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VOLTAGE REGULATING CIRCUITS

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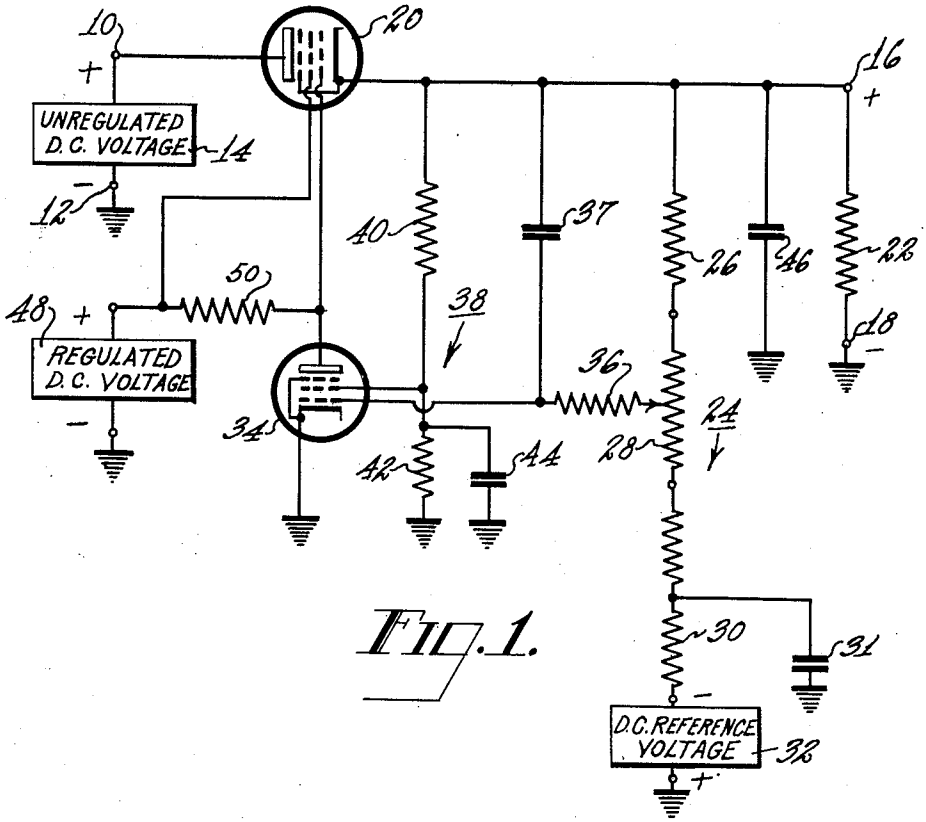


FIG. 1.

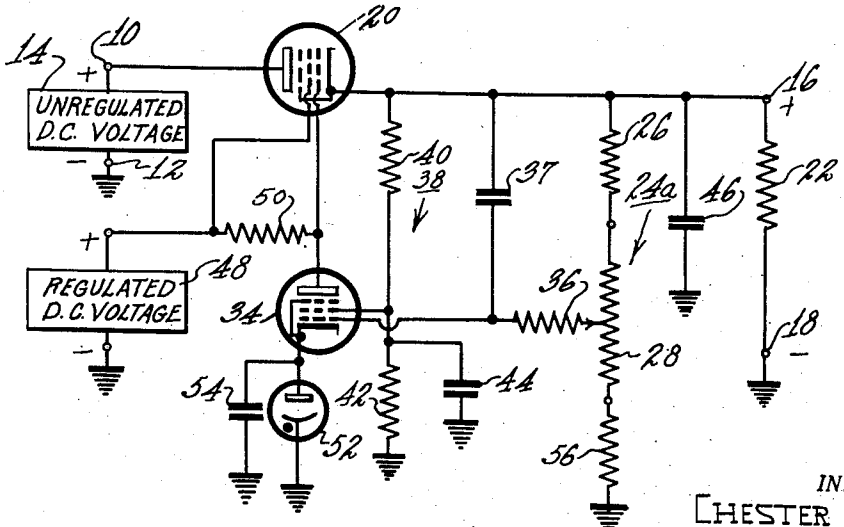


FIG. 2.

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VOLTAGE REGULATING CIRCUITS

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8 Claims. (Cl. 323—22)

This invention relates to regulating circuits for unidirectional voltages, and more particularly to ripple filter-regulator circuits of the type adapted to regulate an unregulated unidirectional voltage having a ripple component of the order of a few volts R. M. S. (root-mean-square) to a regulated voltage having a ripple component of the order of less than one hundred microvolts R. M. S. While neither specifically nor exclusively limited thereto, the voltage regulator circuits of the present invention are particularly useful in power supplies adapted to provide operating voltages for video preamplifiers, and the like.

When conventional regulated power supplies are used to provide a regulated unidirectional operating voltage for a video preamplifier, or the like, it is usually necessary to use a resistance-capacitance filter network in the anode circuits of each of the stages of the video preamplifier in order to filter the residual ripple in the output of the power supply. These resistance-capacitance filter networks usually employ electrolytic capacitors. Electrolytic capacitors, however, do not have a long shelf life, and may explode if connected incorrectly during replacement. Electrolytic capacitors, therefore, are usually not used in equipment requiring a high degree of reliability over a long period of time. Where relatively smaller capacitors of the paper dielectric type are used in the resistance-capacitance filter networks, a special resistance-capacitance network must also be used in the grid circuit of each video preamplifier stage for low frequency compensation purposes. This introduces problems in stability with respect to close temperature and component tolerances.

It has also been proposed to obtain a regulated unidirectional output voltage with a relatively low ripple content by the use of the superregulation method. By the superregulation method, a first power supply is regulated in a conventional manner, and the regulated output voltage therefrom is fed to a second conventional regulator circuit where it is regulated again. Even by the use of superregulation, however, it is extremely difficult to provide a unidirectional output voltage with a ripple component in the order of less than one hundred microvolts. Also, superregulation systems require the use of a relatively large number of tubes and components.

Accordingly, it is a principal object of the present invention to provide improved voltage regulating circuits for regulating a unidirectional voltage and providing a regulated output voltage with a very small and negligible ripple component.

Another object of the present invention is to provide improved ripple filter-regulator circuits adapted to provide a regulated output voltage for operating wide-band amplifiers, such as video preamplifiers, satisfactorily, without the need for resistance-capacitance filter networks in the amplifier stages.

A further object of the present invention is to provide improved voltage regulating circuits employing pentode tubes in a highly efficient manner.

It is still a further object of the present invention to provide improved voltage regulator circuits that are simple in construction and operation, economical to manufacture and highly efficient in use.

These and, perhaps, further objects of the present invention are attained in a unidirectional voltage regulating circuit employing a pair of pentode tubes. One of the pentodes functions as a series regulator tube and is connected in series with an unregulated unidirectional voltage source and the positive and negative output terminals of the regulator circuit. The other of the two pentodes serves as an amplifier control tube for feeding back a sample of the output voltage, appearing across a load connected between the positive and negative output terminals, to the control grid of the series regulator pentode. A separate conventional source of regulated unidirectional voltage is connected in series with the amplifier control pentode through an anode load resistor for the purpose of providing this pentode with an operating voltage. The separate conventional regulated unidirectional source also provides the screen voltage for the series regulator pentode tube. By this unique arrangement, whereby the screen grid of the series regulator pentode and the anode of the amplifier control pentode are provided with operating voltages from a separate regulated unidirectional voltage source, the unregulated unidirectional voltage may be regulated to provide a regulated output voltage having a relatively very low ripple component. For example, with the voltage regulator circuits of the present invention, a 275 volt unregulated unidirectional power supply having a ripple component of three volts R. M. S. may be regulated to provide a regulated output voltage of one hundred fifty volts with a ripple component in the order of fifty microvolts R. M. S..

The novel features of the present invention, as well as the invention itself, both as to its organization and method of operation, will be understood in detail from the following description when considered in connection with the accompanying drawing in which similar reference characters represent similar parts, and in which:

Fig. 1 is a schematic diagram of an improved voltage regulator circuit in accordance with the present invention; and

Fig. 2 is a modification of the regulating circuit of Fig. 1, in accordance with the present invention.

Referring now particularly to Fig. 1, there is shown a voltage regulating circuit having positive and negative input terminals **10** and **12**, respectively, for applying a source of unregulated D.-C. (direct current) input voltage **14** therebetween; and a pair of positive and negative output terminals **16** and **18**, respectively, for deriving a regulated unidirectional output voltage therebetween. The unregulated voltage source **14** may be of the type derived from a full wave or half-wave rectified alternating current voltage. A series regulator pentode tube **20** has its anode connected to the positive input terminal **10**, and its cathode connected to the positive output terminal **16**. The suppressor grid of the pentode tube **20** is connected to the cathode. It will now be understood that the series regulator pentode tube **20** can function as a variable high impedance that forms a voltage divider with a load **22** connected between the positive and negative output terminals **16** and **18**.

Means are provided to feed back, degeneratively, a sample of the output voltage across the load **22**, represented as a resistance for illustrative purposes, to the control grid of the series regulator tube **20** for regulatory purposes. To this end, a voltage divider **24** is connected in a series circuit, with a D.-C. reference voltage source **32**, between the positive output terminal **16** and a point of reference voltage, such as ground. The negative input terminal **12** and the negative output terminal **18** are also

connected to ground. The voltage divider 24 comprises a resistor 26, a potentiometer 28, and a resistor 30. The resistor 30 and the voltage source 32 are bypassed to ground by a capacitor 31, for filtering purposes. The positive terminal of the source of reference D.-C. voltage 32 is connected to ground for the purpose hereinafter appearing.

The movable tap on the potentiometer 28 is connected to the control grid of a control amplifier pentode tube 34 through a resistor 36. The control grid of the tube 34 is also connected to the positive output terminal 16 through a capacitor 37. The cathode of the pentode tube 34 is connected to ground, and to the suppressor grid. The anode of the tube 34 is connected to the control grid of the series regulator pentode tube 20. Proper screen grid voltage for the screen grid of the pentode tube 34 is derived from a tap on a voltage divider 38, connected between the positive output terminal 16 and the negative output terminal 18. The voltage divider 38 comprises serially connected resistors 40 and 42. The resistor 42 is bypassed to ground by a capacitor 44. A capacitor 46 is connected between the positive output terminal 16 and the negative output terminal 18 for filtering purposes. An important feature of the present invention is the novel means for supplying the anode of the amplifier control pentode tube 34 and the screen grid of the series regulator pentode tube 20 with operating voltages in a manner whereby the full advantages of the relatively high amplification and high dynamic plate impedance of the pentode tubes may be utilized without coupling the ripple component of the unregulated D.-C. voltage source 14 to the control grid of the series regulator pentode tube 20. It is noted that in most conventional voltage regulating circuits, the anode voltage for the control amplifier tube is derived from the unregulated source of voltage that is to be regulated. Under such conditions, most of the ripple component of the unregulated voltage source appears across the relatively high effective plate impedance of the amplifier control tube and is, thus, applied to the grid of the series regulator tube.

In order to obviate any coupling of the ripple component of the unregulated voltage source 14 to the control grid of the series regulator tube 20, a separate, conventional regulated, D.-C. voltage source 48 is used to supply the anode voltage for the tube 34. To this end, the positive terminal of the voltage source 48 is connected directly to the anode of the tube 34 through a load resistor 50. The voltage source 48 may provide a regulated output voltage having a ripple component in the neighborhood of 10 millivolts R. M. S. The negative side of the conventional regulated D.-C. voltage source 48 is grounded.

In order to operate the series regulator tube 20 as a pentode, and thereby obtain the relatively high dynamic plate impedance which results from such operation, it is necessary to supply operating voltage to the screen grid of the tube 20 from a low impedance source. To this end, the positive terminal of the conventional regulated D.-C. voltage source 48 is also connected to the screen grid of the tube 20. The output impedance of the conventional regulated D.-C. voltage source 48 may be in the neighborhood of two ohms.

The operation of the voltage regulating circuit of Fig. 1 will now be described. Let it be assumed that there is a tendency for the voltage across the load 22 to increase, either because of a surge in the voltage source 14 or because of a decrease in the load 22. The increase in voltage across the load 22 is sensed by the tap on the potentiometer 28, of the voltage divider 24, and applied to the grid of the amplifier control pentode tube 34. It is noted that the tap on the potentiometer 28 has been previously adjusted to provide class A amplification for the tube 34. The D.-C. voltage reference source 32 makes it possible for the control grid of the tube 34 to have the proper bias applied to it so it is sufficiently negative with respect to the cathode to provide class A amplification in the tube 34. The positive-going signal applied to the control grid of the tube 34 causes the tube 34 to increase conduction therethrough, resulting in a negative-going voltage at the anode thereof. This negative-going voltage is applied to the control grid of the series regulator pentode tube 20 to increase its impedance and thereby decrease the current to the load 22. Thus, the voltage across the load 22 will be decreased and will offset the original tendency of the voltage thereacross to increase. It will now be understood that a tendency for a voltage across the load 22 to decrease will present a reverse set of conditions whereby this tendency is offset by increased current through the load 22.

The impedance of the load circuit of Fig. 1, measured between the positive and negative output terminals 16 and 18, is relatively low compared with the effective plate impedance of the series regulator pentode tube 20. In operation, the effective plate impedance of the tube 20 may be three hundred megohms compared to say 5,000 ohms impedance between the positive and negative output terminals 16 and 18. Thus, the effective plate impedance of the tube 20 forms a voltage divider with the load 22 in a manner whereby the greatest voltage drop appears across the tube 20. The ripple component of the unregulated voltage source 14 is attenuated 60,000 times for the example cited. By using a pentode for the tube 20, the dynamic plate impedance is relatively much higher than can be provided by a triode.

The dynamic plate impedance of a pentode tube may be one megohm, compared with, say, 40,000 ohms dynamic plate impedance for a triode tube. This represents a twenty-five-to-one advantage in dynamic plate impedance for a pentode tube compared with a triode tube. Therefore, all other things being equal, connecting the pentode tube 20 as a triode would reduce the effective plate impedance from 300 megohms to 12 megohms, and the ripple attenuation would be reduced from 60,000 times to 2,400 times.

The use of the separate regulated D.-C. voltage source 48 makes it possible to use the series regulator tube 20 as a pentode. When a pentode has been used, in the prior art, as a series regulator tube, its screen grid was tied to the anode so that it was effectively used as a triode. Under the latter conditions, the high dynamic plate impedance of the pentode could not be obtained.

The use of the separate D.-C. voltage source 48 for supplying the operating voltage for the anode circuit of the amplifier control tube 34 also makes it possible to employ the relatively high amplification factor of a pentode tube without feeding back the relatively large ripple component of the unregulated D.-C. voltage source 14, say three volts R. M. S., to the control grid of the series regulator tube 20. Since the voltage source 48 is already regulated, its ripple component is relatively small, say 10 millivolts R. M. S. It is noted that if the anode load resistor 50 were to be tied to the positive input terminal 10 of the regulating circuit, as is common in prior art regulating circuits, most of the ripple component of the unregulated voltage source 14 would appear across the relatively high plate impedance of the amplifier control pentode tube 34 and would, thus, be fed to the control grid of the pentode 20, in a polarity that would tend to cause conduction, rather than attenuation, of the ripple component. It is for these reasons that pentode tubes for the series regulator tube and/or the amplifier control tube were not used effectively heretofore in prior art circuits.

Referring now to Fig. 2, there is shown a voltage regulating circuit substantially similar to that shown in Fig. 1. The voltage regulating circuit of Fig. 2 differs from that in Fig. 1 in the manner of biasing the control grid of the tube 34. In Fig. 2, the cathode of the control amplifier pentode tube 34 is connected to ground through a voltage regulating tube 52. The tube 52 is bypassed

to ground through a bypass capacitor **54**. Also, in Fig. 2, the means for deriving a sample of the unidirectional output voltage between the positive and negative output terminals **16** and **18** comprises a voltage divider **24***a* connected between the output terminals **16** and **18**. The voltage divider **24***a* comprises the resistor **26**, the potentiometer **28** and a resistor **56**, all connected in series with each other. The tap on the potentiometer **28** is adjusted to provide the control grid of the control amplifier pentode tube with sufficient grid bias to operate the tube **34** as a class A amplifier. The operation of the voltage regulator circuit of Fig. 2 is similar to that described for the voltage regulator circuit of Fig. 1.

It should be noted that the current drain on the regulated unidirectional voltage source **48** is very small compared with the usual load current. All of the load current, with the exception of the screen current for the series regulator pentode tube **20**, is supplied from the unregulated unidirectional voltage source **14**. If the regulated unidirectional voltage source **48** is capable of handling reasonable values of screen current for the series regulator pentode tube **20**, then the magnitude of the load current is limited only by the current-handling capabilities of the series regulator pentode tube **20**, and the unregulated unidirectional voltage source **14**.

What is claimed is:

1. A voltage regulating circuit comprising positive and negative input terminals for applying a source of unregulated unidirectional voltage therebetween, positive and negative output terminals for deriving a regulated unidirectional output voltage therebetween, a first tube having at least an anode, a screen grid, a control grid and a cathode, said first tube having an anode-cathode path connected in series with said positive input terminal and said positive output terminal, a second tube having at least an anode, a screen grid, a control grid and a cathode, means connecting said cathode of said second tube to said negative input terminal, said anode of said second tube being connected to said control grid of said first tube, means connected between said positive and negative output terminals to derive a sample of said regulated output voltage, means to apply said sample voltage to the control grid of said second tube, a resistor connected between said anode of said second tube and said screen grid of said first tube, means connected between said positive and negative output terminals to apply an operating voltage of said screen grid of said second tube, and means to apply a separate regulated unidirectional voltage source between said negative input terminal and said screen grid of said first tube.

2. A voltage regulating circuit comprising positive and negative input terminals for applying a source of unregulated unidirectional voltage therebetween, positive and negative output terminals for deriving a regulated unidirectional output voltage therebetween, a first tube having at least an anode, a screen grid, a control grid and a cathode, said first tube having an anode-cathode path connected in series with said positive input terminal and said positive output terminal, a second tube having at least an anode, a screen grid, a control grid and a cathode, said cathode of said second tube being connected to said negative input terminal, said anode of said second tube being connected to said control grid of said first tube, means connected between said positive and negative output terminals to derive a sample of said regulated output voltage, means to apply said sample voltage to the control grid of said second tube, a resistor connected between said anode of said second tube and said screen grid of said first tube, means connected between said positive and negative output terminals to apply an operating voltage of said screen grid of said second tube, and means to apply a separate regulated unidirectional voltage source between said negative input terminal and said screen grid of said first tube.

3. A voltage regulating circuit comprising positive and negative input terminals for applying a source of unregulated unidirectional voltage therebetween, positive and negative output terminals for deriving a regulated unidirectional output voltage therebetween, a first tube having at least an anode, a screen grid, a control grid and a cathode, said first tube having an anode-cathode path connected in series with said positive input terminal and said positive output terminal, a second tube having at least an anode, a screen grid, a control grid and a cathode, constant voltage means connected between said cathode of said second tube and said negative input terminal, means connecting said anode of said second tube to said control grid of said first tube, means connected between said positive and negative output terminals to derive a sample of said regulated output voltage, means to apply said sample voltage to the control grid of said second tube, a resistor connected between said anode of said second tube and said screen grid of said first tube, means connected between said positive and negative output terminals to apply an operating voltage of said screen grid of said second tube, and means to apply a separate regulated unidirectional voltage source in series with said negative input terminal, said resistor and said second tube.

4. In a ripple filter-regulator circuit of the type wherein a source of unregulated unidirectional voltage applied to positive and negative input terminals thereof is regulated to provide a regulated output voltage between positive and negative output terminals thereof; the combination comprising first and second tubes each having at least an anode, a screen grid, a control grid and a cathode, means connecting said first tube between said positive input and said positive output terminals, means connected between said positive and negative output terminals to derive a sample of said regulated output voltage, means to feed said sample voltage back to said control grid of said second tube, means connected between said positive and negative output terminals to apply an operating voltage to said screen grid of said second tube, means connecting said anode of said second tube to said control grid of said first tube, means to apply a separate source of unidirectional voltage between said anode and said cathode of said second tube, said separate source of unidirectional voltage having a terminal connected to said negative output terminal, and means to apply said separate source of unidirectional regulated voltage to said screen grid of said first tube.

5. In a ripple filter-regulator circuit of the type wherein a source of unregulated unidirectional voltage applied to positive and negative input terminals thereof is regulated to provide a regulated output voltage between positive and negative output terminals thereof; the combination comprising first and second tubes, each having at least an anode, a screen grid, a control grid and a cathode, means connecting said first tube between said positive input and said positive output terminal, means connected between said positive and negative output terminals to derive a sample of said regulated output voltage, means to feed back said sample voltage to said control grid of said second tube, means connected between said positive and negative output terminals to apply an operating voltage to said screen grid of said second tube, means connecting said anode of said second tube to said control grid of said first tube, said cathode of said second tube being connected to said negative output terminal, means to apply a separate source of unidirectional voltage between said anode and said cathode of said second tube, said separate source of unidirectional voltage having a terminal connected to said negative output terminal, and means to apply said separate source of unidirectional regulated voltage to said screen grid of said first tube.

6. In a ripple filter-regulator circuit of the type wherein

a source of unregulated unidirectional voltage applied to positive and negative input terminals thereof is regulated to provide a regulated output voltage between positive and negative output terminals thereof; the combination comprising first and second tubes, each having at least an anode, a screen grid, a control grid and a cathode, means connecting said first tube between said positive input and said positive output terminal, means connected between said positive and negative output terminals to derive a sample of the regulated output voltage, means to feed back said sample voltage to said control grid of said second tube, means connected between said positive and negative output terminals to apply an operating voltage to said screen grid of said second tube, means connecting said anode of said second tube to said control grid of said first tube, constant voltage means connected between said cathode of said second tube and said negative output terminal, means to apply a separate source of unidirectional voltage between said anode and said cathode of said second tube. said separate source of unidirectional voltage having a terminal connected to said negative output terminal, and means to apply said separate source of unidirectional regulated voltage to said screen grid of said first tube.

7. A voltage regulating circuit, for regulating a source of unregulated unidirectional voltage and for providing a regulated unidirectional output voltage between positive and negative output terminals comprising a series regulator pentode tube, having an input, means for connecting said source of unregulated voltage in series with said series regulator pentode tube and said positive and negative output terminals, a control amplifier pentode tube having an input and an output, means connected between said positive and negative output terminals to derive a sample of said regulated output voltage, means to feed back said sample voltage to said input of said control amplifier pentode tube, means to apply said output of said control amplifier pentode tube to said input of said series regulator pentode tube, means connected in series with said control

amplifier pentode tube to apply a separate regulated unidirectional voltage thereto, said separate source of unidirectional voltage having a terminal connected to said negative output terminal, and means to connect the screen grid of said series regulator pentode tube to said separate regulated unidirectional voltage source for applying an operating voltage thereto.

8. A voltage regulating circuit, for regulating a source of unregulated unidirectional voltage and for providing a regulated unidirectional voltage between positive and negative output terminals, comprising a series regulator pentode tube having input means, means connecting said series regulator pentode tube in series with said source of unregulated voltage and said positive and negative output terminals, a control amplifier pentode tube having input means and output means, means connected between said positive and negative output terminals to derive a sample of said regulating output voltage, means to feed back said sample voltage to said input means of said control amplifier pentode tube, means to apply said output means of said control amplifier pentode tube to said input means of said series regulator pentode tube, means comprising a resistor connected in series with said control amplifier pentode tube to apply a separate regulated unidirectional voltage thereto, said separate source of unidirectional voltage having a terminal connected to said negative output terminal, and means to connect the screen grid of said series regulator pentode tube to said separate regulated unidirectional voltage source for applying an operating voltage thereto.

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