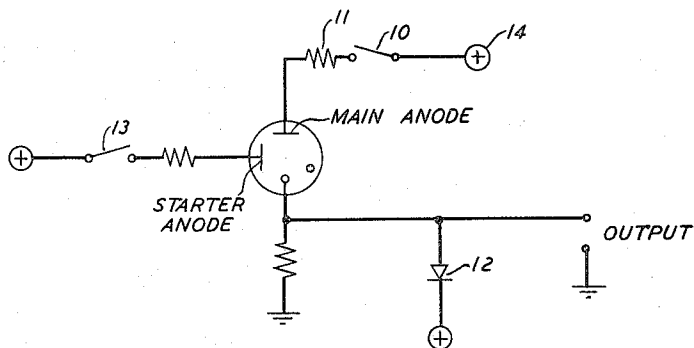
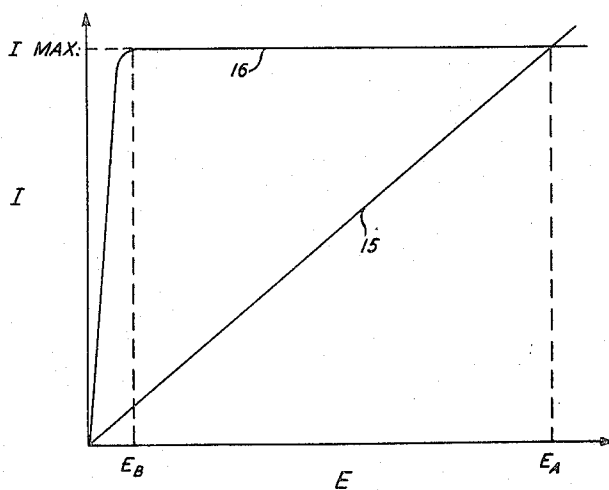


FIG. 2



INVENTOR  
L. W. HUSSEY  
BY  
S. E. Hollander  
ATTORNEY

Aug. 19, 1958

L. W. HUSSEY

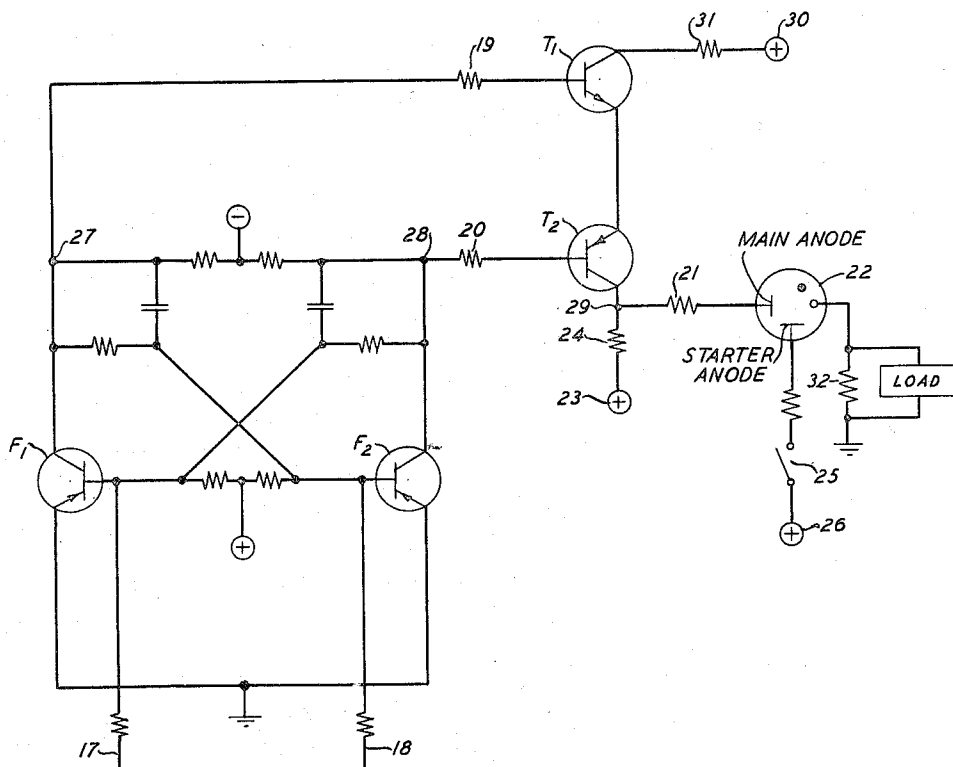
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2 Sheets-Sheet 2

FIG. 3



INVENTOR  
L. W. HUSSEY  
BY  
S. E. Hollander  
ATTORNEY

1

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## TRANSISTOR GATING CIRCUIT

Luther W. Hussey, Sparta, N. J., assignor to Bell Telephone Laboratories, Incorporated, New York, N. Y., a corporation of New York

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9 Claims. (Cl. 315—168)

This invention relates to gating circuits and more particularly to gating circuits for regulating the supply of current of predetermined maximum amplitude to a utilization device.

Certain load devices which operate in the low impedance range, for example, gas tube devices, are sensitive to changes of voltage applied thereto and are thus susceptible to injury from greatly increased current flow in consequence of relatively minor voltage variations. Consequently, it is desirable in supplying low impedance devices, including gas tubes, to utilize a source which has the inherent capability of limiting the current flow through the device to a fixed level. A factor which tends to render protection more difficult is that certain, presumably standard, gas tube devices manufactured under similar conditions exhibit substantial variations in critical characteristics such as main gap sustain potential and main gap breakdown potential.

Thus, if a voltage deemed to produce a safe current flow is applied to a particular type of gas tube, and if the tube is one having an unusually low main gap sustain potential, a significantly higher and possibly injurious current will flow through the tube.

In the past, the means adopted for limiting the current flow through a gas tube have included the introduction of a series impedance in the anode circuit of the tube. A disadvantage in the use of an impedance protective or limiting arrangement, however, is the diminution of the output pulse available from the tube as a result of the voltage drop across the impedance. Thus, in order to provide an output pulse of given magnitude, the voltage applied to the circuit is generally increased to compensate for the voltage drop across the series impedance.

The effectiveness of this procedure is circumscribed since the magnitude of the applied voltage is limited by the breakdown potential of the tube, operation at or in excess of the latter potential causing the tube to be constantly in the firing or conductive condition.

Ideally, to obtain the highest level output pulse from the tube, the protective device employed should exhibit an impedance characteristic which causes minimal voltage drop across the device until a predetermined maximum current level is achieved. At this level, the voltage drop should be permitted to increase to the value required to prevent any increase of current beyond the predetermined level.

It is therefore an object of this invention to improve the protective devices used in conjunction with gas tube circuits.

Another object of this invention is to provide for substantially constant current operation of low impedance devices.

A further object of this invention is to provide for the switching of gas tube circuits from the output of symmetrical two-state devices.

A feature of this invention is the use of serially-con-

2

nected n-p-n and p-n-p transistors, the bases of which are supplied from opposite outputs of a flip-flop circuit.

An additional feature of this invention is the use of a load connected in series with a variable impedance two-transistor switch.

A further feature of this invention is a switching device designed to produce a variable voltage drop thereacross as a function of the current flow therethrough.

These and other objects and features of the invention may be realized by the utilization of an n-p-n and p-n-p transistor, the collector-emitter circuits of which are connected in series with a gas tube and load. The emitter electrodes are joined and the base electrodes are connected to symmetrical outputs of a flip-flop circuit. The magnitude of the base current is controlled by the difference in voltage between the flip-flop outputs and the external base resistances.

When the potential across the bases is of a given polarity the transistors are driven into saturation and present a relatively low impedance in series with the supply source, gas tube and load. When the flip-flop is in the opposite state and the transistors are biased to the cut-off condition, a relatively high impedance is, in effect, inserted in series with the utilization device.

The magnitude of the maximum current flow when the transistors are in saturation (or "on") is limited by the base current and the alpha or current gain of the transistor. If the collector current exceeds the base current divided by  $(1-\alpha)$  the transistors tend to fall out of saturation and the collector current is reduced. In this sense, " $\alpha$ " may be defined as the ratio of change of collector current to change in emitter current for a constant collector voltage.

The above and other objects and features of the invention may be more fully comprehended by an examination of the following specification, appended claims and attached drawings in which:

Fig. 1 shows a known typical current-limiting device for a gas tube circuit employing an anode resistor;

Fig. 2 is a graphical representation of the characteristic of a type of protective device most suited for producing high level output pulses and also the characteristic of the resistive limiter of Fig. 1; and,

Fig. 3 shows an embodiment of the invention utilizing two transistors in series with the load, the base electrodes of the transistors being supplied from symmetrical-ly opposed potentials of a flip-flop output.

In all of the figures where a voltage source is shown by a plus or a minus sign, it is to be assumed that the opposite pole of the source is grounded unless otherwise indicated.

Referring now to Fig. 1, a prior art type of gas tube circuit employing a resistive limiter to protect the gas tube against current overloads, is shown. A separate switch 10 is used in series with the protective resistance 11 to precondition and deenergize the tube. The diode clamp 12 in the cathode circuit fixes the highest level of the voltage pulse obtainable.

In operation when switch 10 is closed, a voltage from source 14, higher than the main gap sustain potential, but lower than the breakdown potential, is applied.

To fire the tube, switch 13 is closed to the starter anode and the control gap of the gas tube ionizes and transfers to the main gap in the usual way, drawing a current which is limited by anode resistance 11. The voltage of the output pulse is determined by the difference between the applied voltage 14 and the sum of the sustain voltage of the tube and the drop across resistance 11 in the anode circuit. It is manifest, therefore, that if there were no resistance in the anode circuit, or if the resistance were lower, the output pulse obtainable would be higher. How-

ever, it is well known that approaching such a low impedance anode load condition may jeopardize the life of the tube due to attendant permissive high currents.

Fig. 2 shows the voltage current-characteristic 15 of the resistance-limiting device of Fig. 1 and also the characteristic 16 of the type of protection most suited for producing high voltage output pulses. In practice, some voltage drop across a protective circuit is inevitable. However, Fig. 2 shows that the voltage drop across the desired type of protection device is much smaller than that across a resistive protector.

Specifically referring to Fig. 2, it is seen that for a particular value of current  $I_{\text{Max}}$  the voltage drop (line 15) across the resistive protection device, such as resistance 11 of Fig. 1, is voltage  $E_a$  while the corresponding voltage drop across the preferred type of arrangement is  $E_b$ , a considerably lower voltage. Since, as explained above, the available output pulse is decreased by the drop across the protection circuit, the voltage of the signal obtainable with a device having the current-voltage characteristic 16 is an improvement over that obtainable from the resistive protector in an amount equal to the difference between  $E_a$  and  $E_b$ .

An arrangement which will manifest a voltage-current relationship similar to that of curve 16 in Fig. 2 is shown in Fig. 3.

Referring to Fig. 3, an illustrative two-transistor bistable or flip-flop circuit including transistors  $F_1$  and  $F_2$  is shown. Pulses over leads 17 and 18 cause the flip-flop circuit to operate in the usual way. The output of the flip-flop circuit includes resistors 19 and 20 which are respectively connected to the bases of transistors  $T_1$  and  $T_2$ .

The latter transistors  $T_1$  and  $T_2$  are respectively n-p-n and p-n-p transistors, the emitters of which are joined. The collector circuit of transistor  $T_2$  is connected through collector external resistance 21 to the main anode of gas tube 22 and to a potential source 23 over resistance 24. The cathode of gas tube 22 is connected to ground over resistance 32. A load device, shown symbolically, is connected in parallel with resistance 32. Switch 25 connects potential source 26 to the starter anode of tube 22.

In operation, assuming that transistor  $F_1$  is in the non-conducting condition and  $F_2$  is in the conducting condition, the output potential at terminal 27 will be somewhat more negative than the output potential at terminal 28. As a result, transistor  $T_1$  will be in the non-conducting or "off" condition due to the negative potential on its base with respect to its emitter potential and transistor  $T_2$  will be in the "off" condition in consequence of the somewhat higher potential on its base electrode with reference to its emitter. These conditions obtain since the potential on the transistor emitters is approximately midway between the voltages applied to the bases.

The impedance presented by transistors  $T_1$  and  $T_2$  is very high in the "off" condition, and is, in effect, a virtual open circuit in series with the gas tube. Since at this time no current flows through resistance 32, the voltage at the cathode of the gas tube approaches ground potential.

In order to energize transistors  $T_1$  and  $T_2$ , a negative pulse may be applied to conductor 17 thereby causing transistor  $F_1$  to conduct and shifting transistor  $F_2$  to the quiescent state in a well-known manner. When transistor  $F_1$  is in the "on" condition, its collector potential increases in the positive direction and the collector potential of transistor  $F_2$ , which is now "off," increases in the negative direction. As a result, terminal 27 is now more positive than terminal 28, thereby driving the base of transistor  $T_1$  positive with reference to the emitter of transistor  $T_1$ , and the base of transistor  $T_2$  negative with respect to its emitter. Transistors  $T_1$  and  $T_2$  are thus shifted to the low impedance state or "on."

When transistors  $T_1$  and  $T_2$  are in the low impedance state, the voltage at terminal 29 and at the main anode

of tube 22 is shifted from the potential of source 23, which may, for example, be 95 volts, to a voltage approximating that of potential source 30 which may illustratively be 150 volts. In practice, the voltage of source 23 is chosen to be somewhat lower than the sustain potential of gas tube 22 while source 30 is higher than the sustain potential but lower than the breakdown potential.

Since the voltage of source 30 is lower than the breakdown potential of tube 22, the tube does not fire although the voltage thereacross has been raised above the sustain potential. When switch 25 is closed, however, a potential is applied to the starter anode from source 26 sufficient to ionize the starter gap. Transfer to the main gap takes place in the well-known manner and tube 22 continues to conduct in consequence of the increased potential at the main anode from source 30.

When tube 22 conducts through its main gap the voltage at the cathode of the tube rises from near ground potential to a voltage approaching that of source 30 less the drop across the main gap of tube 22 and across transistors  $T_1$  and  $T_2$ , thereby applying a sharp pulse to the load device in parallel with resistance 32. The values of resistors 31 and 21 are designed to be sufficiently low to exhibit an insignificant voltage drop thereacross.

The current flow through gas tube 22 is limited by the maximum possible collector current which in turn is governed by the base current flow. The magnitude of the base current itself is determined by the difference between the voltages at terminals 27 and 28 and the values of resistances 19 and 20. The sustain current of the gas tube 22 is, in effect, the collector current of the transistors.

If the collector current exceeds the base current divided by  $(1-\alpha)$  the transistors go out of saturation and the collector current is sharply curtailed.

For example, if the parameters of the circuit are selected to provide a base current flow of 2 mills when transistors  $T_1$  and  $T_2$  are in the "on" condition, and if  $\alpha$  is 0.98, the collector current cannot exceed 100 mills.

To extinguish tube 22, a negative pulse may be applied to lead 18, thereby reestablishing the original flip-flop condition and shifting transistors  $T_1$  and  $T_2$  to the "off" condition.

As an alternative to the operating procedure described above, switch 25 to the starter anode may be closed in advance of the operation of transistors  $T_1$  and  $T_2$  to the low impedance state. In this event, with transistors  $T_1$  and  $T_2$  in the "off" condition, actuating switch 25 will ionize the starter gap but no main gap discharge will take place since the voltage of source 23 is lower than the sustain potential of tube 22.

When transistors  $T_1$  and  $T_2$  are subsequently changed to the "on" condition, however, by the means described above, a voltage will be applied to the main anode of the gas tube 22 sufficient to cause transfer of the starter gap discharge to a main gap discharge. To extinguish the main gap discharge, transistors  $T_1$  and  $T_2$  are switched to the "off" condition as described previously.

It is understood that the arrangements and values shown are merely exemplary and that various modifications may be made by those skilled in the art without departing from the spirit and scope of the present invention.

What is claimed is:

1. A current-regulating device including at least two transistors, each of said transistors having emitter, base and collector electrodes, said emitter electrodes being connected in series relationship, a utilization device connected to one of said collector electrodes, means for supplying operating potentials to said collector electrodes, and switching means for supplying operating potentials to said base electrodes to transfer said transistors between low and high impedance states.

2. A current-limiting switch including at least two transistors of opposite conductivity types, each having

5

base, emitter and collector electrodes, said emitters being connected in series relationship, triggering means operable to supply operating potentials to said base electrodes, means for supplying operating potentials to said collector electrodes, and a utilization device connected to one of said collector electrodes whereby a limited current is driven through said utilization device in response to the operation of said triggering means.

3. A current-regulating gating circuit including at least two transistors, each having base, emitter and collector electrodes, said emitters being directly coupled in serial relationship, a two-state device having symmetrically opposed potential output conductors connected to said base electrodes, an operating potential source connected to said collector electrodes, and a utilization device connected to one of said collector electrodes, whereby a current of predetermined maximum amplitude is supplied to said utilization device in response to the operation of said two-state device to a particular state and substantially no current is supplied to said utilization device in response to the operation of said two-state device to the other state.

4. A current-regulating switch including at least two transistors of opposite conductivity types, each having base, emitter and collector electrodes, means for directly coupling said emitters in series relationship, switching means operable to supply control potentials to said base electrodes, means for supplying operating potentials to said collector electrodes, and a gas tube connected in series with one of said collectors whereby a regulated current is supplied to said gas tube in response to the operation of said switching means.

5. A current-limiting device including at least two transistors, each having base, emitter and collector electrodes, means for directly coupling said emitter electrodes in serial relationship, a two-state device having symmetrically opposed potential output means connected to said base electrodes, means for supplying operating potentials to said collector electrodes, and a gas tube connected in series with one of said collector electrodes whereby a current of predetermined amplitude is supplied to said gas tube in response to the operation of said two-state device.

6. A current-regulating gating circuit including two transistors of opposite conductivity types, each having base, emitter and collector electrodes, means for directly coupling said emitters in series relationship, a bistable triggering device connected to said base electrodes for supplying a potential difference thereacross, a first potential source of relatively high voltage for supplying operating potential to a first of said collector electrodes, a second potential source of relatively lower voltage for supplying operating potential to a second of said collector electrodes, and a utilization device connected to said second collector electrode, whereby the operation of said triggering device to one state produces a potential approximating the level of said first potential source across said utilization device and the operation of said triggering device to the other state produces a potential difference across said utilization device approximating the level of said second potential source.

7. A current-limiting gating circuit including at least two transistors of opposite conductivity types, each having base, emitter and collector electrodes, means for directly coupling said emitter electrodes in series relationship, a first potential source of relatively high voltage connected to a first of said collector electrodes, a second potential source of relatively lower voltage connected to a second of said collector electrodes, a bistable triggering device

6

for supplying a potential difference across said base electrodes, and a gas tube device connected to said second collector electrode, said first potential source having a voltage greater than the sustain voltage of said gas tube but lower than the breakdown voltage thereof, said second potential source having a voltage lower than the sustain value of said gas tube, whereby the operation of said triggering means to one state produces a potential difference across said gas tube proportional to the voltage of said first potential source and the operation of said triggering means to the other state produces a potential difference across said gas tube proportional to the voltage of said second potential source.

8. A current-limiting gating device including at least two transistors of opposite conductivity type, each having base, emitter and collector electrodes, means for directly coupling said emitters in series relationship, a two-state device having symmetrically opposed potential output means connected to said base electrodes to establish a predetermined base current flow when said device is in a particular state, a first operating potential source of relatively high voltage connected to a first of said collector electrodes, a second operating potential source of relatively lower voltage connected to a second of said collector electrodes, a gas tube device having its main discharge circuit connected in series with said second collector electrode, a third potential source, and means connecting a starter anode of said gas tube to said third potential source whereby a current of predetermined maximum amplitude is supplied to said utilization device in response to the operation of said two-state device to said particular state, said current being defined by the relationship

$$I_m = \frac{I_b}{1 - \alpha}$$

wherein  $I_m$  is the predetermined maximum current amplitude,  $I_b$  is the base current and  $\alpha$  is the ratio of the change in collector current to the change in emitter current for a constant collector voltage, and whereby substantially no current is supplied to said gas tube in response to the operation of said two-state device to the other state.

9. A current-regulating gating circuit including a pair of opposite conductivity type transistors, each of said transistors having emitter, base and collector electrodes, means for directly coupling said emitter electrodes in series relationship, a flip-flop circuit having a pair of output leads for supplying symmetrically opposed output potentials, a pair of resistances connecting said output leads to said base electrodes, a first potential source of relatively high voltage connected through impedance means to a first of said collector electrodes, a second potential source of relatively lower voltage connected through impedance means to a second of said collector electrodes, a gas tube triode connected through impedance means to said second collector electrode, a third potential source, switching means operable to connect said third potential source to a starter anode of said gas tube, and impedance means connecting the cathode of said triode to a source of reference potential, whereby a current of predetermined maximum amplitude is supplied to said triode in response to the actuation of said switching means and the operation of said flip-flop to a particular state and whereby substantially no current is supplied to said triode in response to the operation of said flip-flop to the other state.

No references cited.