PATENT SPECIFICATION

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PROVISIONAL SPECIFICATION
No. 16168 A.D. 1937.

Improvements in or relating to Electric Amplifiers

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British company, and ALBERT JESSE BIGGS, of Research Laboratories of The General Electric Company Limited, Wembley, Middlesex, a British subject, do hereby declare the nature of this invention to be as follows:—

This invention relates to electric amplifiers of the type producing from a single input voltage, two output voltages differing in sign and usually differing only in sign. Such arrangements are often used as audio-frequency amplifiers.

The essential components of one known arrangement of this type are depicted in Figure 1 of the accompanying drawings in which 1 represents a triode, the anode of which is connected through a resistance R to the positive terminal of the H.T. supply, and the cathode of which is connected through a similar resistance R^1 to the negative terminal of the H.T. supply, which is preferably earthed as shown. The input voltage is applied between the terminals 2, 3 connected to the grid and cathode respectively and the output voltages are developed between the terminals 4 and 6 and 5 and 6 respectively, the terminal 4 being connected to the anode, 5 to the cathode and 6 to the negative terminal of the H.T. supply. The H.C. components of the output voltages, which may be subject to further amplification, will thus be of different sign and as the two resistances R, R^1 are equal they will be of equal magnitude. Arrangements of this type differ from other arrangements, producing the same result, of the kind known as paraphase amplifiers in that the phase reversing property of a valve is not utilised in order to obtain the result, which is merely an illustration of Ohms law.

The above arrangement suffers from several disadvantages owing to the presence of the high resistance R^1 in the cathode lead. Thus, for example, if the valve 1 has an indirectly heated cathode, the capacity existing between the cathode and the heater circuit will form a shunt across the resistance R^1 giving rise to distortion of the higher frequencies in the output; the cathode is at a high positive potential with respect to earth and the input circuit will also have to be at a high positive potential with respect to earth, unless the terminal 3 is connected to earth instead of to the cathode. In the latter case a large input is required and the valve gives no gain. A further disadvantage lies in the fact that the effective output of the valve is halved, so that if two output valves are to be driven by it, a very large input is required.

It is the object of this invention to overcome these disadvantages in an arrangement of this nature.

According to the invention this object is achieved by making the resistance R^1 in the cathode lead small compared with the resistance R in the anode lead and amplifying the voltages developed across R^1, without phase reversal, by means of a second valve.

The invention will be further described with reference to Figures 2 and 3 of the accompanying drawings, of which Figure 2 illustrates the principles underlying the invention and Figure 3 depicts, by way of example, a more practical embodiment of it. In each of these figures, parts similarly denoted correspond to similar parts in Figure 1.

In Figure 2 the input terminal 3 is depicted as connected to the negative terminal of the H.T. supply, i.e. earth, but it may equally well be connected to the cathode of the valve 1. The voltages developed across the resistance R^1, which is now small compared with R, are amplified by the valve 7, the cathode of which is connected to the cathode of the valve 1 and the grid of which is connected to the negative terminal of the H.T. supply, i.e. earth. The anode is connected to the positive terminal of the H.T. supply through a high resistance S; the output terminal 5 is connected to this anode. 8 is a biassing resistance in the

[*Price* 1/-]

input circuit.

The operation of the arrangement is briefly as follows:—when the input voltage, applied between the terminals 2, 3, increases, the anode current in the valve 1 increases, making the anode more negative and the cathode more positive with respect to earth. The decrease in anode potential will be greater than the increase in cathode potential owing to the dissimilarity of the resistances R and R^1. The potential of the cathode of the valve 7 also increases, making it more positive with respect to the grid; hence the anode current in the valve decreases and the anode becomes more positive with respect to earth. The potentials developed across the resistance R^1 are thus amplified without phase reversal and the resistances R, R^1 and S may be adjusted so that the voltage variations with respect to earth at the terminals 4 and 5 are equal and opposite.

With this arrangement the anode current of the valve 7 also flows through the resistance R^1 setting up potentials across it in opposition to those developed by the anode current of the valve 1. In order that the latter potentials should predominate, so that the correct polarity of output may be obtained, the resistance S must be larger than the resistance R.

Figure 3 of the accompanying drawings depicts a practical embodiment of the invention which represents a stage of push-pull amplification in accordance with the invention, following a detector stage in a wireless receiver. In this arrangement the cathode of the valves 1, 7 are connected through a blocking condenser 9 of low impedance to audio-frequency variations, and the cathode of 7 is connected to earth through a resistance 10, in order that the valves 1, 7 may be differently biassed; the grid of 7 is connected to earth through a source of grid bias between the points A, B shunted by the blocking condenser 11. The valve 1 is a diode-triode, the diode part of which forms part of a known detector circuit comprising the transformer 12, resistance 13 shunted by the condenser 14, and the condenser 15 communicating the audio potentials developed to the control grid. This control grid is connected to a source of grid bias through the resistor 16. The output terminals are connected to further stages in the receiver. The mode of operation of the arrangement will be obvious from the foregoing description to those skilled in the art.

It will also be obvious to those skilled in the art that the above arrangement may be modified in various ways for example, by using multi-electrode valves, without affecting the nature of the invention.

Dated the 10th day of June, 1937.
For the Applicants,
NORMAN R. CAMPBELL.

PROVISIONAL SPECIFICATION
No. 16897 A.D. 1937.

Improvements in or relating to Electric Amplifiers

We, THE GENERAL ELECTRIC COMPANY LIMITED, of Magnet House, Kingsway, London, W.C.2, a British company, and ALBERT JESSE BIGGS, of Research Laboratories of The General Electric Company Limited, Wembley, Middlesex, a British subject, do hereby declare the nature of this invention to be as follows:—

This invention relates to electric amplifiers of the type producing from a single input voltage two output voltages differing in sign and preferably differing only in sign. Such amplifiers are known as push-pull amplifiers. More particularly it relates to push-pull amplifiers in which the output voltages of at least one stage are taken from points in the anode circuits of two different valves.

With such amplifiers, there exists in general a relation between the values of various components in the circuit, such as resistances and the mutual conductances of valves, that must be satisfied in order that exact equality in magnitude of the output voltages may be obtained. The operation of adjusting various components so that this relation is satisfied is known as balancing the amplifier. Thus an amplifier may be balanced by fixing the values of all the components save one and then varying this last one until the aforesaid relation is satisfied.

If, however, at some later stage in the life of the amplifier one or more of the components are replaced by different ones of different value, the balance will be upset and readjustment necessary. It may not be always convenient to effect such readjustment, especially if the push-pull amplifier forms part of a wireless receiving set; in the latter case replacement of one or more valves in the amplifier is very likely to cause such unbalance. It is the object of the invention to obviate the need

for such readjustment when the balance of the amplifier is disturbed for any reason. Also it will be apparent from what follows that the arrangement according to the invention will tend to reduce the effects of any departure from balance of the amplifier such as may arise from departure of actual from theoretical values of the resistances of various resistors in the circuit.

The principles underlying the invention will now be explained with reference to the accompanying drawing which depicts an amplifier of the type described in copending application No. 16168/37 modified in accordance with the invention.

In the figure, 2, 3 are the input terminals across which a voltage E is applied, of which 2 is connected with the grid and 3 with the cathode of the valve 1. 8 is a biassing resistance. The anode of the valve 1 is connected to the positive terminal of the H.T. supply (H.T.+) through a resistor R of resistance R and to the negative terminal of the H.T. supply, depicted as earthed, through the resistor R^1 of resistance R^1, where R^1 is small compared with R. The end of R^1 remote from earth is connected to the cathode of the valve 7, the anode of which is connected to H.T.+ through a resistor S of resistance S. The output terminals 4, 5 are connected to the anodes of 1 and 7 respectively and are at voltages E_1 and E_2 with respect to the neutral output terminal 6, which is earthed. The modification in accordance with the invention consists of the equal resistors r_1, of resistance r_1, connecting the anodes of 1 and 7, the junction of these resistors being connected to earth through the resistor r_2 of resistance r_2; also the grid of 7 is connected to the junction of the resistors r, instead of to earth directly. 9 and 10 are blocking condensers, inserted in the connections to the anodes of 7, 1, whose presence is not essential to the invention but which simplify the description of the operation of the arrangement which will follow later. V is the voltage across r_2.

Assuming for the moment that 9, 10 are absent, there will be steady voltages E_1, E_2 across the output terminals and a steady voltage E across the input terminals. An input voltage represented by δE will then produce output voltages δE_1, and δE_2 and if the amplifier is correctly balanced, $\delta E_1 = -\delta E_2$. In this case it will be apparent that $\delta V = 0$; there is then no change in bias on the grid of 7 and the correct balance is maintained.

Broadly speaking, the operation of the arrangement is as follows. If the amplifier should be unbalanced so that $|\delta E_1| \neq |\delta E_2|$, say $|\delta E_1| > |\delta E_2|$ and δE_1 is positive and that δE_2 negative, it follows that δV will be finite and positive. Hence the bias on the grid of 7 will become more positive, the anode current will increase and the potential of the anode will decrease, thus increasing δE_2 and tending to remove the inequality $|\delta E_1| > |\delta E_2|$. Similarly if $|\delta E_1| < |\delta E_2|$, δV will be finite and negative, the bias on the grid of 7 will become more negative, the anode current will decrease and the anode potential become more positive, so that δE_2 will decrease, tending to remove the inequality $|\delta E_1| < |\delta E_2|$. Similar results hold if δE_1 is negative and δE_2 positive. The only effect of the condensers 9, 10, which are of low impedance to the alternating components of the anode currents, is to make the steady values of E_1, E_2 and V zero.

The actual effect of the modification in accordance with the invention may be seen in more detail from the following discussion. Let I_1 and I_2 be the currents flowing in the anode circuits of the valves 1 and 7 respectively in the directions shown; assume that $r_1 + r_2$ and $2r_1$ are both large compared with S and R so that the alternating components of I_2 and I_1 flowing in the resistances r_1, r_2 are negligible. The following equations then follow from well known theory.

$$\delta I_1 = g_1 \delta E \quad - - - - - - - \quad (1)$$

$$\delta E_1 = R\, \delta I_1 \quad - - - - - - - \quad (2)$$

$$\delta E_2 = S\, \delta I_2 \quad - - - - - - - \quad (3)$$

$$\delta V = \frac{r_2}{r_1 + 2r_2} \cdot (\delta E_1 + \delta E_2) \quad - - - \quad (4)$$

$$\delta I_2 = -g_2[\delta V + R^1(\delta I_1 + \delta I_2)] \quad - - \quad (5)$$

where g_1 and g_2 are constants depending on the particular valves used and on their anode loads. It can be shown from these equations that

$$-\frac{\delta E_1}{\delta E_2} = \frac{\frac{1}{Sg_2} + \frac{R^1}{S} + \frac{r_2}{r_1 + 2r_2}}{\frac{R^1}{R} + \frac{r_2}{r_1 + 2r_2}} \quad - - \quad (6)$$

Hence for the amplifier to be correctly balanced the relation

$$\frac{1}{Sg_2} + \frac{R^1}{S} = \frac{R^1}{R} \quad - - - \quad (7)$$

must hold. (This equation implies S>R.) This is the same condition as for the amplifier not modified in accordance with the invention. However the effect of the modification can be seen from (6) for as S>R from (7), and as R>>R¹ is a feature of the amplifier arrangement, and as $Sg_2>>1$, the dominant term in both the numerator and denominator of the right hand side of (6) is $\frac{r_2}{r_1+2r_2}$. Although the maximum value of this fraction is $\frac{1}{2}$ it can be made within wide limits sufficiently great compared with the other terms to maintain the ratio $\frac{E_1}{E_2}$ near unity in spite of considerable variations in the values of R, R¹, S and g_2. This may be illustrated by a numerical example.

Suppose R = 100,000 Ω
R¹ = 2,000 Ω
g_2 = 100 m.mhos.
S = 200,000 Ω

Then with the arrangement not modified in accordance with the invention

$$\frac{\delta E_1}{\delta E_2}=\frac{.05+.01.}{.02}=3$$

Now with the arrangement in accordance with the invention, with

r_1 = 500,000 Ω
r_2 = 1,000,000 Ω

$$\frac{\delta E_1}{\delta E_2}=\frac{.05+.01+.4}{.02+.4}$$

= 1.1 approx.

Thus the balance is practically maintained.

It will be apparent that even if r_1+r_2 is not large compared with S, and hence R, and if the other factors modifying the above theory are taken into consideration, or if the two resistances r_1 are not equal, the balance of the amplifier will still tend to be maintained.

Thus according to the invention, in a push-pull amplifier stage in which the output voltages of the stage are taken from two points in the anode circuits of two valves, the said two points are connected by two resistances, preferably equal, of impedance large compared with the load impedance of the valves and the common point of these resistances is connected to the neutral output terminal through a further resistance and to the control grid of one of the valves.

The arrangement in accordance with the invention is not limited to the amplifier described with reference to Figure 1 but may be applied to any form of push-pull amplifier of the type specified. When the amplifier comprises more than one push-pull stage of this type, the invention may be applied to any or all of the stages. In the latter case, when the output voltages of one stage are amplified by further valves, the grid leaks of these further valves may form the resistors connecting the anodes of the first pair of valves in accordance with the invention. These grid leaks are then joined together and earthed through a common resistance.

It must be understood that the arrangement described with reference to the figure is intended to illustrate principles only, and may in practice be subject to many modifications without affecting the nature of the invention. Other applications of the invention will be obvious to those skilled in the art.

Dated the 17th day of June, 1937.

For the Applicants,
NORMAN R. CAMPBELL.

COMPLETE SPECIFICATION

Improvements in or relating to Electric Amplifiers

We, The General Electric Company Limited, of Magnet House, Kingsway, London, W.C.2, a British company, and Albert Jesse Biggs, of Research Laboratories of The General Electric Company Limited, Wembley, Middlesex, a British subject, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to push-pull electric amplifiers, that is to say, amplifiers of the type producing from a single varying input voltage, two output voltages whose variations differ in sign and preferably differ only in sign. Such arrangements are often used as audio-frequency amplifiers.

The essential components of one known

arrangement of this type are shown in Figure 1 of the drawings accompanying provisional specification No. 16168/37, in which 1 represents a triode, whose anode is connected through a resistance R to the positive terminal of the H.T. supply and whose cathode is connected through a similar resistance R^1 to the negative terminal of the H.T. supply, which is preferably earthed as shown. The input voltage is applied between the terminals 2, 3 connected to the grid and cathode respectively; the two output voltages are developed between the terminals (4, 6) (5, 6) respectively, the terminal 4 being connected to the anode, 5 to the cathode and 6 to the negative terminal of the H.T. supply. The variations of the output voltages, which may be subject to further amplification, will thus be of different sign; if the two resistances R, R^1 are equal, they will be of equal magnitude. Arrangements on this principle differ from other arrangements, producing the same result, of the kind known as paraphase amplifiers, in that the phase-reversing property of a valve is not utilised in order to obtain the result, which is merely an illustration of Ohm's law.

The arrangement of Figure 1 suffers from several disadvantages arising from the presence of the high resistance R^1 in the cathode lead. Thus, for example, if the valve has an indirectly heated cathode, the capacity between the cathode and the heater circuit will form a shunt across the resistance R^1, giving rise to distortion of the higher frequencies in the output. Again the cathode is at a high positive potential with respect to earth, and the input circuit will also have to be at a high positive potential with respect to earth. If, in order to avoid this second disadvantage, the terminal 3 is connected to H.T.—instead of to the cathode, a large input is required and the valve gives no gain. A further disadvantage lies in the fact that the effective output of the valve is halved, so that, if two output valves are to be driven by it, a very large output is required.

It is the primary object of this invention to overcome these disadvantages in an arrangement operating on the principle described above.

According to the main feature of the invention this object is achieved by making the resistance R^1 in the cathode lead small compared with the resistance R in the anode lead and amplifying the variations in voltage developed across R^1, without phase reversal, by means of a second valve.

The invention will be further described with reference to Figures 2 and 3 of the drawings accompanying provisional specification No. 16168/37, of which Figure 2 shows, by way of example, a relatively simple embodiment of the invention and Figure 3 shows, by way of example, a rather more complicated embodiment of it. In each of Figures 1, 2, 3 parts similarly denoted perform the same function.

In Figure 2 the input terminal 3 is shown connected to the negative earthed terminal of the H.T. supply, but, for the reason explained, it is preferably connected to the cathode of the valve 1 as in Figure 1; in equation (1) below, it is assumed that 3 is connected to the cathode. The voltage developed across the resistance R^1, which is now small compared with R, is amplified by the valve 7, whose cathode is connected to the cathode of the valve 1 and whose grid is connected to the earthed negative terminal of the H.T. supply. The anode of valve 7 is connected to the positive of the H.T. supply through a resistance S; the output terminal 5 is connected to this anode. Resistor 8 represents the resistance of the input circuit.

The operation of the arrangement is as follows:—

Let E be the input voltage, i.e. the voltage of 2 positive to 3 and to the cathode of 1. Let E_1, E_2, be the voltages positive to 6 of 4, 5 respectively. Let I_1 be the anode current of valve 1 flowing through R and R^1, I_2 the anode current of 7 flowing through S, g_1, g_2 the mutual conductances of valves 1 and 7 respectively. Then

$$\delta I_1 = g_1 \delta E \quad - \quad - \quad - \quad - \quad - \quad (1)$$

$$\delta I_2 = -g_2 R^1(\delta I_1 + \delta I_2) \quad - \quad - \quad (2)$$

$$\delta E_1 = -R \delta I_1 \quad - \quad - \quad - \quad - \quad (3)$$

$$\delta E_2 = -S \delta I_2 \quad - \quad - \quad - \quad - \quad (4)$$

so that,

$$\frac{\delta E_1}{\delta E_2} = -\frac{R(1+g_2 R^1)}{S g_2 R^1} \quad - \quad - \quad (5)$$

$$\frac{\delta E_1}{\delta E} = -R g_1 \quad - \quad - \quad - \quad - \quad (6)$$

Consequently the condition that the two output voltages are equal and opposite, so that the amplifier is balanced, is

$$S g_2 R^1 = R(1+g_2 R^1 \quad - \quad - \quad - \quad (7)$$

and the gain is $-R\,g_1$. (7) implies that S is greater than R.

It should be observed than g_1 and g_2 are not exactly the mutual conductances of the valves, since equations (1) and (2) are not subject to the condition that the anode voltage is constant. In terms of the valve constants m and Ra, where m is the amplification factor and Ra the anode impedance, and suffixes 1 and 2 refer to the valves 1 and 7,

$$g_2=(m_2+1)/(Ra_2+S).$$

g_1, which affects the gain, but not the condition of balance, varies somewhat with the ratio $\delta E_1/\delta E_2$. If this ratio is 1,

$$g_1=m_1/\left\{Ra_1+R+R^1(1-R/S)\right\};$$

g_1 will never in practice depart far from this value.

In Figure 3 a stage of push-pull audio-frequency amplification, in accordance with the invention follows a detector stage in a wireless receiver. In this arrangement the cathodes of the valves 1, 7 are connected to each other through a blocking condenser 9 of low impedance to audio-frequency variations, and the cathode of 7 is connected to earth through a resistance 10 (large compared with R^1) in order that the valves 1, 7 may be differently biassed; the grid of 7 is connected to earth through a source of grid bias between the points A B shunted by the blocking condenser 11. The valve 1 is a diode-triode, the diode part of which forms part of the usual detector circuit comprising the transformer 12, resistor 13 shunted by the condenser 14, and the condenser 15 communicating the audio potentials developed across 14 to the control grid. This control grid is connected to a source of grid bias through the resistor 16. The output terminals 4, 5 are connected to further stages in the receiver. The mode of operation of the arrangement will be obvious from the foregoing description to those skilled in the art. So long as the resistance of 10 is large compared with R^1 and the condenser 9 is of substantially zero impedance at the frequencies concerned, the foregoing equations are all still applicable to the push-pull amplifier.

The condition for balance, i.e. $\delta E_1=-\delta E_2$, represented by equation (7), depends upon g_2. If therefore the amplifier is balanced, and subsequently the valve 7 has to be replaced by another having a slightly different m or Ra, the amplifier will need readjustment by variation of one or more of R, R^1, and S. Of course a change in one of these resistances would equally require readjustment of the others or of g_2; but the resistances are less likely to change unintentionally. A further object of the invention is to reduce the departure from balance resulting from a change in one of the components of the amplifier and especially in the valve 7.

According to a subsidiary feature of the invention, this object is attained by connecting between each pair of output terminals a resistor, the two resistors having a common part, and connecting this common part in the grid circuit of the second valve.

The drawing accompanying provisional specification No. 16897/37 shows, by way of example, a push-pull amplifier according to the main feature of the invention, which is also according to this subsidiary feature. The figure differs from Figure 1 aforesaid of provisional specification No. 16168/37 mainly in the presence of the aforesaid resistors. 4 and 5 are each connected to 6 by a resistor made up of the parts r_1 and r_2; the part r_2 is common to both resistors and connects the grid of valve 7 to H.T.−. minor differences are that 3 is connected to the cathode of valve 1 (this matter has already been mentioned) and that blocking condensers 9 (and 10) are inserted in the leads between 5 (and 4) and the anode of valve 7 (and 1); these condensers can be ignored so long as their impedance is substantially zero at all operating frequencies. However, it is to be observed that there is no interruption of the conductive path other than at these condensers. Accordingly, if they were replaced by conductive connections, the amplifier would operate at any frequency, however low.

In virtue of the presence of the resistors r_1 and r_2, the foregoing equation (2) must be replaced by

$$\delta I_2=g_2\left[\frac{m}{m+1}\,.\,\delta V-R^1(\delta I_1+\delta I_2)\right] \quad (8)$$

$$\delta V=r_2/(r_1+2r_2)\,.\,(\delta E_1+\delta E_2) \quad - \quad - \quad (9),$$

where V is the potential of the grid of 7 positive to 6 and m is the amplification factor of the valve 7. (It is to be observed that, according to the convention adopted in these equations, the positive direction of I_1 and I_2 is the opposite of that indicated by the arrows in the figure).

Consequently

$$\frac{\delta E_1}{\delta E_2} = -\frac{\frac{1}{S g_2} + \frac{R^1}{S} + \frac{m}{m+1} \cdot \frac{r_2}{r_1+2r_2}}{\frac{R^1}{R} + \frac{m}{m+1} \cdot \frac{r_2}{r_1+2r_2}} \quad \text{- (10)}$$

The condition for balance is again (7). But so long as $r_2/(r_1+2r_2)$ is large compared with the other terms on the right of (10), balance will be attained very nearly even if (7) is not fulfilled. The balance will be insensitive to variations in g_2, which involves the valve characteristics, and therefore to a change in valve; it will also be insensitive to changes in R, R^1 and S, so that accurate balancing in the first instance will not be so important.

The following example will show that this state of affairs can be attained conveniently.

Suppose that

R = 100,000 ohms.
R^1 = 2,000 ,,
S = 200,000 ,,
Ra = 60,000 ,,
m = 25

Then $g_2 = 26/(200{,}000 + 60{,}000) = 10^{-4}$ mho

If r_1 and r_2 were absent, we should have from (5)

$$-\frac{\delta E_1}{\delta E_2} = \frac{10^5 + 10^5 \times 10^{-4} \times 2 \times 10^3}{2 \times 10^5 \times 10^{-4} \times 2 \times 10^3} = \frac{0.05 + 0.01}{0.02} = 3$$

If now $r_1 = 0.5 \times 10^6$ ohms, $r_2 = 10^6$ ohms, so that $mr_2/(m+1)(r_1+2r_2) = 0.384$, we have from (10).

$$-\frac{\delta E_1}{\delta E_2} = \frac{0.05 + 0.01 + 0.384}{0.02 + 0.384} = 1.1$$

If, as is preferable, r_2 is less than r_1 and equal to 0.25×10^6 ohms, $mr_2/(m+1)(r_1+2r_2) = 0.24$ and

$$-\frac{\delta E_1}{\delta E_2} = \frac{0.05 + 0.01 + 0.24}{0.02 + 0.24} = 1.15$$

It will now be apparent that, if exact balance is not required, the two resistors described by r_1 in the aforesaid figure need not be exactly equal; but no advantage is known in making them unequal. If, as is usual, the output of an amplifier according to the invention is amplified by other valves, the resistors r_1, r_2 may act conveniently as the grid leaks of these valves.

Again it will be apparent that in any arrangement according to the invention nothing material would be changed, if only part of the voltage developed across R^1 were tapped off and applied to the second valve, the gain of that valve being correspondingly increased. But again no advantage is known in applying to the second valve less than the whole voltage across R^1.

Having now particularly described and ascertained the nature of our said invention and in what manner the same is to be performed, we declare that what we claim is:—

1. A push-pull amplifier comprising (1) a first grid-controlled valve to whose grid circuit the single input voltage is applied, whose anode is connected to the positive terminal of the high tension supply through a resistance R, and whose cathode is connected to the negative terminal of the said supply through a resistance R^1 much less than R, (2) a second grid controlled valve to whose input is applied the voltage developed across the said resistance R^1 (or some constant fraction of that voltage) and whose anode circuit contains the load resistance S greater than R, (3) output terminals, 4, 5, 6, the said elements (1), (2), (3) being so connected that if E_1 is the voltage between 4 and 6 and E_2 the voltage between 5 and 6, the variations of E_1 and E_2 are related to each other, to variations in the anode current in the valves (1) and (2), to R, R^1, and S, and to the characteristics of the valve (2), so that, over the operating range of frequencies, equations (1) to (5) aforesaid are satisfied.

2. A push-pull amplifier according to Claim 1 wherein the said R, R^1, S and the characteristic of valve (2) are related so that equation (7) aforesaid is substantially satisfied, whereby the amplifier is balanced.

3. A push-pull amplifier comprising (1) a first grid-controlled valve to whose grid circuit the single input voltage is applied, whose anode is connected to the positive terminal of the high tension supply through a resistance R, and whose cathode is connected to the negative terminal of the said supply through a resistance R^1 much less than R, (2) a second grid-

controlled valve to whose input is applied the voltage developed across the said resistance R^1 (or some constant fraction of that voltage) and whose anode circuit contains the load resistance S greater than R, (3) output terminals 4, 5, 6, (4) resistors connecting respectively terminals (4, 6), and (5, 6), having a common part of resistance r_2 and separate parts each approximately of resistance r_1, the elements (1), (2), (3), (4) being so connected that, if E_1 is the voltage between 4 and 6 and E_2 the voltage between 5 and 6, the variations of E_1 and E_2 are related to each other, to variations in the anode currents in the valves (1) and (2), to R, R^1 and S, and to the characteristics of the valve (2), so that, over the operating range of frequencies, equations (8), (9), (10) aforesaid are fulfilled.

4. A push-pull amplifier according to Claim 3 wherein $r_2/(r_1+2r_2)$ is so much greater than the other terms on the right-hand side of the said equation (10) that $\delta E_1/\delta E_2$ is substantially unchanged by the substitution for the valve (2) of another valve of the same commercial type.

5. A push-pull amplifier substantially as hereinbefore described with reference to Figure 2 or 3 of the drawing accompanying provisional specification No. 16168/37 or to the drawing accompanying provisional specification No. 16897/37.

Dated the 23rd day of March, 1938.

NORMAN R. CAMPBELL,
For the Applicants.

Leamington Spa: Printed for His Majesty's Stationery Office, by the Courier Press.—1938.

Fig. 1.

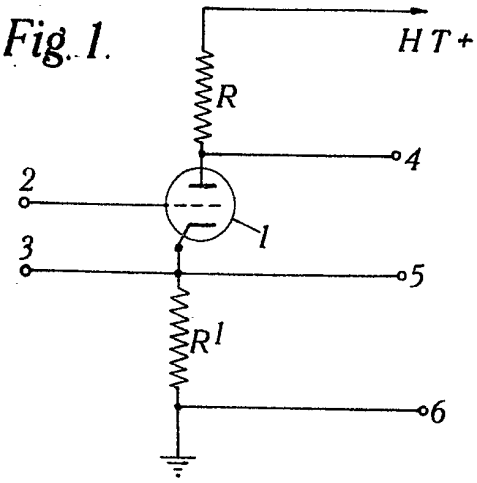


Fig. 2.

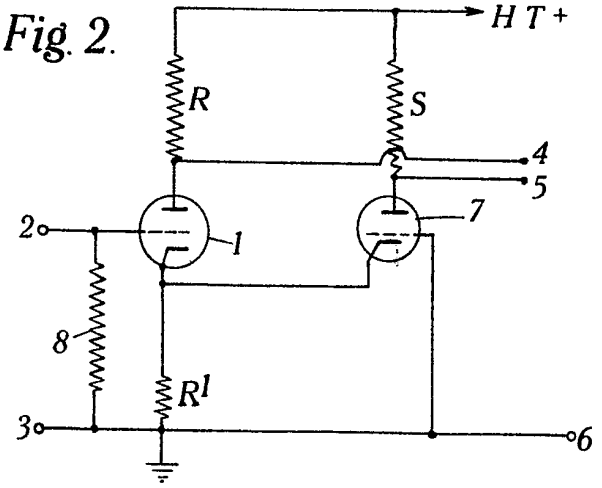
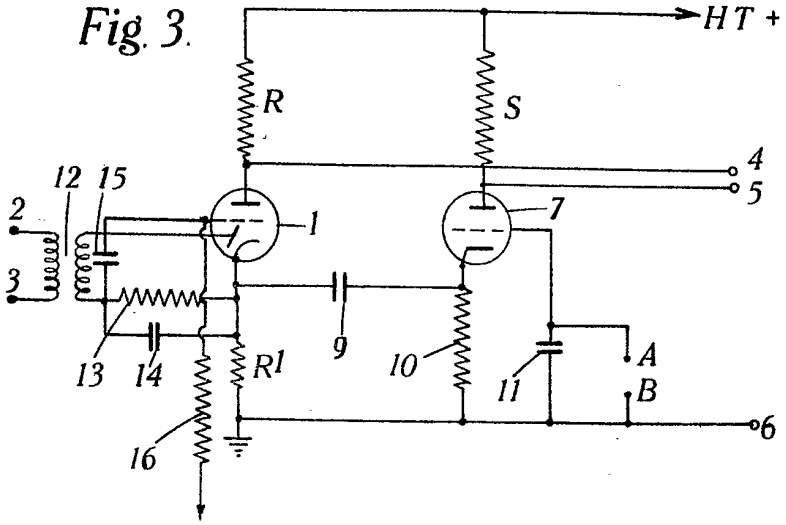


Fig. 3.



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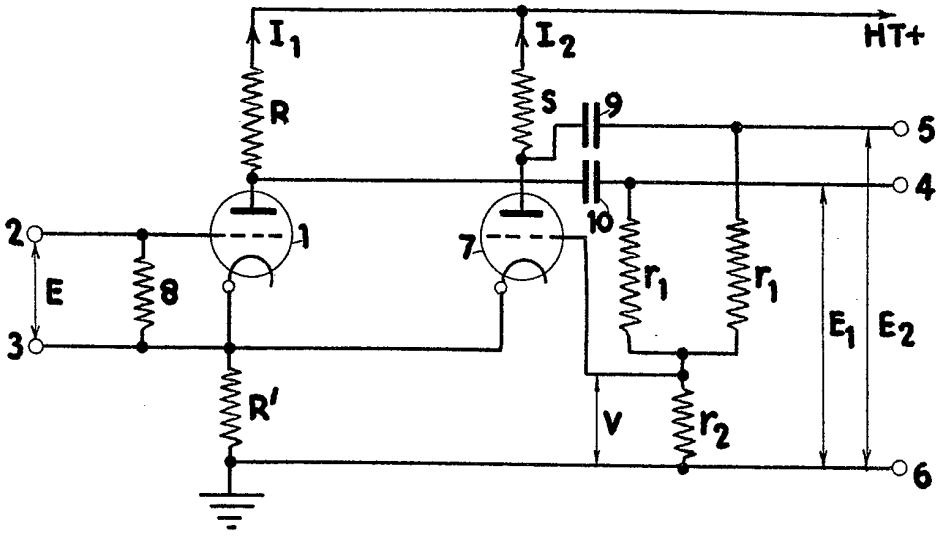

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