June 15, 1948. H. M. NEUSTADT 2,443,541

VOLTAGE REGULATOR

Filed Jan. 11, 1945 2 Sheets-Sheet 1

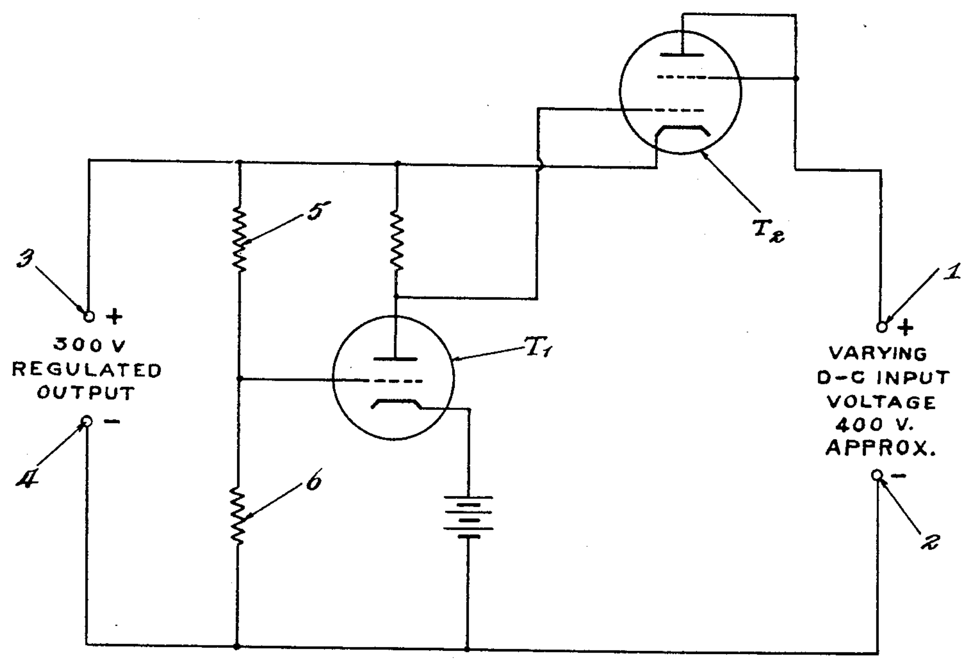

Fig.1.

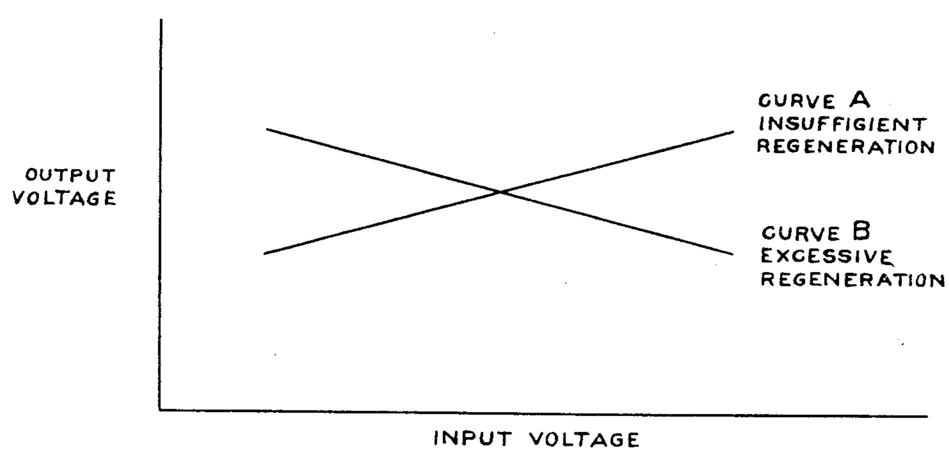

Fig.2.

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VOLTAGE REGULATOR

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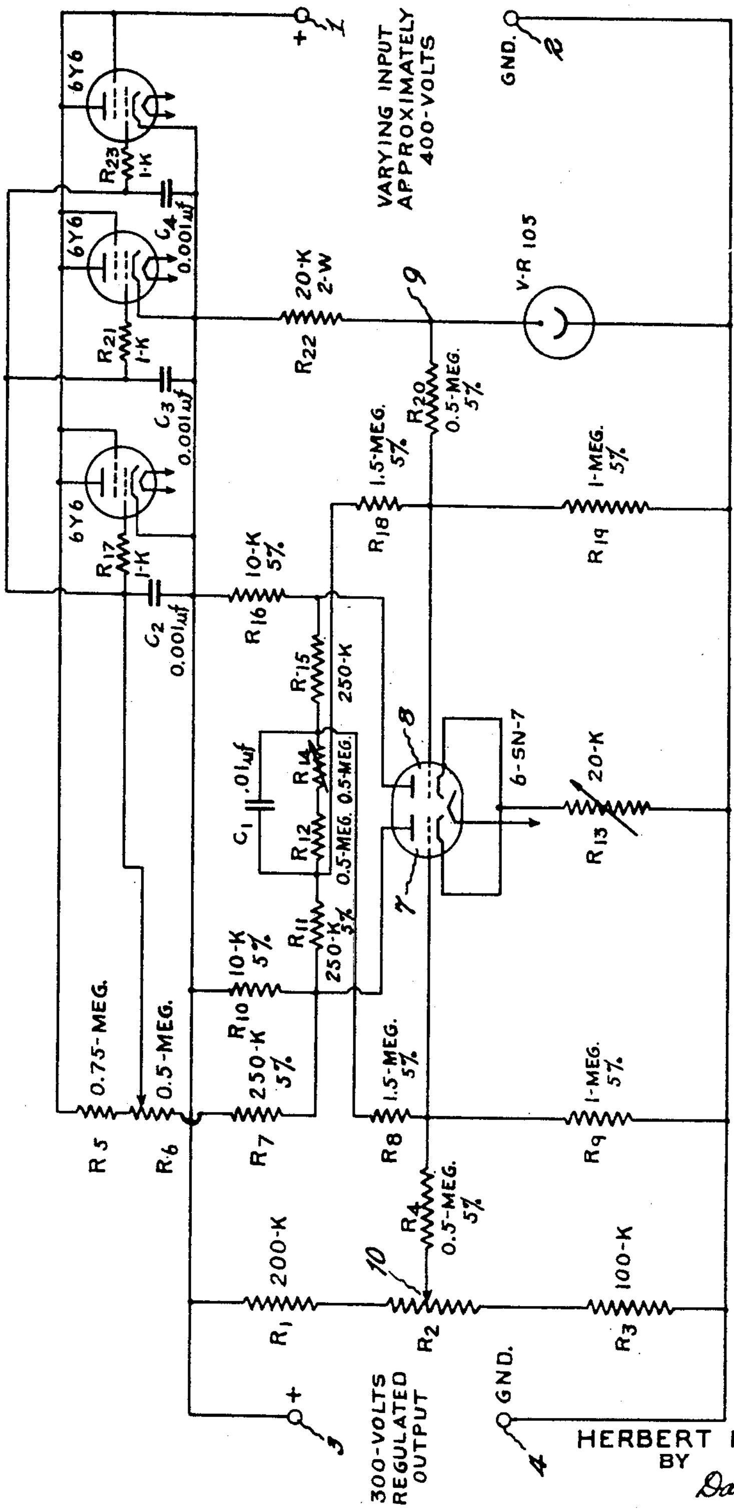

Fig. 3

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VOLTAGE REGULATOR

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4 Claims. (Cl. 323—22)

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The object of this invention is to provide a D. C. power supply voltage which stays constant in spite of normal variations in A. C. line voltage, or in current drawn by the load.

A feature of the invention is the provision of an amplifier stage having practically infinite gain which is responsive to variations in output voltage for providing a voltage to control the regulation.

Another feature of the invention is the provision of means for regeneratively amplifying a voltage corresponding to variations in output voltage with a time delay to prevent hunting.

Another feature of the invention is circuit connections permitting the amplifying stage having infinite gain to be connected across the varying input voltage.

In the drawings,

Figure 1 is a diagram illustrating a circuit which has been previously used for voltage regulation and which is included here for use in explaining my invention;

Figure 2 is a graph illustrating certain features of my invention; and

Figure 3 is a circuit diagram illustrating one form of my invention.

In Figure 1 there is impressed across the input terminals, 1, 2 a varying D. C. input voltage of approximately 400 volts. This is the voltage which is to be regulated. It may be the output of a rectifier connected to an A. C. power line, for example. The circuit of Figure 1 is illustrated as regulating such a varying D. C. input voltage of approximately 400 volts to produce across the output terminals 3, 4, a regulated output voltage of exactly 300 volts. In the circuit any increase in the output voltage will cause increased current to flow through the resistances 5, 6. This will, of course, cause an increased voltage drop through resistance 6 between the grid and cathode of tube T1, resulting in a higher positive voltage on this grid. This increase in the output voltage therefore makes the grid of tube T1 less negative with respect to its cathode. This change in grid voltage causes the anode on tube T1 to be more negative. This anode is connected to the control grid of tube T2, and therefore causes this control grid to be more negative with respect to its cathode. With this increased negative grid voltage on tube T2, the internal resistance of the tube increases, and the voltage drop across T2 must increase in order for T2 to supply the current drawn by the load, the anode-cathode circuit of the tube T2 being in series with the load. As a result, when the input voltage increases by only a comparatively small amount most of the increase is absorbed by tube T2. In this way the circuit functions to hold the output voltage close to a constant value.

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It may be seen that the accuracy with which this circuit regulates the output voltage depends on the gain of tube T1. If tube T1 could be made to have infinite gain the circuit would regulate with perfect accuracy.

Figure 3, illustrating my invention, shows how I employ D. C. regeneration to provide infinite gain, and consequently perfect regulation. The circuit for obtaining D. C. regeneration is disclosed in copending application of Francis H. Shepard, Jr., Serial No. 499,774, filed August 24, 1943, for Follow-up device.

Referring to Figure 3, the input voltage to be regulated is again connected across the terminals 1. 2 and may be the same voltage as before, and the regulated output voltage is taken from the output terminals 3, 4. The circuit illustrates an actual apparatus constructed and operated by me which provides voltage regulation with great accuracy. The actual apparatus constructed employed the components shown in Figure 3 with the values shown. Such components and values are therefore to be taken as illustrative of my invention, which is, however, not necessarily limited thereto.

In Figure 3 the three 6Y6 tubes shown connected in parallel correspond to the tube T2 of Figure 1, while the tube 7 which may be one triode portion of a tube of the 6SN7 type corresponds to the tube T1 in Figure 1.

D. C. regeneration for the tube 7, in order to produce infinite gain, is accomplished in the following manner, as described in said pending application of Francis H. Shepard, Jr. When the grid of tube 7 goes positive its plate, of course, goes negative. This plate is connected through resistances R11, R18 to the grid of tube 8, making this grid go negative. When the grid of tube 8 goes negative its plate goes positive. This plate is connected through resistances R15 and R8 to the grid of tube 7, making this grid go positive, and thereby regenerating the positive impulse first applied to this grid. The amount of regeneration may be controlled by varying resistance R14.

In the circuit of Figure 1 it will be noted that the anode-cathode circuit of tube T1 is connected in parallel with the load, while in the circuit of Figure 3 the anode of tube 7 is connected through resistances R5, R6, and R7 to the positive terminal of the input voltage. This connection permits the use of a potentiometer R6 in the plate circuit of tube 7, which is tapped to provide grid voltage for the 6Y6 tubes. If the grids of the 6Y6 tubes of Figure 3 were connected directly to the anode of tube 7, as the grid of T2 in Figure 1 is connected directly to the anode of tube T1 in that figure, the voltage applied to the grids of the 6Y6 tubes would be too highly negative. This voltage could be made less negative by returning the 6Y6 grid lead in Figure 3 to a tap on R10. However this tap would reduce the effective gain of tube 7 because it would apply only a portion of the signal output of tube 7 to the 6Y6 grids. This loss of gain is not entirely eliminated but it is made small by means of the arrangement used in Figure 3. In this arrangement, the 6Y6 grids are returned to a tap on a high-resistance voltage divider connected between the plate of tube 7 and a highly positive voltage. Because of this high positive voltage, the tap can be set at the proper operating bias for the 6Y6 grids and still be fairly close to the plate of tube 7.

Condenser C1 makes the response of the regenerative circuit of the tubes 7 and 8 slower than the response of the 6Y6 tubes, and thus prevents hunting of the regulated output voltage.

In describing above the operation of the circuit producing D. C. regeneration, this was defined with respect to a change in the voltage on the grid of tube 7. When the circuit is used for regulating, the voltage on the grid of tube 8 must also be considered. That is, if a change in output voltage causes the voltage on the grids of tubes 7 and 8 both to move in the same direction there would be no regeneration. The voltage on the grid of tube 8 is maintained substantially constant by the use of a voltage regulator tube VR105 connected between point 9 and ground. This tube has the characteristic that the voltage across it remains substantially constant despite the variations in current through the tube. An increase or decrease in current through the tube therefore does not change the voltage on the grid 8, or at least changes it less than the voltage on the grid of tube 7 is changed, so that the regeneration previously described may occur despite the fact that resistance R22 and tube VR105 are connected in parallel with the resistances R1, R2 and R3.

The resistance R13 is made variable in order to provide a proper bias for the grids of tubes 7 and 8 with respect to their cathodes.

The tap 10 on resistance R2 permits the system to operate properly despite variations between tubes 7 and 8. It also regulates the output voltage. That is, if an output voltage of say 310 volts is desired tap 10 may be moved downward until the output voltage reaches this figure. Similarly, of course, tap 10 may be moved upward to decrease the output voltage.

The operation of Figure 3 should be clear from the foregoing description, but will now be described briefly in order to be sure it is fully understood. If the output voltage tends to increase more current will be drawn through resistances R1, R2 and R3. This will result in the voltage on the grid of tube 7 being less negative with respect to its cathode. This voltage will be regenerated by the circuit connecting tubes 7 and 8 to make the grid of tube 7 still less negative. As the grid of tube 7 goes less negative the anode of tube 7 goes more negative. As this anode is connected to the grids of the three 6Y6 tubes, these grids go more negative with respect to their cathodes. This increases the resistance of these tubes, and therefore increases the voltage drop across them necessary to supply the current drawn by the load. As these three tubes in parallel are connected in series with the load some of the voltage is absorbed in the three tubes. A smaller voltage will appear across the output circuit thus restoring it to 300 volts, where it will remain with great constancy.

If the output voltage tends to fall the converse operation will take place. That is the grid of tube 7 will become more negative with respect to its cathode, the anode of tube 7 will become less negative, the grids of the 6Y6 tubes will become more positive, the resistance of the 6Y6 tubes will be decreased, the voltage across the 6Y6 tubes will decrease, and the output voltage will be restored to exactly 300 volts.

Figure 2 illustrates the effect of varying amounts of regeneration in the circuit of tubes 7 and 8. Curve A of this figure shows the effect on the output voltage for variations in input voltage if there is insufficient regeneration, showing that in this case the output voltage will increase with increase in input voltage. Curve B shows the effect of output voltage for variations in input voltage for excessive regeneration showing that in this case the output voltage will decrease with increases in input voltage. Between the two positions illustrated by curves A and B the resistance R14 may be adjusted to give the correct amount of regeneration, so that, in spite of normal variations in the 400 volt input voltage, the 300 volt output voltage will be held constant with substantially perfect accuracy.

It will be understood that my circuit is capable of various modifications, and I do not, therefore, desire to be restricted to the specific details of the circuit shown and described, but only within the scope of the appended claims.

What is claimed is:

1. A voltage regulator comprising an amplifying stage responsive to variations in output voltage, means for regeneratively amplifying in said stage a signal corresponding to variations in output voltage, and means responsive to said amplified signal for controlling said output voltage.

2. A voltage regulator comprising an amplifying stage responsive to variations in output voltage, means for applying to said stage a signal corresponding to variations in output voltage, means for regeneratively amplifying said signal, means responsive to said amplified signal for controlling said output voltage, and means for delaying said regeneration so that it occurs more slowly than the controlling means operates.

3. A voltage regulator comprising an input circuit and an output circuit, a power amplifier connected to said input circuit in series with said output circuit, a regenerative voltage amplifier having its anode-cathode circuit connected across said input circuit, means for applying a signal corresponding to variations in output voltage to the grid of said voltage amplifier so it is regeneratively amplified therein, and means for applying said amplified signal to the grid of said first mentioned amplifier.

4. A voltage regulator comprising a regenerative D. C. amplifier stage having its anode-cathode circuit connected across the input circuit, means for applying a signal corresponding to a variation in output voltage to the grid of said amplifier, a second amplifier stage for regenerating said signal, and means for maintaining the grid of said second stage tube at a voltage which

remains more nearly constant than the voltage of the grid of said first stage.

HERBERT M. NEUSTADT.

REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
2,247,082	Gardiner	June 24, 1941
2,362,769	Parratt	Nov. 14, 1944

Certificate of Correction

Patent No. 2,443,541. June 15, 1948.

HERBERT M. NEUSTADT

It is hereby certified that the name of the assignee in the above numbered patent was erroneously described and specified as "Remco Electronics, Inc.", whereas said name should have been described and specified as *Remco Electronic, Inc.*, as shown by the record of assignments in this Office; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 14th day of September, A. D. 1948.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.