July 13, 1943. F. G. MARBLE 2,324,408

AMPLIFIER

Filed Dec. 31, 1941

FIG. 1

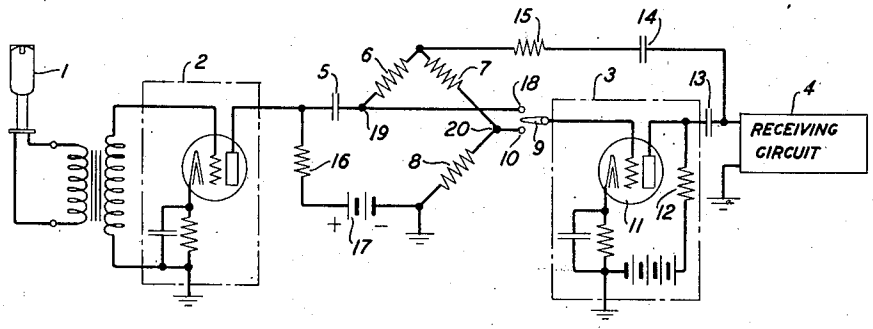
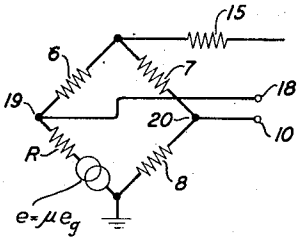


FIG. 2



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Patented July 13, 1943 2,324,408

UNITED STATES PATENT OFFICE

2,324,408

AMPLIFIER

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Application December 31, 1941, Serial No. 425,091

4 Claims. (Cl. 179—171)

This invention relates to amplifiers and particularly to amplifiers involving feedback circuits.

In amplifiers for certain special applications such, for example, as sound level meters it is necessary to be able to change the gain by definite amounts. In such applications stable and uniform response over a wide range of frequencies is often required and this is conveniently obtained by using a large amount of negative feedback. In conventional circuits of this type, however, the gain cannot be changed within the feedback loop without at the same time affecting the feedback circuit which in turn gives rise to a further rather indefinite change in gain which cannot be tolerated in applications of the type referred to above. While this could be avoided by adjusting the gain in some portion of the circuit not within the feedback loop this usually involves the addition of other stages or circuit elements not otherwise required and in many cases cost, weight or other considerations make it undesirable to resort to such expedients.

In accordance with this invention the gain of a feedback amplifier is made adjustable within the feedback loop by any given amount by adjusting the signal voltage effective at the grid of the tube to which the feedback is applied in such a manner that the impedance of the circuit to feedback currents is not changed. In the case of feedback to the grid of a tube, signal input voltages for the tube, differing in level by the amount required, are derived from suitable points on an impedance shunting the source of signals and the feedback circuit is connected to the impedance at an intermediate point such that the feedback potentials at the two points of connection to the grid are equal.

Fig. 1 of the drawing shows an amplifying system according to the invention and Fig. 2 shows the equivalent of the bridge portion of the circuit of Fig. 1.

In this system a microphone 1 or other source of signal currents is connected by tandem vacuum tube amplifiers 2 and 3 to a receiving circuit or device 4. For purposes of illustration the amplifiers 2 and 3 are shown as single, self-biased battery operated triodes but obviously each amplifier may comprise any desired number of stages of any known type.

The output voltage of the amplifier 2 is impressed through condenser 5 on the shunt impedance composed of the resistors 6, 7 and 8 in series and when the switch 9 is closed on the contact 10 a portion of the output voltage is effective at the grid 11 of the amplifier 3. The voltage developed across resistor 12 in the output circuit of the amplifier 3 is applied through the coupling condenser 13 to the receiving circuit or device 4 where it is utilized for any desired purpose but a portion of this voltage is also fed back through the usual condenser 14 and resistor 15 to the junction of resistors 6 and 7. From this point there are two paths to ground, one through resistors 7 and 8 and the other through condensers 5 and the output impedance of the amplifier 2. This latter impedance (R of Fig. 2) consists essentially of the plate resistance of the output tube of amplifier 2 and the resistance 16 in parallel since the impedances of condenser 5 and the power supply, which is shown in this case as a battery 17, will ordinarily be relatively very small for currents of signal frequencies.

When using a sound level meter to measure sounds of very low intensity, very high gain is required whereas less gain is sufficient for ordinary purposes. Since the amplifier of such a meter is less likely to become unstable or to be affected by mechanical vibrations when in the less sensitive state, it is convenient to provide a switch for increasing the gain by 20 decibels above normal when low intensity sounds are to be measured. In the circuit shown, when the switch 9 is moved from contact 10 to contact 18, the gain is to be increased by this amount without affecting the feedback voltage effective at the grid 11.

Since a change in level of 20 decibels is equivalent to a voltage ratio of 10 it follows that the signal voltage between point 19 and ground must be ten times the voltage between point 20 and ground. From simple bridge theory it follows that the feedback voltage at grid 11 will not be changed by the switching operation if the resistances are such that

$$R_8=\frac{RR_7}{R_6} \qquad (1)$$

where the numerical subscripts refer to the correspondingly numbered resistors of Fig. 2 and R is the output impedance of the amplifier 2 as defined above. The conductance of the input circuit of the amplifier 3 will usually be negligible and the value of resistor 15 will ordinarily be large as compared with either resistor 7 or resistor 8 so that the shunting effect of the feedback path on resistors 7 and 8 may be neglected. On this basis the potential of point 19 is

$$e_{19}=\frac{(R_6+R_7+R_8)e}{R+R_6+R_7+R_8} \qquad (2)$$

and the potential of point 20 is

$$e_{20}=\frac{R_8e}{R+R_6+R_7+R_8} \qquad (3)$$

where $e=-\mu e_g$ and e_g is the signal voltage at the input of the amplifier 2 in each case.

For a 20-decibel change in gain

$$\frac{e_{19}}{e_{20}}=\frac{R_6+R_7+R_8}{R_8}=10 \quad (4)$$

$$10R_8=R_6+R_7+R_8 \quad (5)$$

$$9R_8=R_6+R_7 \quad (6)$$

But for the same feedback at either gain

$$R_8=\frac{RR_7}{R_6} \text{ (Equation 1 above)}$$

Substituting this value of R_8 in Equation 6

$$9RR_7=(R_6)^2+R_6R_7 \quad (7)$$

If the values of resistors **6**, **7** and **8** are chosen to satisfy both Equations 1 and 7 then the operation of switch **9** will change by 20 decibels the gain of a feedback amplifier of the type shown.

Similarly, any other desired gain ratio may be obtained by setting Equation 4 equal to the corresponding voltage ratio and the general principles of the invention may be utilized in connection with various other circuits.

If for any reason the shunting effect of the feedback path on the signal potentials of points **19** and **20** cannot be neglected the balance Equation 1 is unchanged but the following equation must be substituted for Equation 7 above

$$10R_XR_{15}R_8=(R_Y+R_6)(R+R_6+R_{15})R_Z-(R_{15})^2 \quad (8)$$

where

$$R_X=R_Y+R_6+R$$

$$R_Z=R_{15}+R_7+R_8$$

$$R_Y=\frac{(R_7+R_8)R_{15}}{R_7+R_8+R_{15}}$$

As is well known, the actual resistance of ordinary commercial resistors varies as much as ±10 per cent of their nominal ratings and hence special resistors are ordinarily required where the design value is at all critical. It will be noted, however, that in this circuit relatively large deviations from the design value of resistors **7** and **8** are permissible since the changes in the loss produced by these variations are made negligibly small by the feedback action at the two settings of the switch **9**. If, for example, the value of resistor **7** is too high then the potential drop across resistor **8** will be too low, the signal potential at point **20** will be more than 20 decibels below the potential of point **19**. However, the feedback potential at point **20** will also be correspondingly too low and hence the net gain of the amplifier system tends to remain constant. Similarly other deviations from design value in the resistors **7** and **8** produce compensating changes in the amount of feedback applied to the amplifier **3**.

While the invention has been described for purposes of illustration in connection with a sound level meter it is obviously applicable to any other system where a similar problem is involved and various changes may be made in the application and circuit details of the invention within the scope of the following claims.

What is claimed is:

1. In an amplifying system, first and second vacuum tubes connected in tandem, a negative feedback path around the second tube and means for changing the gain of the system without substantially affecting the feedback comprising a shunt impedance connected between the tubes, an intermediate point of connection on the impedance for the feedback path, a grid in the second tube and means for selectively connecting the grid to the impedance at points of equal feedback potential on opposite sides of the intermediate point.

2. In an amplifying system, a source of signal currents, an amplifier having input and output circuits, an impedance shunting the source of signal currents, a feedback path from the output circuit to an intermediate point on the impedance and means for selectively connecting the input circuit to other points on the impedance at which equal potentials are produced by currents in the feedback path and unequal potentials are produced by currents from the signal source.

3. In an amplifying system, a source of signal currents of predetermined impedance, three other impedances forming with the impedance of the source a balanced bridge, an amplifier having an input grid and an output circuit, a feedback path from the output circuit to diagonally opposite points of the bridge and means for selectively connecting the grid to the points on the bridge which are conjugate to the points of connection of the feedback circuit.

4. A system according to claim 3 in which the impedances forming the bridge are proportioned to produce a change of 20 decibels in the output level of the amplifier when the grid connection is moved from one of the conjugate points to the other.

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