

Oct. 7, 1952

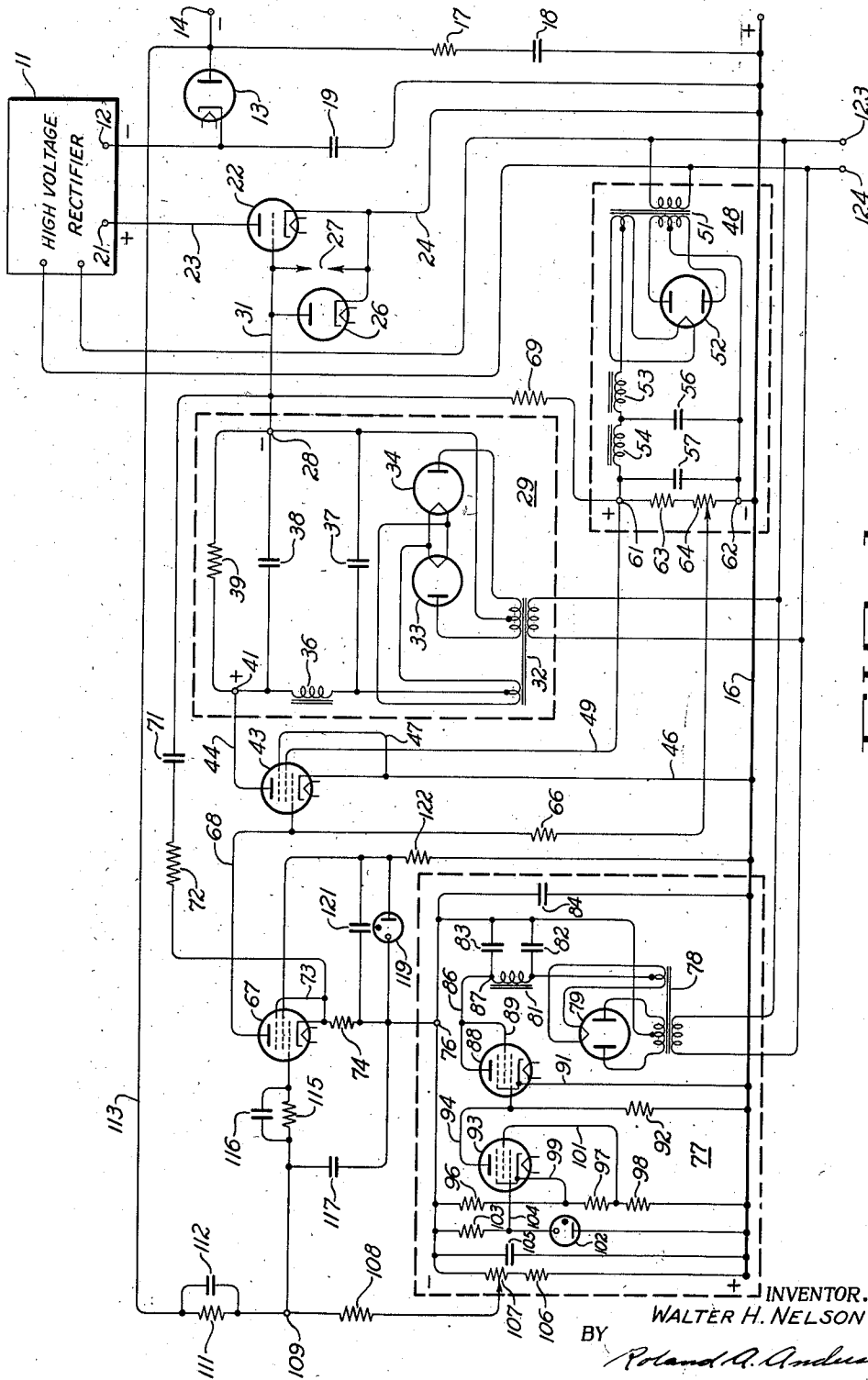
W. H. NELSON

2,613,344

HIGH-VOLTAGE REGULATOR

Filed March 8, 1949

2 SHEETS--SHEET 1



THE

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2 SHEETS--SHEET 2

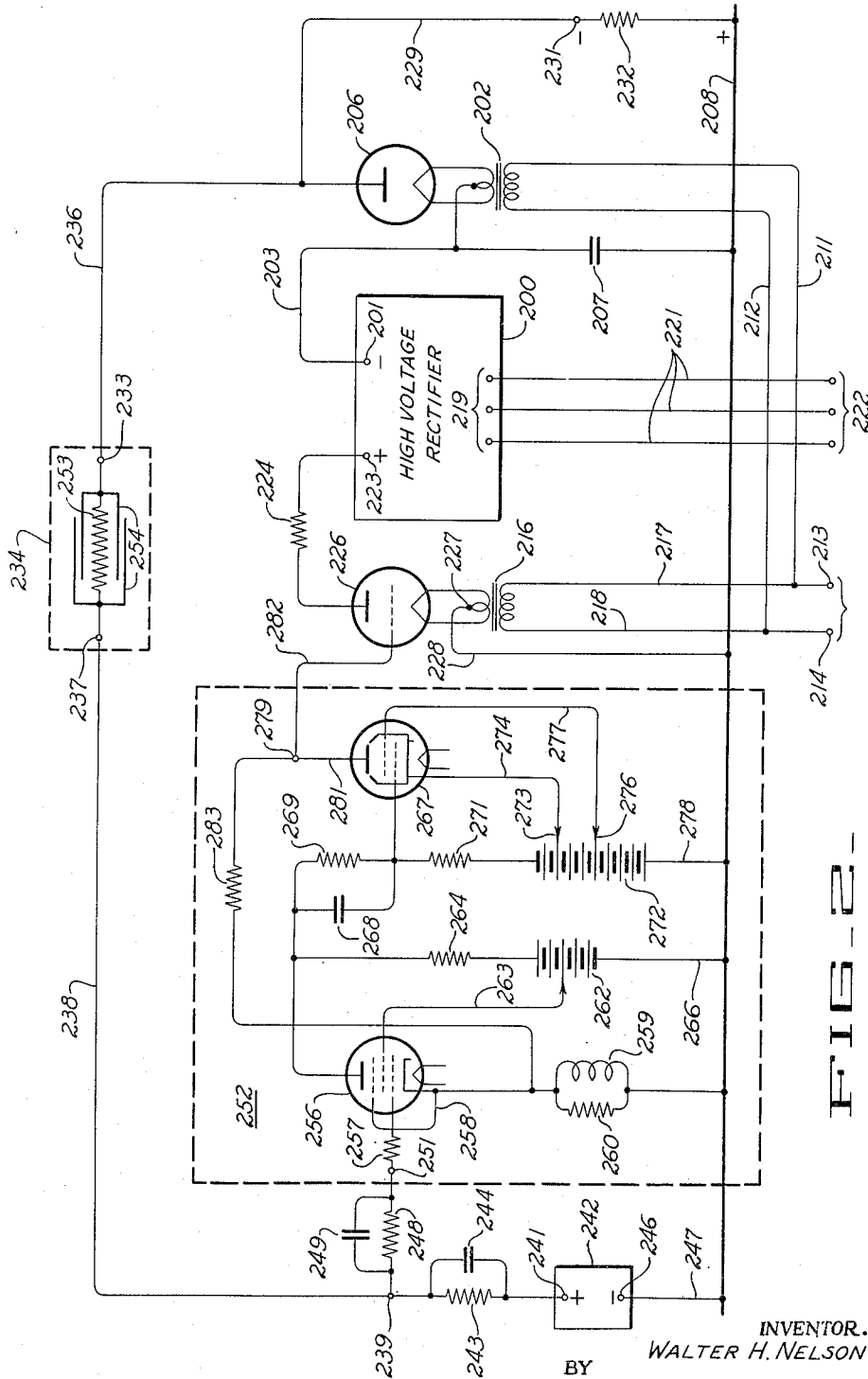


FIG. 2

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2,613,344

HIGH-VOLTAGE REGULATOR

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Application March 8, 1949, Serial No. 80,269

5 Claims. (Cl. 323-22)

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This invention relates to a high voltage regulator and more particularly to an improved high voltage regulator using internal negative feedback within the regulator amplifier proper.

An important problem which has long confronted engineers in the design of precision high voltage regulators is that of avoiding oscillation within the regulator circuit.

A simplified approach to the problem of 180° phase shift, which is inevitable when a two-stage amplifier is used, is to minimize all "resistance-capacitance" time constants in the regulator circuit except that of the output. This method is quite effective but results in excessive capacitance in the output of the high voltage supply which is undesirable where the load is characterized by occasional short circuits. Moving the controlling time constant to another location in the network makes the impedance, looking back into the regulator circuit inductive in nature, which is also undesirable for certain applications.

A method of reducing the capacitance required in the output of a regulated high voltage supply called the "phase advance" method was tried, wherein a resonant circuit was introduced into the regulator network in such a way as to avoid enclosing the point (1,0) on a polar diagram of the quantity $\mu\beta$. This effect is possible because of the fact that a resonant circuit exhibits a phase shift below resonance in a direction opposite to that shown above resonance. The use of this "phase advance" circuit permits a much smaller output capacitance, which means a faster regulator response, but this circuit is still not independent of the output capacitance because a smaller output capacitance requires a higher resonant frequency for the resonant circuit.

With these disadvantages of the usual high voltage regulator in mind, the improved regulator amplifier circuit as hereinafter described provides an apparatus wherein the regulator is simplified and the margin against oscillation is made substantially independent of the output capacitance. This is accomplished by applying frequency selective negative feedback within the regulator amplifier proper. This feedback is such as to provide two levels of amplification, both with low phase shift. One gain level is high at low frequencies and the other gain level is low at high frequencies with a transition range in which the maximum phase shift is 90°. Thus the phase shift caused by the feedback network decreases with increasing frequency as the low gain plateau is approached. The smaller the

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value of capacitance used in the output of the high voltage supply the less phase shift there is around the internal feedback loop. In a high voltage regulator using negative feedback as hereinafter described, the output capacitance is no longer a critical factor in the stability of the amplifier.

An object of this invention is to provide an improved high voltage regulator, using a series-connected lossy tube, in which the control voltage is supplied to the lossy tube control grid by an amplifier having internal negative feedback, said amplifier having its input associated with the load circuit supplied by the high voltage regulator.

Another object of this invention is to provide an improved and simplified high voltage regulator using a series-connected lossy tube controlled by a negative feedback amplifier wherein the output capacitance is not a critical factor in the prevention of self-oscillation.

Another object of this invention is to provide an improved and simplified high voltage regulator having a series-connected lossy tube controlled by a feedback amplifier, the gain of which is substantially reduced above a certain frequency but maintained at a high value between this frequency and zero frequency.

Still another object of this invention is to provide an improved and simplified high voltage regulator having a series-connected lossy tube controlled by an amplifier having a gain characteristic such that the possibility of oscillation around the regulator loop is minimized.

A still further object of this invention is to provide an improved and simplified high voltage regulator having a series-connected lossy tube controlled by a negative feedback amplifier having a minimum phase shift around the regulator loop.

Other and further objects of this invention will be apparent to those skilled in the art to which it pertains, upon consideration of the following specifications and drawings in which:

Figure 1 is a schematic wiring diagram of a preferred embodiment of a high voltage regulator of the direct coupled type; and

Fig. 2 is a schematic wiring diagram of a second embodiment of a high voltage regulator of the direct coupled type.

Referring to Fig. 1 in detail there is shown one embodiment of the high voltage regulator of this invention in schematic form. A conventional high voltage rectifier unit 11 has a negative terminal 12 connected directly to the cathode of a diode current limiting vacuum tube 13, while the

anode of the vacuum tube 13 is connected to an output terminal 14. The output terminal 14 is connected to ground bus 16 by a series network comprising a resistor 17 and a condenser 18. The cathode of the diode limiter tube 13 is by-passed to the ground bus 16 by a condenser 19. A positive terminal 21 of the high voltage rectifier unit 11 is connected directly to the anode of a triode regulator tube 22 by a conductor 23. The cathode of regulator tube 22 is connected to the ground bus 16 by a conductor 24. A diode tube 26 has its anode connected to the control grid of regulator tube 22, and its cathode is connected to the cathode of such tube. A spark gap 27 is also connected between the control grid and the cathode of the regulator tube 22 to prevent surges from damaging the tube. The control grid of regulator tube 22 is connected to a negative terminal 28 of a low voltage power supply 29 by a conductor 31.

This low voltage power supply 29 is a conventional, full-wave alternating current rectifier unit comprising a transformer 32 and a pair of diode vacuum tubes 33 and 34. The output of rectifier unit 29 is applied to a pi-section smoothing filter comprising an iron core inductance 36 in series with a pair of filter condensers 37, 38. This filter is shunted by a resistor 39 for discharging the filter condensers 37 and 38 when the rectifier unit is not energized. The direct current voltage supplied by low voltage supply 29 is obtainable at negative terminal 28 and positive terminal 41.

The positive terminal 41 of the low voltage supply 29 is connected to the anode of a pentode vacuum tube 43 by a conductor 44; the cathode of the pentode 43 is connected to the ground bus 16 by a conductor 46. The suppressor grid of this tube 43 is connected by conductor 47 to its cathode. The screen grid voltage of pentode 43 is supplied from a second low voltage supply 48 by a conductor 49.

The low voltage supply 48 comprises a power transformer 51, a rectifier tube 52, and a filter network made up of two iron core inductances 53 and 54 and filter condensers 56 and 57 connected thereto as shown. The voltage of this supply 48 is obtainable at terminals 61 and 62. A voltage divider comprising series-connected resistors 63 and 64 is connected across the terminals 61 and 62. A tap on resistor 64 is connected through a resistor 66 to the control grid of pentode tube 43 and also to the anode of an input pentode 67 which is connected to the control grid of pentode 43 by conductor 68, for supplying the proper voltages thereto. A resistor 69 connects the positive terminal 61 of the second low voltage supply 48 to the negative terminal 28 of the first low voltage supply 29.

A negative feedback network comprising a series-connected condenser 71 and resistor 72 is connected between the grid of regulator triode 22 and the cathode of the input pentode tube 67. The cathode and the suppressor grid of this pentode tube 67 are connected together by a conductor 73. The cathode of pentode 67 is connected through a resistor 74 to the negative terminal 76 of the low voltage standard 77 now to be described.

The low voltage standard 77 is comprised of a transformer 78, a diode rectifier tube 79, and a pi-section filter made up of the iron core inductance 81 and condensers 82 and 83. A condenser 84 is connected between the negative terminal 76 and the ground bus 16. A conductor 86 connects the positive terminal 87 of the filter section to the

anode of a pentode 88. The anode and screen grid of pentode 88 are connected together by a conductor 89. The cathode of pentode 88 is connected to the ground bus 16 by conductor 91. The control grid of pentode 88 is connected to the ground bus 16 by a resistor 92 and also to the anode of a pentode tube 93 by conductor 94.

A voltage divider comprising series-connected resistors 96, 97, and 98 is connected between the negative terminal 76 and the ground bus 16. The junction between resistors 96 and 97 is connected to the cathode of pentode 93 by conductor 99 while the junction between resistors 97 and 98 is connected to the screen grid of the same pentode 93 by conductor 101. A series-connected gaseous voltage regulator tube 102 and its current limiting resistor 103 are also connected between the negative terminal 76 and the ground bus 16. The junction between the gaseous regulator tube 102 and the current limiting resistor 103 is connected to the control grid of the pentode 93 by conductor 104. A condenser 105 is connected between the negative terminal 76 and the ground bus 16, as is another voltage divider comprising the series-connected resistors 106 and 107. A tap on resistor 107 connects through a resistor 108 to one end of a resistor 111 and a condenser 112 connected in shunt, while the other end of the resistor 111 and condenser 112 is connected to the negative high voltage terminal 14 by a conductor 113. The junction 109 between the resistor 108 and shunt-connected resistor 111 and condenser 112, is connected through another shunt network comprising a resistor 115 and condenser 116 connected to the control grid of the pentode tube 67. The above-mentioned junction point 109 is also connected to the negative terminal 76 of the voltage standard 77 by the by-pass condenser 117.

A gaseous voltage regulator tube 119 shunted by a by-pass condenser 121 is connected between the screen grid of the pentode tube 67 and the negative terminal 76 of the voltage standard 77, for maintaining the screen grid voltage constant. The screen grid of the pentode tube 67 is also connected to the ground bus 16 by a resistor 122.

With the foregoing interconnection of components in mind, let us now consider the operation of the high voltage regulator described. Terminals 123 and 124 are connected to a suitable source of alternating current, thereby energizing the transformers 32, 51, and 78 of voltage sources 29, 48 and 77, and the high voltage rectifier unit 11. During operation of the regulator a suitable load is connected between terminal 14 of the regulator and the ground bus 16.

It will be apparent that such load connection is also across the two regulator vacuum tubes 13 and 22.

Thus it will be seen that there are two regulating actions taking place across the output of the rectifier unit 11. Firstly, the diode 13 acts as a current limiter to prevent excessive current from flowing through the circuit in case the load should become short circuited. This limiting action is accomplished by operating the diode 13 "emission limited" by setting the cathode heating voltage below its normal value through the provision of means well known in the art. Secondly, a concurrent regulating action is provided by the regulator tube 22 which acts as a lossy tube and tends to keep the output voltage between terminal 14 and the ground bus 16 substantially constant. Tube 22, therefore, acts as a variable electronic impedance the value of which is con-

trolled by the voltage applied to the control grid thereof.

Two safety devices are shown as connected between the control grid and the cathode of the regulator tube 22. The spark gap 27 is to protect the regulator tube 22 from any high voltage surges which might appear in this part of the circuit, while the diode 26 which is also connected between the control grid and the cathode of the regulator tube 22 prevents the control grid from becoming positive with respect to the cathode, thereby preventing an excessive current from flowing through the regulator tube.

The high voltage divider network previously described and comprising resistors 106, 107, 108 and 111 has one end connected to the ground bus 16 and one end connected through the conductor 113 to the high voltage output terminal 14. The junction 109 between resistor 108 and resistor 111 is connected to the control grid of the vacuum tube 67 for supplying a signal voltage thereto from the voltage dividing network where the load voltage and standard voltage are compared. Junction 109 will have a certain negative voltage with respect to the ground bus 16 due to the action of the aforementioned voltage divider upon the high voltage from the high voltage rectifier 11. The standard voltage supply 77 is also connected across resistors 106 and 107 and impresses a voltage on these resistors which is opposite in polarity to that impressed by the high voltage rectifier 11. By the selection of an appropriate tap or by correctly positioning a slider on resistor 107 a predetermined voltage of correct magnitude and polarity may be impressed on the control grid of pentode 67.

Since the standard voltage obtained from the supply 77 is maintained highly constant, the voltage at the junction point 109 which is due to the standard voltage is also constant. The second voltage which is of opposite polarity to the standard voltage that is also present at the point 109 is a sample of the voltage to be regulated and contains various excursions due to variations in load current, line voltage, etc. The comparison of this sample voltage and the standard voltage results in a low voltage containing all the variations of the sample voltage. These variations are amplified by the pentode 67 and passed on to the control grid of the pentode 43 by the conductor 68; here the signal is amplified further and finally coupled to the control grid of the regulator tube 22 through the power supply 29.

The signal voltage on the control grid of the regulator tube 22 is coupled through a frequency discriminating network comprising condenser 71 and resistor 72 to the cathode of the input pentode 67 to provide negative feedback of a desired frequency characteristic. This feedback network is chosen so that the gain of the amplifier is high at low frequencies, and low at high frequencies; preferably with a transition range where the gain drops off at the rate of six decibels per octave.

Now it will be seen that if the high voltage across the load increases in magnitude there will be a differential increase in voltage applied to the input of the direct coupled amplifier due to the voltage dividing action of resistors 111, 108, 107 and 106. This signal voltage is then amplified by the vacuum tubes 67 and 43 and applied to the control grid of the regulator tube 22 with the correct polarity and magnitude to increase the impedance or lossier action of the lossier tube 22 so as to increase the voltage drop thereacross and

absorb the "extra" voltage, thereby maintaining the load voltage substantially constant.

Similarly, if the high voltage across the load decreases in magnitude, there is a differential decrease in the voltage impressed on the control grid of the vacuum tube 67 due to the voltage dividing action of resistors 111, 108, 107 and 106. This differential voltage is amplified by the vacuum tubes 67 and 43 and applied to the control grid of the regulator tube 22 and is of such magnitude and polarity as to decrease the internal resistance or lossier action of the regulator tube 22, thereby lowering the voltage drop across this tube and increasing the output voltage obtainable at the terminal 14 back to a predetermined value.

In this manner the output voltage is restricted within narrow limits and is kept substantially constant; and by using an emission limited diode 13 in the negative lead as previously described, the output current is prevented from becoming too large in case of a short circuit in a load connected between the terminal 14 and the ground bus 16.

The regulator is prevented from breaking into self-sustaining oscillation by the negative feedback network comprising the condenser 71 and the resistor 72, which maintains the gain high at low frequencies and low at the high frequencies.

A second embodiment of my invention is shown in Fig. 2. In this embodiment a high voltage rectifier and filter 200 has a negative terminal 201 connected to a center tap on the secondary winding of a cathode heating transformer 202 by a conductor 203. The transformer 202 has its secondary directly connected to an emission limited diode 206 and supplies cathode power thereto. A condenser 207 is connected between the center tap on the secondary winding of transformer 202 and a ground bus 208. The primary winding of transformer 202 is connected by means of conductors 211 and 212 to the terminals 213 and 214 for receiving suitable power therefrom. These terminals 213 and 214 are also connected to the primary winding of a second filament heating transformer 216 by conductors 217 and 218 for supplying suitable power thereto. Terminals 219 of the high voltage rectifier unit 200 are connected by conductors 221 to terminals 222 which are in turn connected to a suitable source of power for energizing the high voltage rectifier and filter unit 200.

A positive terminal 223 of the high voltage rectifier 200 is connected by a resistor 224 to the anode of a series lossier triode tube 226. The cathode of vacuum tube 226 is connected directly to the secondary winding of the transformer 216. The center tap 227 of transformer 216 is connected to the ground bus 208 by a conductor 228.

The anode of the current limiting diode 206 is connected through conductor 229 to the negative output terminal 231. A suitable load 232 is connected between the terminal 231 and the ground bus 208. The anode of diode 206 is also connected to one terminal 233 of a compensated voltage divider unit 234 by a conductor 236. A second terminal 237 of the compensated voltage divider 234 is connected through a conductor 238 to a terminal 239. The latter is connected to a positive terminal 241 of a voltage standard 242 by a shunt-connected network comprising a resistor 243 and a condenser 244. A negative terminal 246 of the voltage standard 242 is connected to the ground bus 208 by a conductor 247. A shunt-connected network comprising a resistor 248 and a condenser 249 is connected between

the terminal 239 and a terminal 251 of the direct coupled amplifier 252.

The compensated voltage divider 234 is comprised of a resistor 253 enclosed in a concentrically arranged condenser element 254 for making the voltage divider 234 substantially independent of frequency.

The input terminal 251 of the direct coupled amplifier 252 is connected to the control grid of a pentode vacuum tube 256 by a resistor 257. The suppressor grid of the pentode 256 is connected to the cathode of this tube by a conductor 258, and the cathode is in turn connected to the ground bus 208 through a shunt network comprising an inductance 259 and a resistor 260. The screen grid of the pentode 256 is connected to a tap on battery 262 by a conductor 263 for receiving the proper operating voltage therefrom. The anode of the pentode receives its proper operating voltage from the positive end of battery 262 through a resistor 264. The negative end of the battery 262 is directly connected to the ground bus 208 by conductor 266. The anode of pentode 256 is also connected to the control grid of a multigrid vacuum tube 267 by the shunt network comprising a condenser 268 and a resistor 269. The control grid receives its correct operating bias voltage through a resistor 271 from the negative end of a battery 272. The cathode of tube 267 is connected to a tap 273 on the battery 272 by a conductor 274. The screen grid of the tube 267 receives its operating voltage from a more positive voltage tap 276 through a conductor 277. The battery 272 has its positive end connected directly to the ground bus 208 by conductor 278.

The anode of the vacuum tube 267 is connected to the output terminal 279 of the direct coupled amplifier 252 by the conductor 281. This output terminal 279 is connected to the control grid of the regulator tube 226 by a conductor 282 for supplying the control voltage thereto. The output terminal 279 is connected back through a resistor 283 to the cathode of the input pentode 256 in order to feed back a portion of the output signal. The actual negative feedback loop comprises the resistor 283 and the shunt circuit comprising the resistor 260 and the inductance 259. The anode of the tube 267 also receives its operating voltage from the battery 272 through this above-mentioned feedback loop.

The operation of this second embodiment will now be discussed. The terminals 222, 213 and 214 are connected to suitable sources of power for energizing the various components of the regulator. The output voltage of the rectifier unit 200 is applied to the load connected between terminal 231 and the ground bus 208 through an emission limited diode 206, which acts to prevent an excessive flow of current in case of short circuits in the load circuit and through the series regulator tube 226, which acts to regulate the voltage across the load.

Since the voltage standard 242 is connected in opposition to the voltage produced by the high voltage rectifier unit 200, it is seen that the voltage at the junction 239 is a low negative voltage which is applied to the input terminal 251 of the direct coupled amplifier 252 through a frequency compensated coupling network comprising the resistor 248 and the condenser 249. The frequency response curve of the direct coupled amplifier 252 has been warped by using frequency responsive negative feedback so as to provide two amplification levels; the gain being high at the low frequencies and low at the high

frequencies preferably with a transition range in between where the attenuation is six decibels per octave.

The differential voltage applied to the input terminal 251 is produced by comparing a sample of the high voltage across the load with the standard voltage 242. This differential signal voltage has all of the voltage variations that are present in the output of the high voltage rectifier unit 200 superimposed upon it. These voltage variations are amplified by the direct coupled amplifier 252 and applied to the control grid of the regulator lossy tube 226 of such magnitude and sign as to cause the internal impedance of the regulator lossy tube to change, thereby producing a variable voltage drop between the positive terminal 223 of the rectifier unit 200 and the ground bus 208. This variable voltage drop when correctly applied causes the load voltage appearing between the terminal 231 and the ground bus 208 to remain substantially constant.

In both embodiments of this invention a sample of the high voltage is compared with a standard voltage and a differential voltage is produced containing any variations which were originally present in the high voltage. This differential voltage and the superimposed variations are amplified by the direct coupled amplifier comprising tubes 67 and 43 (Fig. 1) and the direct coupled amplifier 252 (Fig. 2), both amplifiers using internal negative feedback, and the resulting voltage applied to the control grid of series type lossy tubes 22 (Fig. 1) and 226 (Fig. 2). These series lossy tubes act as variable electronic impedances of the correct magnitude to keep the output voltage of the high voltage regulators depicted in Figs. 1 and 2 substantially constant. Both regulators include an emission limited diode (13 Fig. 1 and 206 Fig. 2) which serves to limit the maximum current which may be drawn from the high voltage rectifier unit.

It will be apparent that the two direct coupled amplifiers disclosed in Figs. 1 and 2 differ somewhat in the way that the negative feedback is inserted.

In Fig. 1 the negative feedback voltage fed back to the input is determined by the condenser 71, the resistor 72, and the cathode resistor 74. At the low frequencies the voltage fed back to the cathode resistor 74 is negligible, as the condenser 71 offers a large impedance at these frequencies, and in this range the gain is high. At the high frequencies the impedance of the condenser 71 is small compared to the resistors 72 and 74 and these resistors are the determining factor; in this range the amplification is low. There is a transition range where the impedance of the condenser 71 is comparable to that of the resistors 72 and 74, and in this range the attenuation proceeds at the rate of six decibels per octave. The foregoing method using condensers and resistors is considered preferable.

It will be noted that in the second embodiment shown in Fig. 2 the negative feedback loop includes the resistor 283 and the shunt circuit in the cathode circuit of tube 256 which comprises the resistor 260 and the inductance 259. At the low frequencies the feedback voltage developed in the cathode circuit is very small due to the fact that the inductive reactance of the inductance 259 is small and the cathode of tube 256 is virtually connected to the ground bus 208. At the high frequencies where the inductive reactance of the inductance 259 is large compared to the resistor 260, the negative feedback is determined by the resistors 283 and 260, these resistors being

correctly proportioned to make the amplification low at the high frequencies. The phase shift is also small because the feedback network at the high frequencies is nearly purely resistive in nature.

In the frequency range where the reactance of the inductance 259 is comparable to the resistance of the resistor 260, the attenuation due to feedback is preferably about six decibels per octave. In this range the phase shift is limited to 90° when attenuation proceeds at the six decibels per octave rate.

As mentioned above the method of introducing the negative feedback disclosed in Fig. 1 is the preferred method, as the method disclosed in Fig. 2 uses an inductance in the cathode circuit of the input stage (vacuum tube 256 Fig. 2) of the amplifier 252 (Fig. 2), and this inductance 259 must be well shielded if hum is to be kept to a satisfactorily low level.

Although I have described my invention with respect to two particular embodiments thereof, it is not limited to these embodiments nor otherwise, except by the terms of the following claims.

What is claimed is:

1. In a high voltage regulator of the direct coupled type and adapted to be connected to a source of voltage to be regulated and a load circuit requiring a constant voltage, the combination comprising a variable impedance means serially connected with said load circuit across said source of unregulated voltage, a voltage dividing network, a source of standard voltage connected to said voltage dividing network to provide a differential voltage, and a broadband direct coupled amplifier having a negative feedback circuit therein, said amplifier being connected to said voltage dividing network for receiving said differential voltage therefrom and also connected to said variable impedance, said feedback circuit comprising resistive and reactive elements forming a high impedance at low frequencies and a low impedance at high frequencies, said amplifier serving to apply an amplified differential voltage of such sign and magnitude to said variable impedance as to cause said variable impedance to maintain said load voltage substantially constant.

2. In a voltage regulator of the high voltage direct coupled type and adapted to be connected to a source of high voltage to be regulated and a load circuit requiring a constant voltage, the combination comprising a variable electronic impedance serially connected with said load circuit across said unregulated voltage source, a voltage dividing network connected across said load for obtaining a sample of the voltage thereacross, a source of standard voltage connected to said voltage dividing network to provide a differential voltage, broadband amplifying means connected to said voltage dividing network for amplifying said differential voltage, and a resistive and reactive network connected between the output and input of said amplifying means for negatively feeding back a portion of the voltage at said output dependent upon the frequency response of the elements of said network, said variable electronic impedance being connected to said amplifying means for receiving said amplified differential voltage therefrom, said amplified differential voltage when applied to said variable electronic impedance being translated into a varying voltage drop whereby said load voltage is kept substantially constant.

3. In a high voltage regulator of the direct

coupled type and adapted to be connected to a source of high voltage to be regulated and a load circuit requiring a constant voltage, the combination comprising a series regulator tube containing at least a cathode, an anode, and a control grid serially connected with said load circuit across said source of unregulated voltage, a voltage dividing network connected across said load circuit for obtaining a sample of the high voltage thereacross, a source of standard voltage connected to said voltage dividing network to provide a differential voltage, and a broadband direct coupled amplifier having a negative feedback circuit therein for amplifying said differential voltage produced by comparing said sample voltage and said standard voltage, said feedback circuit comprising a resistance and reactance network and having a frequency response characteristic determined by the values of the elements thereof to provide a high impedance at low frequencies and a low impedance at high frequencies, said series regulator tube being connected to said amplifier for receiving said amplified differential voltage therefrom, said series regulator tube changing its internal impedance in response to said amplified differential voltage so as to keep the voltage across said load substantially constant.

4. In a high voltage regulator of the direct coupled type and adapted to be connected to a source of voltage to be regulated and a load circuit requiring a constant voltage, the combination comprising a series regulator tube containing at least a cathode, an anode, and a control grid, said anode being connected to the positive terminal of said source of voltage to be regulated, said cathode being connected to one side of said load, the negative terminal of said source of voltage to be regulated being connected to the remaining side of said load, a voltage dividing network connected across said load for sampling the voltage thereacross, a standard voltage connected across a portion of said voltage dividing network to provide a differential voltage by comparison of said sample voltage and said standard voltage, a direct coupled broadband amplifier having an input, an output, first and second amplifier tubes and a second source of power, said amplifier having its input connected to said voltage dividing network for receiving said differential voltage therefrom, the output of said amplifier being connected through said second source of power to the control grid of said series regulator tube; and a resistance-capacitance network connected between the output and the input of said amplifier so as to provide negative feedback therein for providing a predetermined gain vs. frequency characteristic within said amplifier.

5. In a high voltage regulator of the direct coupled type and adapted to be connected to a source of voltage to be regulated and a load circuit requiring a constant voltage, the combination comprising a regulator tube containing at least a cathode, an anode, and a control grid; the anode of said regulator tube being connected to the positive terminal of said source of voltage to be regulated, said cathode being connected to one end of said load circuit, the negative terminal of said source of voltage to be regulated being coupled to the other end of said load circuit; a voltage dividing network and a source of standard voltage serially connected across said load circuit for producing a differential voltage by comparing said load voltage and said standard voltage, a direct coupled broadband amplifier comprising

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first and second amplifier tubes, said first amplifier tube having its control grid connected to said voltage dividing network to receive said differential voltage therefrom, said first amplifier tube having an inductive cathode circuit; the anode of said second amplifier tube being connected to the control grid of said regulator tube, and a resistor connecting between said anode of said second amplifier tube and said cathode of said first amplifier tube, said resistor and said inductive cathode circuit forming a negative feedback network for providing a desired gain vs. frequency characteristic within said amplifier.

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