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[54] **TRAVELING-WAVE TUBE PACKAGE WITH INTEGRAL VOLTAGE REGULATION CIRCUIT FOR REMOTE POWER SUPPLY**

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(Under Rule 47)

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Related U.S. Patent Documents

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Appl. No.: **2,589**
Filed: **Jan. 13, 1970**

[52] **U.S. Cl.** **315/3.5**; 315/39.3; 330/43; 331/82
[51] **Int. Cl.**[2] **H01J 25/34**
[58] **Field of Search** 315/3.5, 3.6, 39.3; 331/82; 330/43

[56] **References Cited**

UNITED STATES PATENTS

3,114,886	12/1963	DeSantis et al.	330/43 X
3,165,696	1/1965	Poole	330/43 X
3,249,889	5/1966	Brocato	331/82
3,293,479	12/1966	Chalk	330/43 X
3,737,713	6/1973	Kalish	315/3.5
3,849,701	11/1974	Kerfoot et al.	315/3.5

FOREIGN PATENTS OR APPLICATIONS

74,801	1/1956	France	330/43

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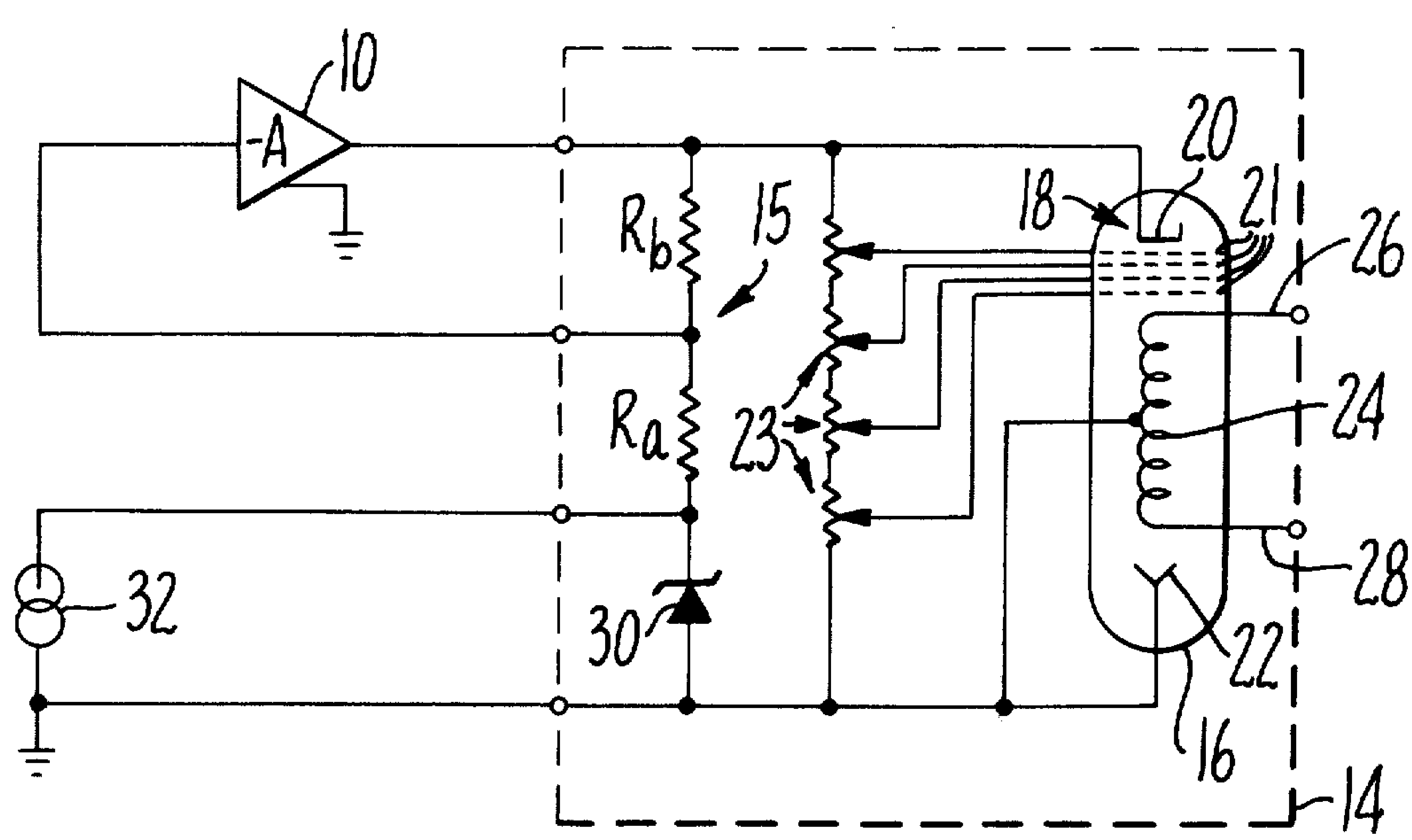
Attorney, Agent, or Firm—Limbach, Limbach & Sutton

[57] **ABSTRACT**

A circuit is provided in a traveling-wave tube package which eliminates the need of manually setting the power supply voltage to match the proper operating voltage of the tube. The circuit utilized within the traveling-wave tube package forms a part of the power supply, the remainder of which is provided externally of the traveling-wave tube package. By selecting the proper circuit components, the traveling-wave tube package can be connected without adjustment to a power supply and still operates at the desired voltage.

20 Claims, 7 Drawing Figures



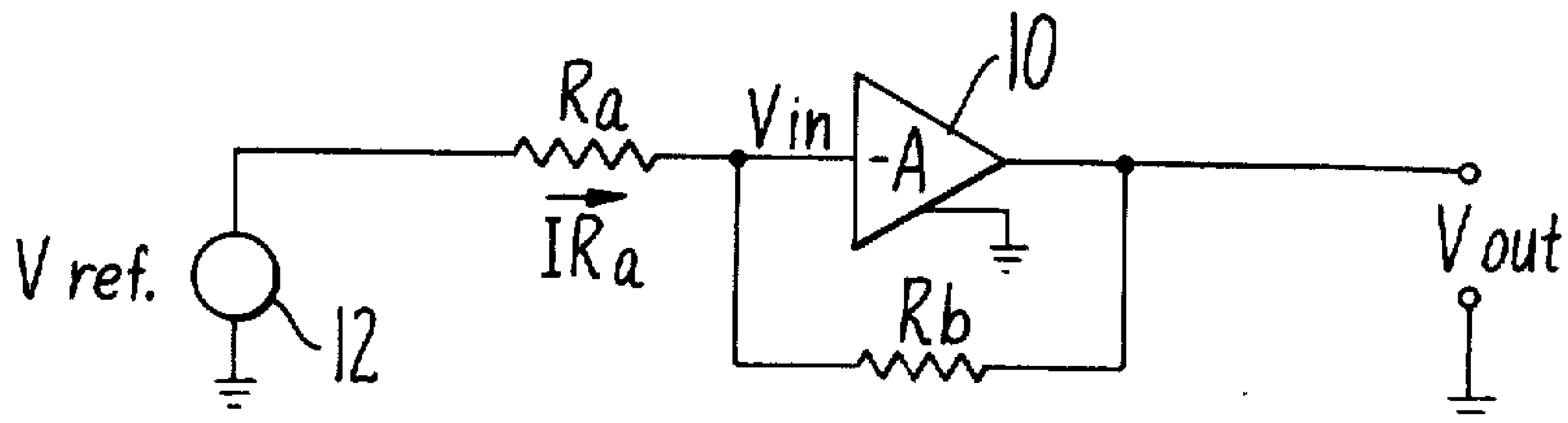


FIG. 1.

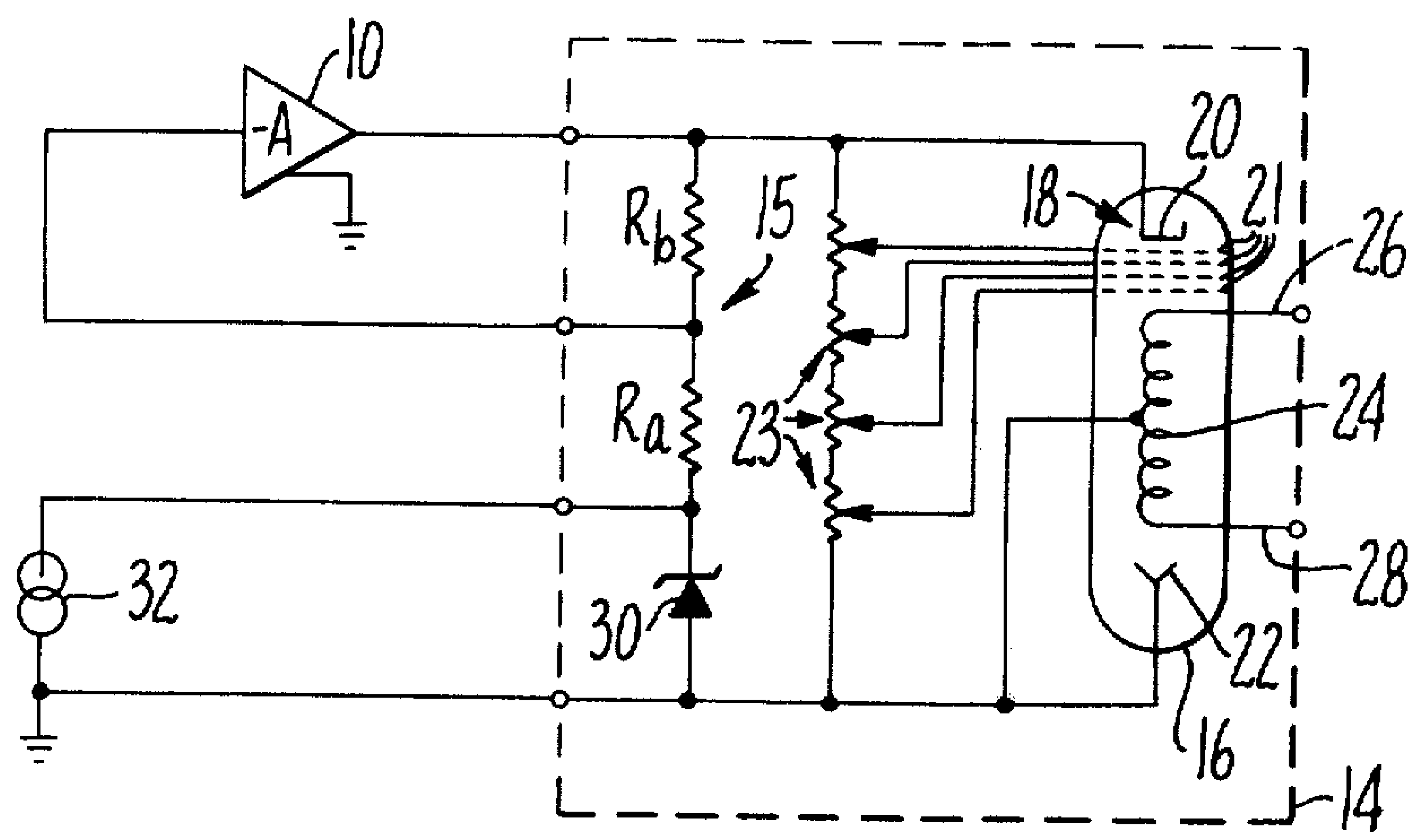


FIG. 2.

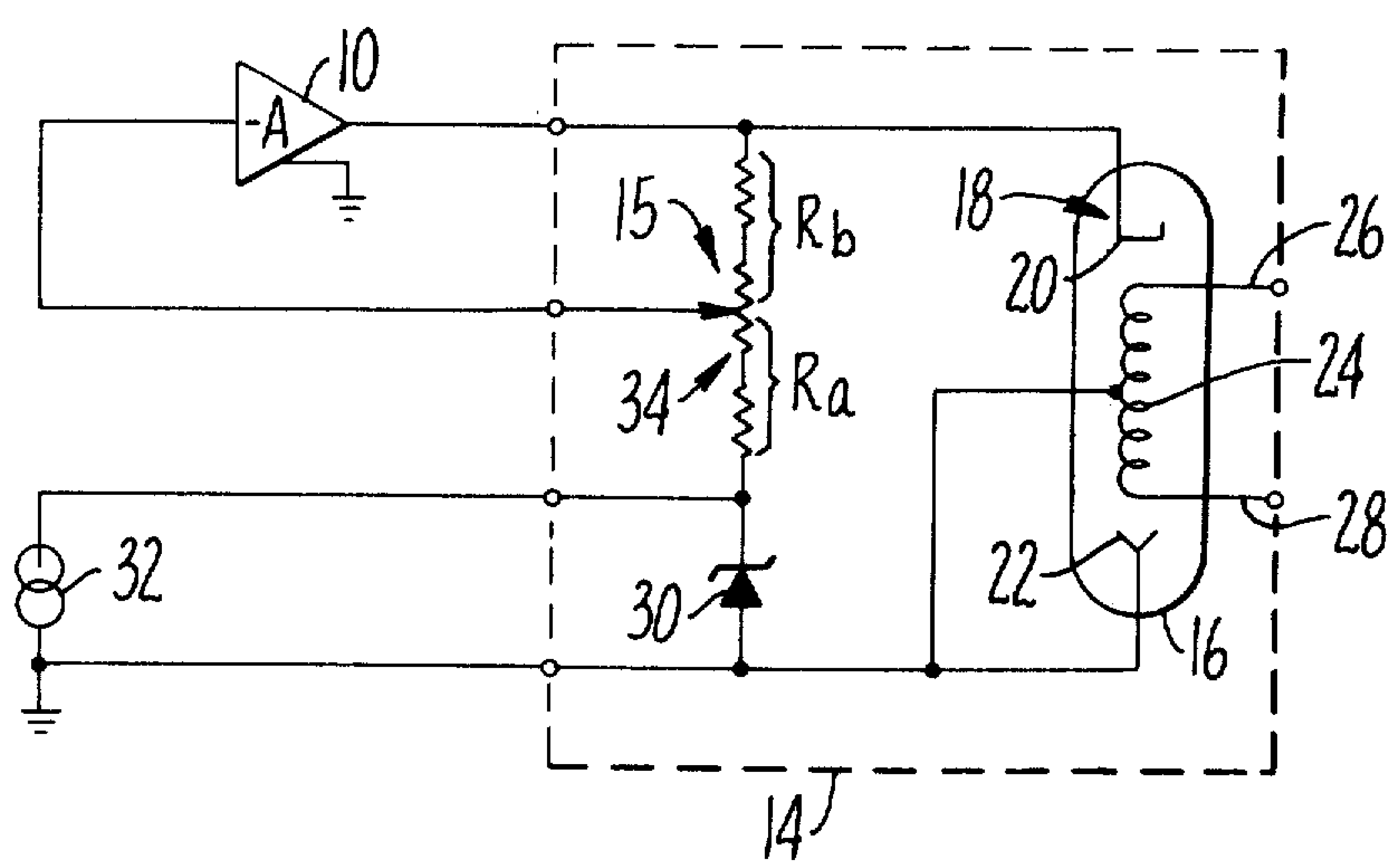


FIG. 3.

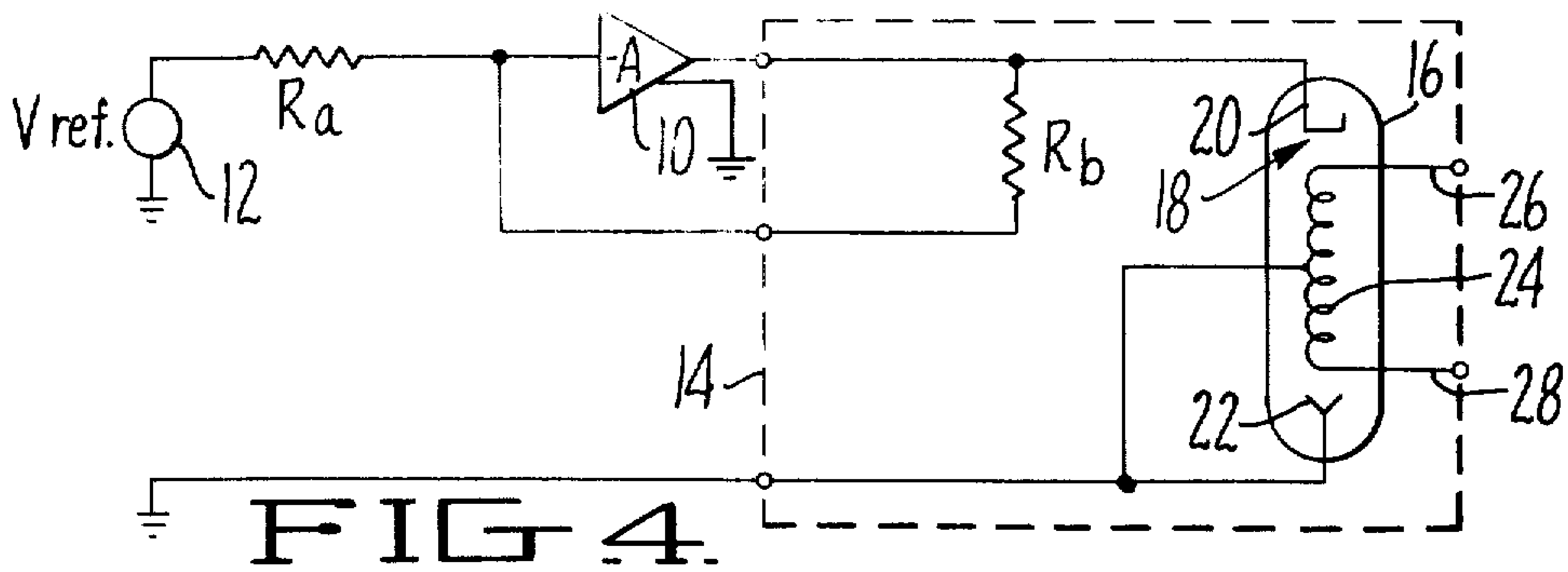


FIG. 4.

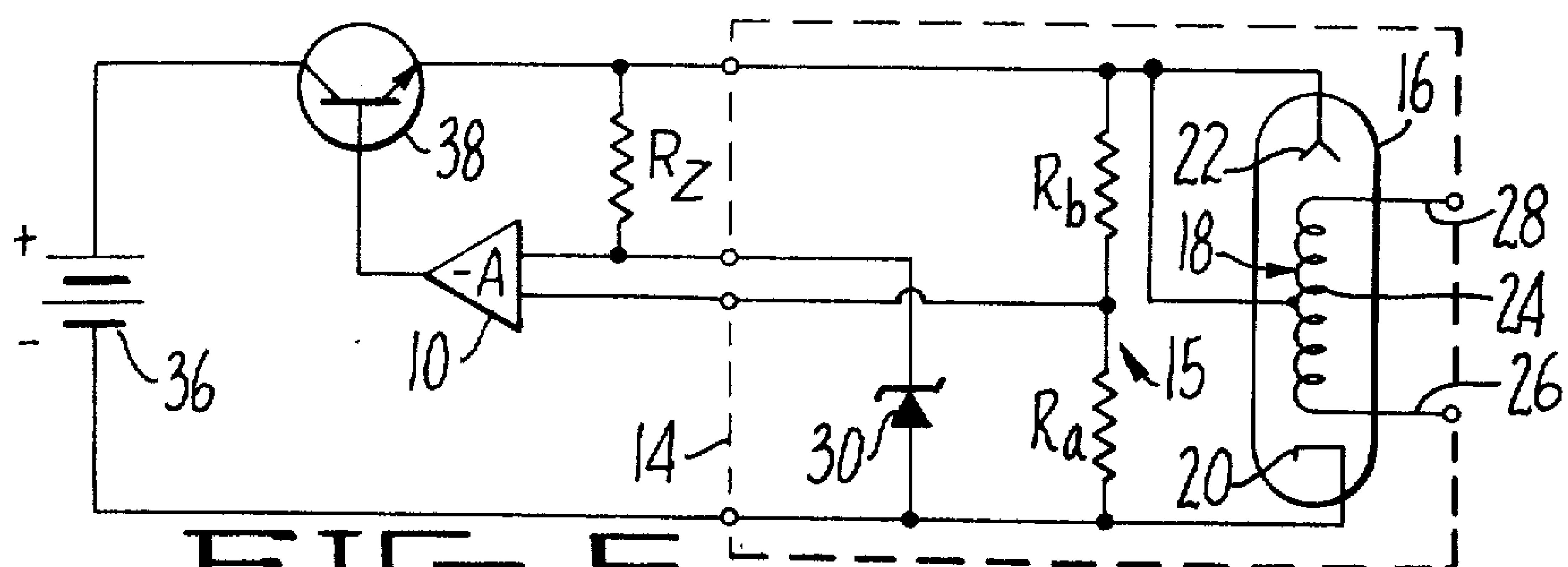


FIG. 5.

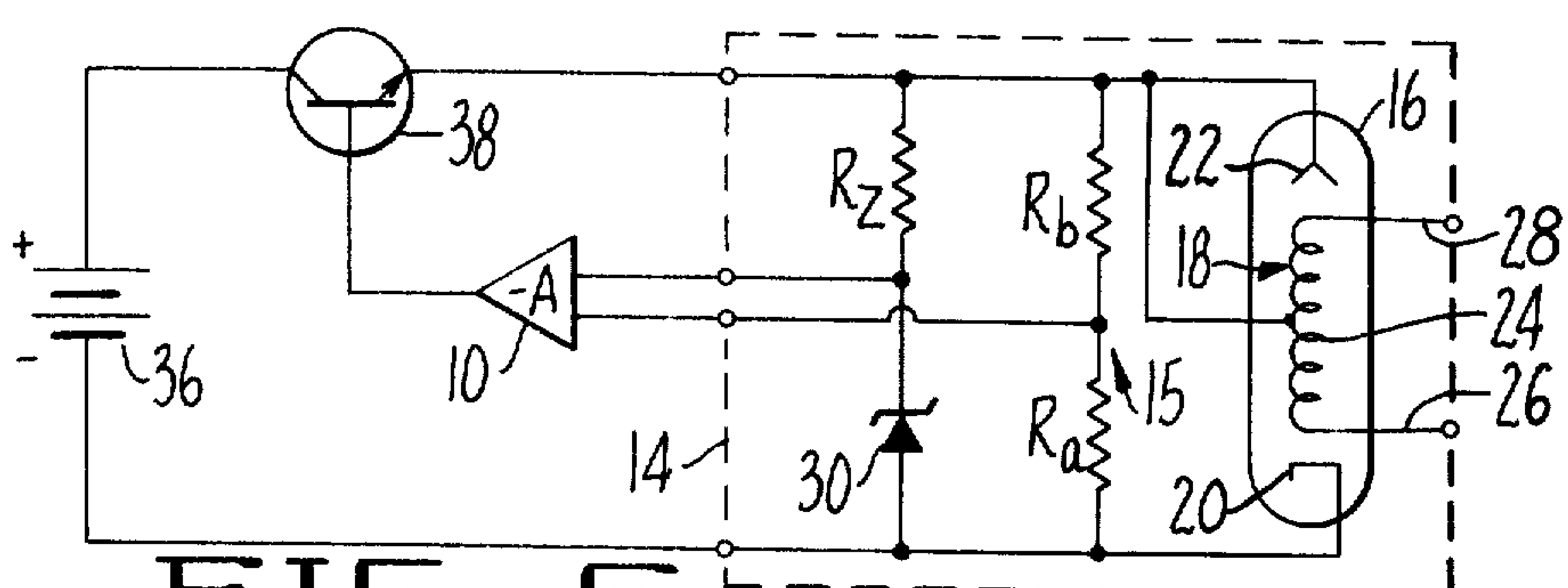


FIG. 6.

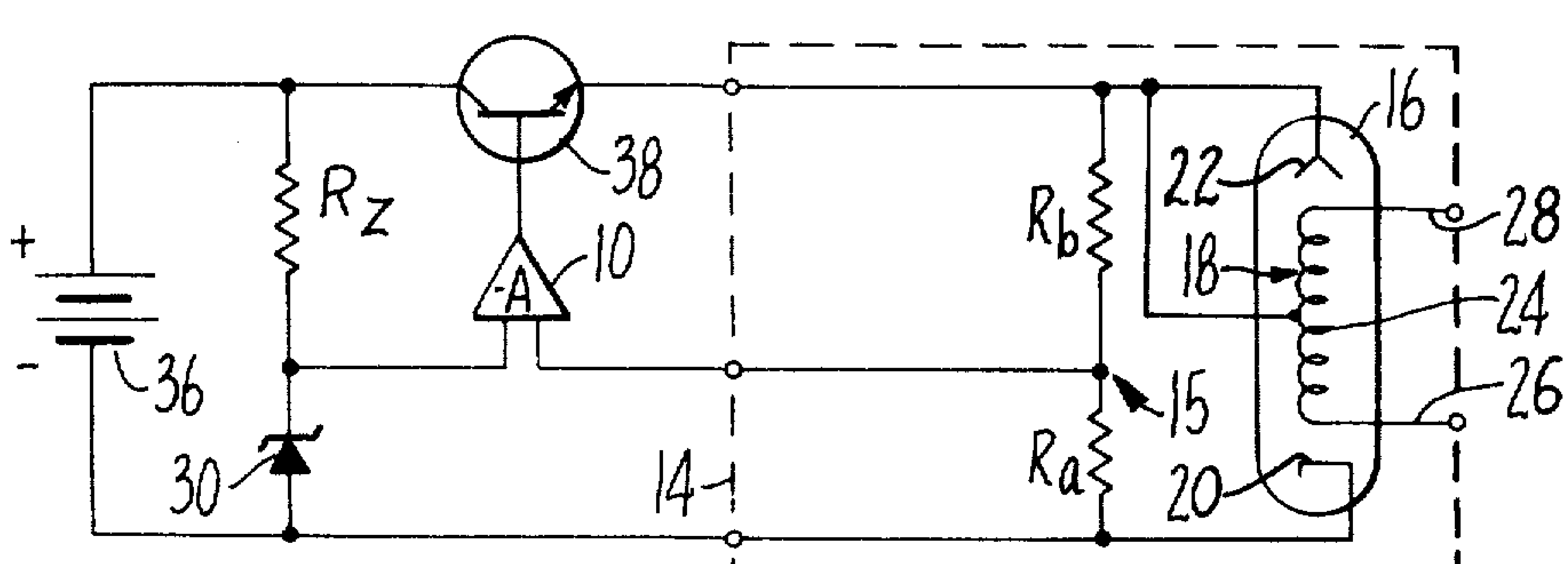


FIG. 7.

TRAVELING-WAVE TUBE PACKAGE WITH INTEGRAL VOLTAGE REGULATION CIRCUIT FOR REMOTE POWER SUPPLY

Matter enclosed in heavy brackets [ ] appears in the original patent but forms no part of this reissue specification; matter printed in italics indicates the additions made by reissue.

BACKGROUND OF THE INVENTION

The present invention relates in general to electron discharge devices and more particularly to a traveling-wave tube including electronic circuitry so that no adjustment is required in the field to provide the voltage necessary for proper operation of the traveling-wave tube.

Many complex electronic systems utilize one or more electron discharge devices as traveling-wave tubes and, in general, these traveling-wave tubes are field replaceable; i.e., a tube is replaced directly in the field whenever it fails to meet specifications. However, because the performance of a travelling-wave tube, particularly a low noise traveling-wave tube, is critically dependent upon the high electrode voltages, typically in the range of thousands of volts, supplied by the system's power supply and because it is not unusual to find the regulation of the system power supply just barely within the regulation limits permitted by the traveling-wave tube specifications, operation of the traveling-wave tube within specified performance can be achieved only if the error in setting electrode voltages is extremely small. A typical cathode helix voltage regulation specification for a low-noise traveling-wave tube with a helix slow-wave structure is at most ±0.5 percent.

Presently, one common method in field adjustment of low-noise traveling-wave tubes is to adjust the cathode-to-helix voltage for optimum small signal gain at the highest operating frequency. This method has the advantage of not requiring an accurate voltmeter since the voltage is not even measured; however, it does require much more skill in setting the voltage. Furthermore, the design of equipment may require certain modifications to permit a small signal gain measurement. Another difficulty is that many low-noise traveling-wave tubes exhibit optimum performance at a voltage different from that producing maximum gain at the highest operating frequency. Finally, this procedure does not provide a method for accurately setting the various anode voltages, necessary in low-noise traveling-wave tubes, without use of an accurate voltmeter which has a very high internal impedance.

As a general rule voltmeters with the required accuracy for setting the electrode voltage are not available in the field. Therefore, optimum performance is seldom achieved in replacement traveling-wave tubes. Even when accurate voltmeters are available in the field, they require frequent calibration checks which are often logistically impossible. Additionally, required accuracy is difficult to achieve even if the particular meter setting happens to be a full scale reading, and danger to the operator exists in setting up such a meter to read a high voltage.

Coupled with the problem of proper setting of the cathode-to-helix voltage in low noise traveling-wave tubes is the setting of various anode voltages for multi-

ple anode electron guns present in all low noise traveling-wave tubes. The required anode voltages are determined by the particular design of the low noise gun. Because of manufacturing tolerances there is rather a wide variation in anode voltages from tube to tube, but the tolerance within which these voltages must be set in order to achieve the desired noise figure is only about ±1.0 percent of the nominal values. Thus, the problems encountered in setting the anode voltages are similar to, and as difficult as, those encountered in setting the cathode-to-helix voltage.

In another prior art system a voltage bridge network is connected within the traveling-wave package between the cathode and slow-wave structure of the traveling-wave tube. The bridge network is adjusted by the manufacturer such that a reading can be made in the field across the bridge of the bridge network, and the voltage applied between the electrodes adjusted until a null reading exists in the measuring device. At this point a desired predetermined voltage exists between the electrodes. Such a system is more fully described in a pending patent application entitled "Electron Discharge Device with Integral Voltage Bridge and Method of Setting Same," filed Feb. 3, 1969, Ser. No. 796,133, by James L. Palmer and G. E. Tallmadge, and assigned to the assignee of the present invention. Such a system, while an improvement over the previously described prior art system, still has the significant disadvantage that a null reading must be taken to provide the proper voltage setting and complete interchangeability of tubes and supplies without adjustment is not possible.

SUMMARY OF THE INVENTION

These and other difficulties of the prior art systems are eliminated in accordance with one aspect of the present invention by providing within the traveling-wave tube package electronic circuitry for automatically regulating the voltage across the traveling-wave tube regardless of the power supply provided. This is accomplished by including within the traveling-wave tube package those elements normally associated with the power supply which are effective in determining the output parameters of the power supply.

More particularly, a typical power supply for a traveling-wave tube includes a reference voltage supply, an input resistance connected between the reference voltage and a high gain amplifier, and a feedback resistor connected between the output and the input of the amplifier. It will be shown subsequently that the output voltage V_{out} of the aforedescribed power regulator is substantially a function of three parameters of such a power supply, according to the relationship;

$$V_{out} = -V_{ref}\frac{R_b}{R_a}$$

where V_{out} is the output voltage from the amplifier which is applied across the cathode to helix terminals of a traveling-wave tube, V_{ref} is the reference voltage, R_b is the feedback resistance and R_a is the input resistance.

Accordingly, by including the circuit elements determinative of the V_{out} within the traveling-wave tube package, the output voltage applied to the traveling-wave tube will be a predetermined constant and will require no adjustment in the field.

According to another aspect of the present invention, nly certain rather than all of the aforesaid circuit lements determinative of V_{out}, are included within the 'aveling-wave tube and those not included are precise. herefore, the desired V_{out} will be obtained.

It is therefore an object of the present invention to rovide an improved traveling-wave tube which has nproved operating characteristics due to more accuately provided operating voltages.

Another object of the present invention is to provide traveling-wave tube which is adjusted for proper opration during manufacturing and does not require ırther adjustment in the field.

Another object of the present invention is to provide traveling-wave tube tube package with separable ower supply and tube but with complete field interhangeability of tube and power supply without adjustnent.

Still another object of the present invention is to rovide electronic circuitry within an electron disharge device such that the device is operable over a ange of field applied voltages.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic diagram of a basic power supply ircuit used with traveling-wave tubes.

FIG. 2 is a schematic diagram of a traveling-wave ube utilizing aspects of the present invention.

FIG. 3 is a schematic diagram similar to that shown in 'IG. 2 and showing another embodiment of the present nvention.

FIGS. 4, 5, 6 and 7 are schematic diagrams illustratng still other embodiments of the present invention.

DETAILED DESCRIPTION OF THE DRAWINGS

FIG. 1 illustrates a highly stable fixed gain power upply suitable for use with a traveling-wave tube. The ower supply includes a high gain amplifier **10.** A referınce voltage source **12** is provided which is connected o the input of the amplifier **10** through input resistance R_a. A feedback resistance R_b is placed across the input ınd output terminals of the amplifier **10.** The power upply output voltage, V_{out}, is taken from the output of ımplifier **10.** As previously stated, the output voltage V_{out}, essentially, is given by:

$$V_{out} = -V_{ref}\frac{R_b}{R_a}$$

This may be derived as follows. If one assumes that ın amplifier is an ideal amplifier, with an infinite input impedance, then the input voltage to the amplifier will be equal to ground voltage. While no amplifier can be made which is ideal, commercially available amplifiers have such high input impedance that they may be considered as having the properties of an ideal amplifier for many purposes. Since the input voltage to amplifier **10** is substantially equal to ground potential, the input current to amplifier **10** is zero and hence all the current, I_R, flowing through R_a flows through R_b, i.e.,

$$I_{R_b} / I_{R_a} \text{ and since } I_{R_a} = \frac{V_{ref}}{R_a}$$

$$= \frac{V_{ref}}{R_a} \text{ then with } V_{in} = \text{ground voltage},$$

$$V_{out} = -I_{R_b} R_b \text{ and substituting}$$

$$V_{out} = -V_{ref}\frac{R_b}{R_a}$$

Thus the output voltage is determined substantially by three parameters, i.e., V_{ref}, R_b, and R_a, and by varying or selecting any one or any combination of these three, the desired output voltage for the traveling-wave tube can be set.

According to the present invention, all of the three controlling components are provided within the traveling-wave tube package, or at least one of these components is provided in the traveling-wave tube package and those components not included, or their ratio, is precise. The value or values of the components selected are selected so as to provide the proper output voltage for that particular traveling-wave tube. This simplifies installation of the traveling-wave tube in the field since no adjustment is required during its installation, such adjustment being provided during the manufacturing process.

FIG. 2 illustrates the preferred embodiment of the present invention. Shown therein is a traveling-wave tube package **14** of conventional structure which includes an envelope **16** provided with a beam-generating assembly **18** including a cathode **20** at one end position of the envelope **16** for generating and projecting a beam of electrons longitudinally of the envelope **16** to a collector assembly **22.** A slow-wave structure **24** such as a helix is positioned between the beam generating assembly **18** and the collector assembly **22** for providing wave-beam interaction between a radio frequency electromagnetic wave traveling along the slow-wave structure **24** from an input waveguide **26** to an output waveguide **28.** While the present invention is schematically illustrated and will be described for purposes of illustration as applied to a low power traveling-wave tube utilizing a helix slow-wave structure, it will be appreciated that the invention is applicable for use with tubes having other types of slow-wave structures.

In the case of low noise traveling-wave tubes, a multiple anode low noise electron gun it utilized, and the appropriate voltages intermediate the cathode voltage and ground are established on anodes **21** with potentiometers **23** which can be factory adjusted to the desired auxiliary voltage when the proper cathode voltage is applied. For simplicity this low noise gun will not be illustrated in the other embodiments.

The traveling-wave tube is operated with application of a high voltage between the cathode and the slow-wave structure. Provided within the traveling-wave tube package **14** is bridge circuit **15** including feedback resistor R_b and an input resistor R_a which are connectable in the same manner as shown in FIG. **1** with an externally provided amplifier **10,** also identical to the one shown in FIG. **1.** Connected between the input resistor R_a and ground is Zener diode **30** having a breakdown voltage equal to the desired reference voltage. To maintain the Zener diode at its breakdown potential, a current supply **32** is provided. Both the amplifier **10** and the current supply **32** are physically separate from the traveling-wave tube package **14** in the embodiment shown in FIG. **2.** Since the traveling-wave tube package **14** includes the three determining elements of the power supply, i.e., R_b, R_a and Zener **30** which provides the reference voltage, V_{ref}, the voltage supplied to the tube **16** is self-regulating and all that is required when a tube is replaced in the field is that an amplifier and a current source be provided for operation of the tube. No adjustments are required during the installation of the tube. This results in reduced labor cost and also provides a more accurate discharge tube voltage than possible with manual adjustment in the field. All the advantages of an integral amplifier approach (combined power supply and tube) are achieved and at the same time the disadvantages usually associated with a separable amplifier are eliminated.

FIG. 3 is similar to FIG. 2 with the exception that an additional variable resistance 34 is provided in bridge 15. Since the output voltage is a function of the ratio of R_b and R_a, by including the variable resistance 34 it is a simple matter to adjust the ratio of R_b to R_a while in the factory to provide the proper ratio.

In some situations it is less desirable to provide all of the three controlable elements of the power supply within the discharge tube package, as, for example, when a less expensive or a less bulky traveling-wave tube package is required. Referring to FIG. 4, only the feedback resistance R_b is provided within the traveling-wave tube package 14. The input resistance R_a and the reference voltage source 12 are external to the traveling-wave tube package 14. However, as long as the critical element or elements which are in the power supply are precisely the same value or precisely the same ratio of values, the critical element or elements in the tube package can be adjusted to match the tube to all power supplies.

FIG. 5 is similar to FIG. 2 except that an additional power stage is provided, including a direct current source or battery 36 and transistor 38. Additionally, amplifier 10 is of the type characterized as a differential amplifier. A resistance R_z is provided externally of the traveling-wave tube package 14 as a part of the current supply required to maintain Zener diode 30 in the breakdown condition.

The embodiment shown in FIG. 6 is identical with that in FIG. 5 with the exception that resistor R_z is also included within the traveling-wave tube package 14.

FIG. 7 is identical with FIG. 5 except that Zener diode 30 is included with the externally provided portion of the power supply rather than within the traveling-wave tube package. This arrangement requires a precise value for the Zener diode for complete interchangeability.

While the present invention has been described above in sufficient detail to enable a person skilled in the art to practice the invention, by way of further illustration the component values used for a typical circuit illustrated in FIG. 3 are listed in the following table.

TABLE 1

Zener diode 30	1N4773 A having a breakdown voltage of 9.1 volts
R_b	12 mΩ
R_a	39 8 KΩ
Resistor 34	15 KΩ
Amplifier 10	RCA CA 3033A plus additional amplification stages to handle high voltage output

Although the foregoing invention has been described in some detail by way of illustration and example for

purposes of clarity of understanding, it is understood that certain changes and modifications may be practiced within the spirit of the invention as limited only by the scope of the appended claims.

What is claimed is:

1. A traveling-wave tube assembly having voltage control for use with an associated remote power supply having a high gain amplifier providing sufficient voltages for the electrodes of the traveling-wave tube comprising:
   - a tube package housing;
   - a vacuum envelope located within said housing;
   - a beam generating assembly for generating and projecting a beam of electrons from one position within said envelope to another position therein and including a cathode;
   - a collector assembly located at said other position for collecting said beam of electrons,
   - a slow-wave structure located between said positions for providing interaction between said beam and a radio frequency wave propagating along said slow-wave structure; and
   - circuit means connected to said tube package housing and remote from the power supply including at least part of a voltage regulation circuit comprising electronic components for operatively cooperating with the high gain amplifier for automatically establishing a predetermined voltage across said cathode and said collector assembly.

2. A traveling-wave tube assembly as in claim 1 wherein said voltage regulation circuit regulates external high gain amplifier and comprises an input impedance, a reference voltage source for soupling to the input of said amplifier through said input impedance, and a feedback impedance for connection between the input and output of said amplifier.

3. A traveling-wave tube assembly as in claim 2 wherein said input impedance, said reference voltage source and said feedback impedance are all connected to said tube package housing and remote from the power supply.

4. A traveling-wave tube assembly of claim 3 wherein said predetermined voltage, V_{out}, is determined by the equation:

$$V_{out} = -V_{ref}\frac{R_b}{R_a}$$

and wherein V_{ref} is the voltage of said reference voltage source, R_b is the impedance of said feedback impedance and R_a is the impedance of said input impedance.

5. A traveling-wave tube assembly as in claim 2 wherein at least one of said components consisting of said input impedance, said reference voltage source and said feedback impedance is included in said housing connected circuit means and the other of said components have precise values.

6. An electron discharge device having voltage control comprising:
   - an electron discharge tube package housing;
   - a vacuum envelope located within said housing;
   - a beam generating assembly for generating and projecting a beam of electrons from one position within said envelope to another position therein and including a cathode;
   - a collector assembly located at said other position for collecting said beam of electrons;

a power supply remote from said housing and including a high gain amplifier; and,

circuit means connected to said tube package housing and remote from said power supply and including at least part of a voltage regulation circuit comprising electronic component means for operatively cooperating with said high gain amplifier for automatically establishing a predetermined voltage across said cathode and said collector assembly.

7. The electron discharge device of claim **6** wherein ıid voltage regulation circuit regulates said high gain nplifier and comprises an input impedance, a referıce voltage source coupled to the input of said ampliər and a feedback impedance connected between the put and output of said amplifier.

8. The electron discharge device of claim **7**, wherein ıid input impedance, said reference voltage source ıd said feedback impedance are all included in said ɔusing connected circuit means.

9. The electron discharge device of claim **8**, wherein ıid predetermined voltage, V_{out}, is determined by the ɿuation:

$$V_{out} = V_{ref}\frac{R_b}{R_a}$$

nd wherein V_{ref} is the voltage of said reference voltage ɔurce, R_b is the impedance of said feedback impednce and R_a is the impedance of said input impedance.

10. The electron discharge device of claim **7**, wherein t least one of said components consisting of said input npedance, said reference voltage source and said ɛedback impedance is included in said housing conected circuit means and the other of said components ave precise values.

11. A traveling-wave tube assembly having voltage ɔntrol for use with an associated power supply having a igh gain amplifier providing sufficient voltages for the lectrodes of the traveling-wave tube comprising:

a tube package housing;

a vacuum envelope located within said housing;

a beam generating assembly for generating and projecting a beam of electrons from one position within said envelope to another therein and including a cathode;

a collector assembly located at said other position for collecting said beam of electrons;

a slow-wave structure located between said positions for providing interaction between said beam and a radio frequency wave propagating along said slow-wave structure; and

circuit means connected to said tube package housing and remote from the power supply including at least part of a voltage regulation circuit comprising electronic components for operatively cooperating with the high gain amplifier for automatically establishing a predetermined voltage across said cathode and said slow-wave structure.

12. A traveling-wave tube assembly as in claim 11 vherein said voltage regulation circuit regulates external ıigh gain amplifier and comprises an output impedance, ı reference voltage source for coupling to the input of ·aid amplifier through said input impedance, and a feedɔack impedance for connection between the input and ɔutput of said amplifier.

13. A traveling-wave tube assembly as in claim 12 vherein said input impedance, said reference voltage ;ource and said feedback impedance are all connected to ;aid tube package housing and remote from the power ;upply.

14. A traveling-wave tube assembly of claim 13 wherein said predetermined voltage, V_{out}, is determined by the equation:

$$V_{out} = -V_{ref}\frac{R_b}{R_a}$$

and wherein V_{ref} is the voltage of said reference voltage source, R_b is the impedance of said feedback impedance and R_a is the impedance of said input impedance.

15. A traveling-wave tube assembly as in claim 12 wherein at least one of said components consisting of said input impedance, said reference voltage source and said feedback impedance is included in said housing connected circuit means and the other of said components have precise values.

16. An electron discharge device having voltage control comprising:

an electron discharge tube package housing;

a vacuum envelope located within said housing;

a beam generating assembly for generating and projecting a beam of electrons from one position within said envelope to another position therein and including a cathode;

a collector assembly located at said other position for collecting said beam of electrons;

a slow-wave structure located between said positions for providing interaction between said beam and a radio frequency wave propagating along said slow-wave structure;

a power supply remote from said housing and including a high gain amplifier; and

circuit means connected to said tube package housing and remote from said power supply and including at least part of a voltage regulation circuit comprising electronic component means for operatively cooperating with said high gain amplifier for automatically establishing a predetermined voltage across said cathode and said slow-wave structure.

17. The electron discharge device of claim 16 wherein said voltage regulation circuit regulates said high gain amplifier and comprises an input impedance, a reference voltage source coupled to the input of said amplifier and a feedback impedance connected between the input and output of said amplifier.

18. The electron discharge device of claim 17, wherein said input impedance, said reference voltage source and said feedback impedance are all included in said housing connected circuit means.

19. The electron discharge device of claim 18, wherein said predetermined voltage, V_{out}, is determined by the equation:

$$V_{out} = V_{ref}\frac{R_b}{R_a}$$

and wherein V_{ref} is the voltage of said reference voltage source, R_b is the impedance of said feedback impedance and R_a is the impedance of said input impedance.

20. the electron discharge device of claim 17, wherein at least one of said components consisting of said input impedance, said reference voltage source and said feedback impedance is included in said housing connected circuit means and the other of said components have precise values.

* * * * *