June 13, 1939. H. MAYER 2,162,267

AMPLIFIER

Filed May 14, 1936

Fig. 1

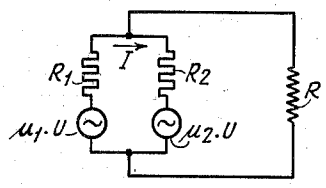


Fig. 2

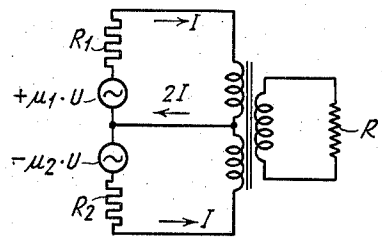


Fig. 3

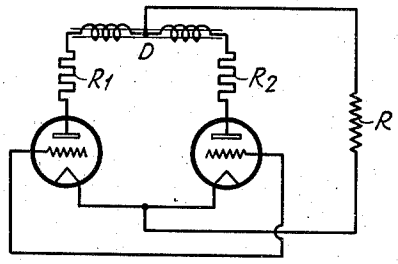


Fig. 4

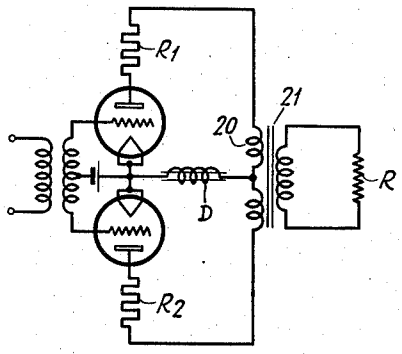
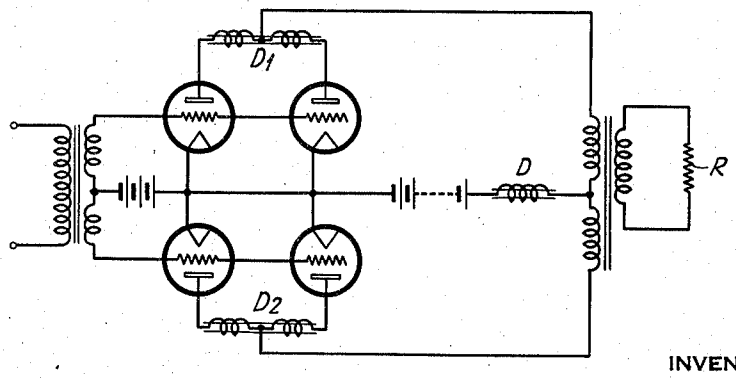


Fig. 5



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AMPLIFIER

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Application May 14, 1936, Serial No. 79,631
In Germany July 10, 1935

3 Claims. (Cl. 179—171)

It is known that non-linear distortions appearing in tubes especially in end stages of amplifier circuits can be eliminated by excessive matching of the outer load resistance i. e. by choosing the latter high as compared with the inner resistance of the respective tube. The linearity is produced since at very high values of the outer resistance, the linear current becomes very small and due to the fact that the non-linear electro-motive forces controlled by the linear current meet with a high resistance.

If the linearity obtained by excessive matching is to be applied to tubes connected in parallel or in push-pull, an extremely exact equality of the tubes operating in pairs is required, so as to avoid a decrease in the effect of the excessive matching due to compensating currents passing between the two tubes.

It is accordingly an object of this invention to prevent distortion in amplifiers connected either in parallel or push-pull.

For a better understanding of the invention reference is made to the accompanying drawing in which,

Fig. 1 is a schematic circuit diagram of two amplifiers connected in parallel to a common load resistance,

Fig. 2 is a similar diagram with the amplifiers connected in push-pull,

Fig. 3 is a circuit diagram showing an embodiment of the invention as applied to parallel connected tubes,

Fig. 4 is a circuit diagram showing the invention as applied to two tubes connected in push-pull, and

Fig. 5 is a circuit diagram showing the invention as applied to two pairs of tubes connected in push-pull, each pair being connected in parallel.

In Figure 1 there is shown schematically the parallel connection of two tubes loaded by the outer load resistor R. The tubes whose internal resistances are designated by R_1 and R_2 respectively, produce the electro-motive forces $\mu_1 \cdot U$ and $\mu_2 \cdot U$ respectively. The factor μ designates the amplification factor. The potential U is the voltage applied to the input circuits of the tubes and which is to be amplified.

In case the amplification factors μ_1 and μ_2 are not equal it will not be possible even in case of an infinitely high outer resistor R to cause disappearance of the linear current in the tubes. In the circuit formed by the two tubes a compensating current I flows, whose value is given by the following equation:

$$(1) \qquad I = U\frac{\mu_1 - \mu_2}{R_1 + R_2}$$

The tube with the internal resistance R_1 hence, does not operate with the very high outer load resistor but operates with a resistor R'_0 having the value:

$$(2) \qquad R'_0 = \frac{\mu_1 \cdot U}{I} = \frac{\mu_1}{\mu_1 - \mu_2} \cdot (R_1 + R_2)$$

In a corresponding manner the value of the load resistance R''_0 of the tube having the internal resistance R_2 is found to be:

$$(3) \qquad R''_0 = \frac{\mu_2 \cdot U}{I} = \frac{\mu_2}{\mu_1 - \mu_2}(R_1 + R_2)$$

Thus it is seen that the intended excessive matching cannot take place and consequently the desired reduction of non-linear distortions will not be achieved.

The same conditions prevail in push-pull circuits according to Figure 2. Even at infinitely high outer resistance R the tubes do not operate at no-load. There passes a residual current through each tube whose value is:

$$(4) \qquad I = U \cdot \frac{\mu_1 - \mu_2}{R_1 + R_2}$$

An effective excessive matching is thus prevented.

It is difficult to obtain for both tubes the same amplification factor and furthermore in all probability even where initially equal, irregularities will occur during operation or due to an exchange of tubes. In order to obtain, despite these conditions, a sufficient linearity by means of excessive matching the invention provides means by which the unbalanced current produced by irregularities in the tubes operating in pairs will be reduced. This may be accomplished in tubes connected in parallel by means of a differentia choke for instance, which is placed in series with the two tubes. In push-pull stages the same effect can be achieved with a choke coil inserted in the common plate circuit of the two tubes.

Several circuits embodying the invention are represented in Figures 3 to 5. Figure 3 shows the parallel connection of two tubes with the internal resistances R_1 and R_2. In series with the plate circuits of the two tubes there is placed the differential choke coil D having the outer load resistance R connected to its electrical center. Owing to the differential action, the choke does not influence the currents passing through the outer resistance R, but it increases the im-

pedance of the circuit formed by the two tubes R_1 and R_2. Consequently, the compensating or circulating current will be decreased, thus obtaining excessive matching and linearity.

Figure 4 shows the application of the invention to a push-pull circuit. The choke D is inserted in the common part of both plate circuits, i. e. between the cathodes of the tubes and the center point of the primary winding 20 of the output transformer 21. This arrangement assures the desired excessive matching even in case of unequal amplification factors of the tubes. The choke does not influence the amplification factor and the supplied A. C. energy since the amplified currents pass through the choke with equal intensity, but in opposite directions thus not producing voltage loss therein. In this case the load resistor R is shown in the secondary circuit.

Figure 5 shows the end or power stage of an amplifier in which push-pull operated pairs of tubes are connected in parallel. In this case it is necessary to prevent the compensating currents between the tubes placed in parallel as well as between the groups operating in push-pull. This is carried out in accordance with the invention by interposed choke coils D, D_1 and D_2. As in the case of Figure 2, the choke coils D_1 and D_2 are differential chokes.

The invention is not only applicable to amplifier tubes, but in all cases in which the effect of linearity of an excessive matching in circuit elements operating in parallel or in push-pull is to be assured even where the electrical properties of these circuit elements differ from each other.

Having described my invention, what I claim as novel and desire to secure by Letters Patent is:

1. An amplifier comprising two vacuum tubes, a differential choke coil having its ends connected to the plates of said tubes, and a circuit connecting the electrical center of said choke coil and said tube cathodes and including an impedance having a value higher than the plate resistance of either of said tubes.

2. An amplifier comprising the combination of two electron discharge tubes each having a cathode, grid and plate, a direct connection between said grids, a differential choke coil having its ends connected directly to said plates and having a high impedance to currents of the frequency to be amplified, and a circuit connecting the electrical center of said choke coil and said tube cathodes and including a resistance having a value higher than the plate resistance of one of said tubes, whereby the current passing through said resistance varies linearly with the voltage applied to said grids when the amplification factors of said tubes are of somewhat different values.

3. A power amplifying stage comprising the combination of a first pair of vacuum tubes, a second pair of vacuum tubes, each of said tubes having a cathode, control grid and plate, a direct current connection between said tube cathodes, an input transformer having one end of its secondary winding connected to the grids of said first pair of tubes and its other end to the grids of the second pair of tubes, a circuit connecting the midpoint of said secondary winding to said tube cathodes, a differential choke coil connecting the plates of the first pair of tubes, a second differential choke coil connecting the plates of the second pair of tubes, a divided output impedance, direct current connections between the ends of said impedance and the midpoints of said choke coils and a circuit including the series connection of a source of positive potential and a high inductance connected between the midpoint of said output impedance and said tube cathodes.

HANS MAYER.