Sept. 16, 1947. W. P. BOOTHROYD 2,427,382

POWER SUPPLY SYSTEM FOR VELOCITY MODULATED VACUUM TUBES

Filed Feb. 29, 1944 2 Sheets-Sheet 1

FIG. 1.

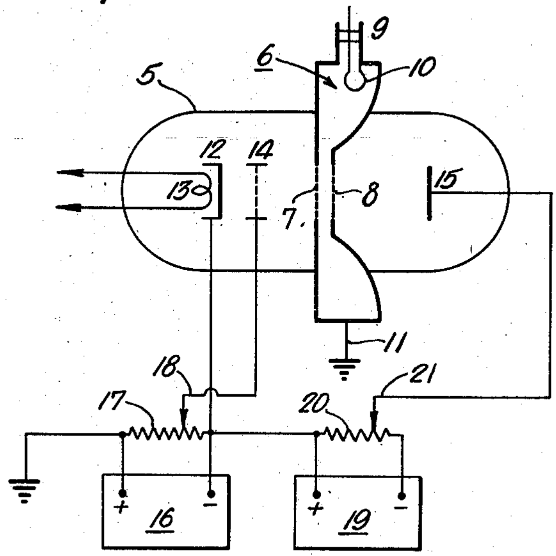
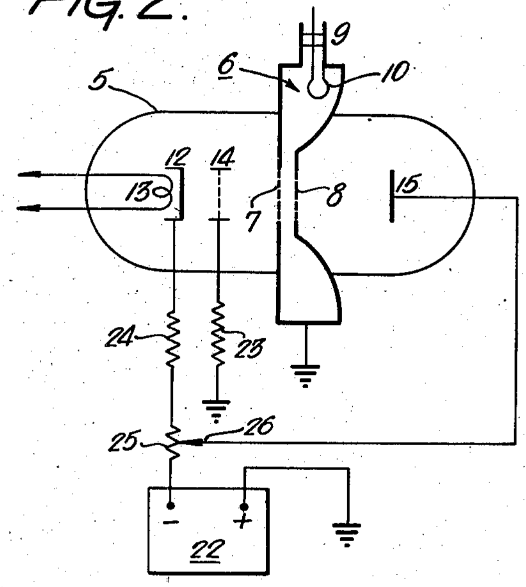


FIG. 2.



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Filed Feb. 29, 1944 2 Sheets-Sheet 2

FIG. 4.

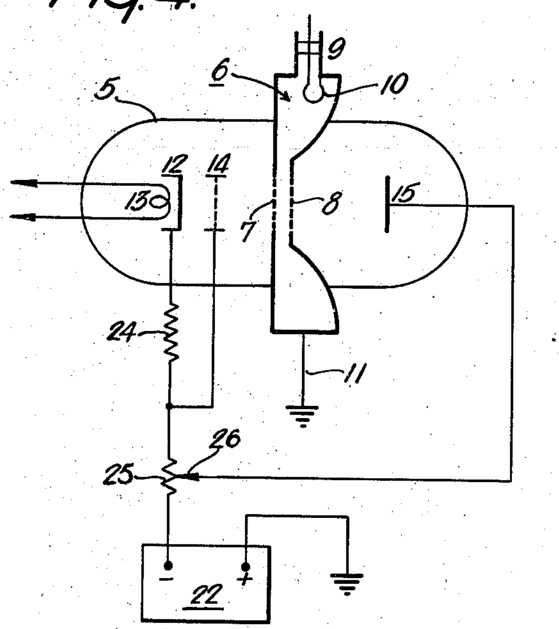
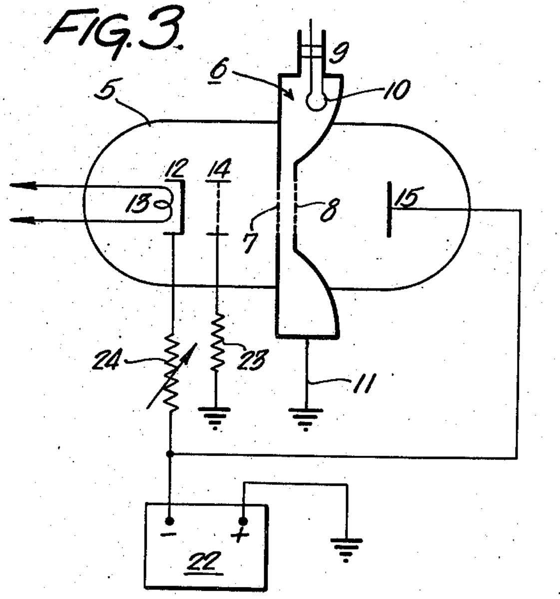


FIG. 3.



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POWER SUPPLY SYSTEM FOR VELOCITY MODULATED VACUUM TUBES

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8 Claims. (Cl. 315—5)

1

This invention relates to velocity modulation vacuum tubes, and more particularly to arrangements for providing a simple and efficient control system for modifying the operating potentials applied to the electrodes of the tubes.

The principal object of this invention is to provide a simple and more economical power supply system for supplying the operating potentials applied to the electrodes of velocity modulation vacuum tubes.

Another object of this invention is to provide a simple control for varying or adjusting the operating potentials applied to the electrodes of velocity modulation vacuum tubes.

Another object is to provide a simple means for pulse modulation of the output of velocity modulation vacuum tubes.

Other objects and advantages of this invention will become apparent during the course of the following description with reference to the accompanying drawings, in which,

Fig. 1 is a schematic illustration of a reflex type velocity modulation vacuum tube oscillator connected according to usual practice;

Fig. 2 shows, schematically, the connections to a similar type of vacuum tube connected in accordance with the principles of the present invention;

Fig. 3 is a schematic diagram of an alternative embodiment of the invention; and

Fig. 4 illustrates still another embodiment of the invention.

While the following description and the above figures relate to one particular type of velocity modulation vacuum tube commercially known as the "Reflex Klystron oscillator," it is to be understood that the invention is not limited thereto and that its principles may be applied to other types of velocity modulation tubes or the like.

Referring to Fig. 1, there is represented a typical reflex Klystron oscillator tube connected, in accordance with usual practice, to two well regulated power supplies. The Klystron comprises an evacuated envelope 5, a cavity resonator 6 with its grids 7 and 8, its sealed output terminal 9 and pick-up 10, the cathode 12 with its heater 13, the beam forming and focusing grid 14, and the reflector or repeller plate 15. The cavity resonator 6 is conventionally connected to ground through the conductor 11.

One power pack 16, the positive terminal of which is grounded, furnishes the necessary negative potential to the cathode 12. The voltage divider 17 is connected across the output terminals of power supply 16. The adjustable tap 18 on voltage divider 17 is suitably connected to the grid 14 to provide the necessary potential on grid 14.

2

The second power pack shown at 19 has its positive terminal connected to the negative terminal of power pack 16. The voltage divider 20 is connected across the output terminals of supply 19. The adjustable tap 21 on voltage divider 20 is suitably connected to the reflector plate 15 to provide the necessary potential on this electrode.

The operation of the cavity resonator and its exposed metallic parts at ground potential is a conventional safety precaution. In accordance with this practice, the cathode is at a high negative potential with respect to the grounded cavity resonator.

In this usual method of supplying the operating potentials to the electrodes at least two power supplies, with a voltage divider or resistor connected across the output terminals of each, are required.

It is, of course, possible to eliminate one of the two power supply systems by employing a single power pack having a voltage output equal to the sum of the voltages of packs 16 and 19, and by employing a voltage dividing resistance having such adjustable taps as may be necessary to provide the required electrode potentials. However, the power consumed in this bleeder resistor is usually comparable to that consumed by the tube. This may be readily illustrated by assigning practical values to the various components of Fig. 1. The voltages supplied by power packs 16 and 19 may be of the order of 500 volts and 200 volts respectively. The Klystron cathode current may be 30 milliamperes, and bleeder 17 across supply 16 may take 10 milliamperes. Power supply 16 must then furnish 15 watts to the tube and 5 watts to the bleeder 17, or a total of 20 watts. The bleeder resistor 20 for supply 19 may require only 2 milliamperes since there is practically no current supplied to reflector plate 15, as it is operated at a high negative potential and repels practically all electrons approaching it. The power output of supply 19 is then 0.4 watt. Thus we have a total of 20.4 watts for both power supply systems, of which 15 watts is useful power to the tube.

Now if only one power supply system were used with a tapped voltage divider, the output of this supply would be 700 volts. Considering the same conditions as above, namely 500 volts negative potential on the cathode and 30 milliamperes taken by the tube the power consumed by the tube would still be 15 watts. However, with 10 milliamperes flowing through the bleeder and 30 milliamperes in the tube the power output of this one power supply system would be 28 watts. With 15 watts supplied to the tube there is a power loss of 13 watts in the bleeder resistor which is more than 46% of the total power output of the power supply, or more than 86% of the useful power output. For this reason the usual practice is to employ at least two highly filtered and well regulated power supply systems.

In the operation of velocity modulation vacuum tubes where the size and efficiency of the power supply system are of particular importance, it is desirable to employ the smallest possible power supply system. The present invention is directed toward this end and the elimination of the disadvantages of prior practices. Fig. 2 illustrates one form of the invention for the operation of a reflex Klystron oscillator. The corresponding parts of the Klystron are numbered identically to those in Fig. 1. However, there is now only one power supply 22. It will be noticed that no bleeder or voltage dividing resistor is required across the output terminals of the supply system 22. The positive terminal of the power supply 22 is grounded. The grid 14 is connected to ground, i. e. to the positive terminal of power supply 22, through a high resistance 23. The resistance 23 may comprise a variable resistance element, or, if desired, a fixed resistor as shown. The cathode 12 may be connected to the negative terminal of power supply 22 by way of the resistor 24, the resistance of which may, if desired, be included in the variable tapped resistor or potentiometer 25. The reflector plate 15 is connected to the variable tap 26 of potentiometer 25.

In accordance with the embodiment of the invention illustrated in Fig. 2, there is shown a method of supplying the various electrode potentials which requires only one power supply, and in which the power supply does not require the customary voltage dividing resistance across its output terminals. This means a considerable saving in space, weight and cost over the dual power supply method employed in usual practice as represented in Fig. 1. The power requirement of the one power supply of Fig. 2, assuming the same operating voltages and currents as given in the previous illustration, would be 30 milliamperes at 700 volts, or 21 watts, which is practically the same as the power output of the two supplies 16 and 19 in Fig. 1, and which is but 75% of the power output required if a one-power-supply system, with bleeder, were used to replace the dual power supply system of Fig. 1. The above comparison does not take into account the internal power losses within the power packs, of which the system of Fig. 1 has two, and that of Fig. 2 only one.

The operation of the invention in accordance with the embodiment shown in Fig. 2 is as follows. It is known in the art that, for any given accelerating voltage (i. e., cathode-to-cavity voltage), there exists a plurality, or a series, of reflector potentials at which the tube will oscillate properly. Conversely, for any given reflector voltage there exists a plurality of accelerating voltages which will produce oscillations. The oscillations of the tube at these various relative potentials are known as "modes of oscillation." In practice, the cathode potential is generally fixed to give some desired accelerating voltage, and the reflector voltage is adjusted to the potential which will cause the tube to oscillate at the desired mode. The output of a reflex Klystron oscillator is generally greater, for a given accelerating voltage and beam current, at those modes of oscillation corresponding to the more negative reflector potentials. Also the output of this type of Klystron increases rapidly at first as the beam current is increased beyond the starting current, until a value of beam current is reached which produces a saturation effect. The best efficiency may therefore occur at a relatively low beam current.

Referring again to Fig. 2, the desired negative potential on cathode 12 is derived from the power supply 22, and is determined by the voltage drop across resistor 24 and potentiometer 25 due to the cathode current flowing through these resistances. The negative potential on reflector plate 15 is adjustable from some negative potential with respect to the cathode, depending upon the voltage developed across resistor 24, to more negative values determined by voltage developed across that portion of potentiometer 25 which is included between resistor 24 and contact arm 26. If the resistance of 24 is included in the potentiometer 25, the potential on reflector plate 15 can be reduced to zero with respect to the cathode.

The combined resistance of resistor 24 and potentiometer 25 is so chosen that the voltage drop developed across these two resistances due to the cathode current through them will place the cathode at the desired negative potential for the particular voltage of the power supply, while at the same time providing a sufficient range of adjustment of reflector potential.

The grid resistor 23 is of the resistance necessary to develop a voltage drop, due to the grid current therethrough, sufficient in magnitude to place the grid at the desired small positive potential with respect to the cathode 12. This potential may be of the order of 20 volts.

With the values of resistors 23, 24 and 25 suitably selected, the potential on reflector plate 15 may be varied by means of contact arm 26 on potentiometer 25 until the desired mode of oscillation of the Klystron is obtained. For indication of oscillation any suitable indicating device may be coupled to output coupling means 9.

In practicing this invention according to the embodiment shown in Fig. 2, the regulated power supply 22 had a terminal voltage of 700 volts. The resistance of potentiometer 25 was 10,000 ohms, and that of resistor 24 was 2000 ohms, for a negative potential of 500 volts on the cathode. The grid resistor 23 was 200,000 ohms.

It will be apparent to those familiar with the art that various arrangements of the resistors 24 and 25 in the cathode circuit are possible to obtain the relative differences of potential between the cathode 12 and reflector plate 15 for producing the various modes of oscillations.

For example, in Fig. 3 the reflector plate is connected directly to the negative terminal of the power pack 22 to provide, thereby, a fixed reflector voltage. The single cathode resistor 24 is made variable simultaneously to provide such adjustment of the cathode to ground accelerating voltage and the reflector to cathode voltage as may be required to induce the desired mode of oscillation for the particular reflector voltage. The grid resistor 23 should be such as to give the correct grid potential for the particular cathode potential. In one physical embodiment of the system of Fig. 3, the element 24 was a variable resistor having a maximum resistance of 10,000 ohms, but adjusted normally to about 5000 ohms.

The grid resistor 23 had a resistance of about 200,000 ohms. The voltage of the power pack 22 was about 700 volts.

Another embodiment of the invention is illustrated in Fig. 4. In referring to this figure, it will be noticed that only the one power supply is required and likewise no voltage dividing or bleeder resistor is connected across its output terminals. This embodiment of the invention may be used when it is desired to operate the grid at a negative potential with respect to the cathode.

Referring to Fig. 4, the identical parts of the reflex Klystron oscillator tube and the power supply are numbered as in Fig. 2. In Fig. 4 the cathode 12 is connected to the negative terminal of the power supply 22 through resistor 24 and potentiometer 25 in series. The grid 14 is connected to the junction of resistors 24 and 25. The reflector plate 15 is connected to the contact arm 26 of potentiometer 25. In this embodiment the potential on the cathode is determined by the voltage of power supply 22 and the voltage drop across resistors 24 and 25 due to the cathode current through these resistors. The negative potential on grid 14 with respect to the cathode is the voltage developed across resistor 24. The negative potential on reflector plate 15 is varied by changing the position of the potentiometer arm 26. Thus the cathode potential is substantially fixed and the reflector potential is adjusted to the potential necessary for the desired mode of oscillation.

The present invention is particularly advantageous when inserting or replacing reflex Klystron oscillator tubes in circuits which have been designed for operation with a particular type tube and at a particular mode of oscillation. The tube may be inserted in the circuit and the reflector voltage adjusted, by manipulation of the potentiometer contact arm 26 of Fig. 2 or arm 26 of Fig. 4, to that potential which gives the particular mode of oscillation desired. The self biasing feature of the grid resistor 23 in Fig. 2 or of cathode resistor 24 in Fig. 4 will automatically adjust the grid 14 to the correct operating potential to give essentially the same cathode current for each tube placed in the circuit.

With the grid potential automatically adjusted by the self biasing feature of this invention, tubes of the same type and operating at a given mode of oscillation may be replaced or exchanged in reflex Klystron oscillator circuits without further manual adjustment of grid potential for the same cathode current or power output, thus eliminating the need of the grid bias control found in usual practice.

It is to be understood that changes in the operating potentials of the cathode or the reflector or both, to yield different modes of oscillation than that for which the circuit was designed, will require a change in the value of the grid resistor 23 in Figs. 2 and 3 or cathode resistor 24 in Fig. 4 to maintain the same cathode current or power output.

In actual tests of this invention in accordance with the embodiment shown in Fig. 2, the self biasing of the grid was found to be fully as satisfactory as the grid bleeder or voltage dividing method found in usual practice as illustrated by the circuit of Fig. 1. By elimination of one of the two well filtered and regulated power supplies of the usual practice, a power supply system which is more economical in space, weight, and cost is provided.

Where adjustments in the grid potential are desired, the grid resistor 23 of Figs. 2 and 3 may be a variable type resistor. Likewise, adjustment of grid potential in the embodiment of Fig. 4 may be made, if desired, by using a voltage divider or potentiometer for resistor 24 and connecting grid 14 to the movable tap or arm of the potentiometer, or alternately making resistor 24 of Fig. 4 a variable resistance instead of a fixed resistor.

The grid circuit of a Klystron connected according to usual practice is of comparatively low impedance. With the grid of the Klystron biased in accordance with the embodiment of Fig. 2, the grid circuit is of higher impedance, thus permitting coupling of a modulating voltage to the grid by means of a capacitor.

In the interests of simplicity the usual RF bypass condensers have been omitted from the several schematic illustrations. It is to be understood that such condensers are to be employed where necessary in accordance with the common practice of the art.

I claim:

1. A circuit for a velocity modulated tube, said tube comprising a cathode, a grid, a cavity resonator, and a reflector plate; said circuit comprising a single source of unidirectional voltage for supplying the operating voltages for said tube, a low-impedance connection between the positive terminal of said source and said resonator, a resistive connection between said cathode and the negative terminal of said source, a low impedance connection between said reflector plate and said last-named connection, and means connected to said source for supplying a predetermined potential to said grid.

2. A circuit for a velocity modulated tube, said tube comprising a cathode, a grid, a cavity resonator, and a reflector plate; said circuit comprising a single source of unidirectional voltage for supplying the operating voltages for said tube, a low-impedance connection between the positive terminal of said source and said resonator, a connection including a resistance element between said cathode and the negative terminal of said source, a low-impedance connection between said reflector plate and a variable point on said resistance element, and means connected to said source for supplying a predetermined potential to said grid.

3. A circuit for a velocity modulated tube, said tube comprising a cathode, a grid, a cavity resonator, and a reflector plate; said circuit comprising a single source of unidirectional voltage for supplying the operating voltages for said tube, a low-impedance connection between the positive terminal of said source and said resonator, a connection including a resistance element between said cathode and the negative terminal of said source, a direct connection between said reflector plate and the negative terminal of said source, and means connected to said source for supplying a predetermined potential to said grid.

4. A circuit for a reflex-type velocity modulated tube wherein said tube comprises a cathode, a grid, a cavity resonator, and a reflector plate; said circuit comprising a source of unidirectional voltage, a low-impedance connection between said resonator and the positive terminal of said source, a resistive path between said cathode and the negative terminal of said source, a low-impedance connection between said reflector plate and a point on said path, and a high resistance

path connected between said grid and said positive terminal.

5. A circuit for a reflex-type velocity modulated tube wherein said tube comprises a cathode, a grid, a cavity resonator, and a reflector plate; said circuit comprising a source of unidirectional voltage, a low-impedance connection between said resonator and the positive terminal of said source, a connection including a resistance element between said cathode and the negative terminal of said source, a low-impedance connection between said reflector plate and a variable point on said resistance element, and a high resistance path connected between said grid and said positive terminal.

6. A circuit for a reflex-type velocity modulated tube, said tube comprising a cathode, a grid, a cavity resonator, and a reflector plate; said circuit comprising a source of unidirectional voltage, a direct connection between the positive terminal of said source and said resonator, a resistor connected between said cathode and the negative terminal of said source, a direct connection between said negative terminal and said reflector plate, and a high resistance path connected between said grid and said positive terminal.

7. A circuit for a reflex-type velocity modulated tube, said tube comprising a cathode, a grid, a cavity resonator, and a reflector plate; said circuit comprising a source of unidirectional voltage, a direct connection between the positive terminal of said source and said resonator, a variable resistor connected between said cathode and the negative terminal of said source, a direct connection between said negative terminal and said reflector plate, and a path connected between said grid and said positive terminal.

8. A circuit for a reflex-type velocity modulated tube wherein said tube comprises a cathode, a grid, a cavity resonator, and a reflector plate; said circuit comprising a single source of unidirectional voltage, a low-impedance path connected between said resonator and the positive terminal of said source, a resistive path connected between said cathode and the negative terminal of said source, a connection between said grid and a first point on said resistive path, and a connection between said reflector plate and a second point on said resistive path between said first point and said negative terminal.

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