

March 3, 1942.

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2,275,023

THERMIONIC VALVE CIRCUIT ARRANGEMENT

Filed May 9, 1940

5 Sheets-Sheet 1

Fig. 1

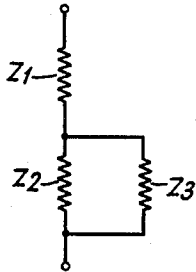


Fig. 2

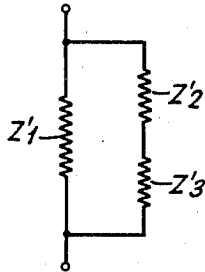


Fig. 3

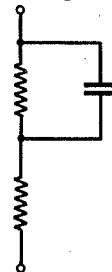


Fig. 4

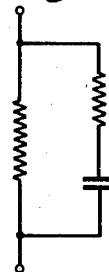


Fig. 5

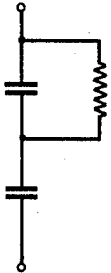


Fig. 6

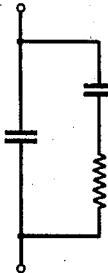


Fig. 7

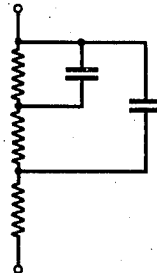


Fig. 8

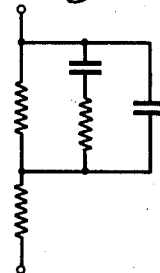


Fig. 9

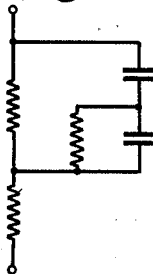


Fig. 10

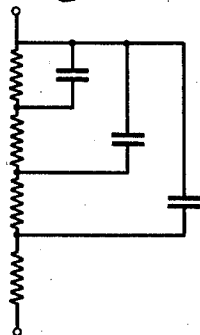


Fig. 11

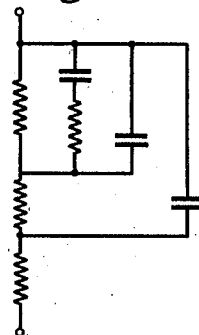


Fig. 12

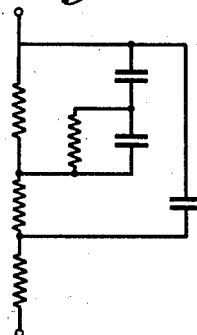


Fig. 13

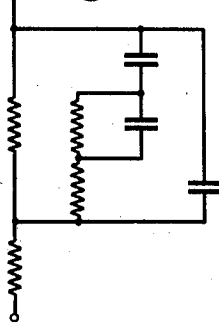
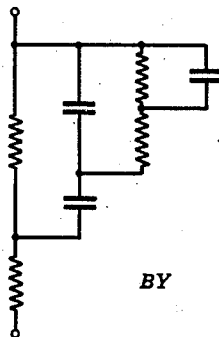


Fig. 14



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2,275,023

THERMIONIC VALVE CIRCUIT ARRANGEMENT

Filed May 9, 1940

5 Sheets-Sheet 2

Fig. 15

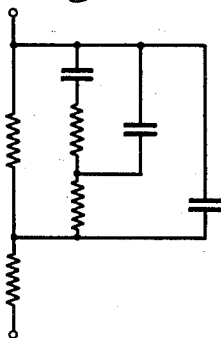


Fig. 16

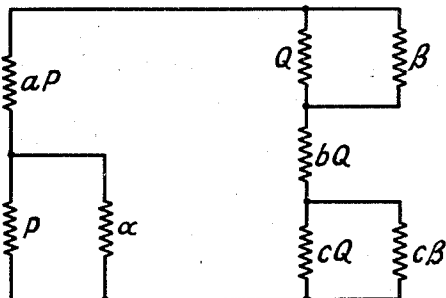


Fig. 17

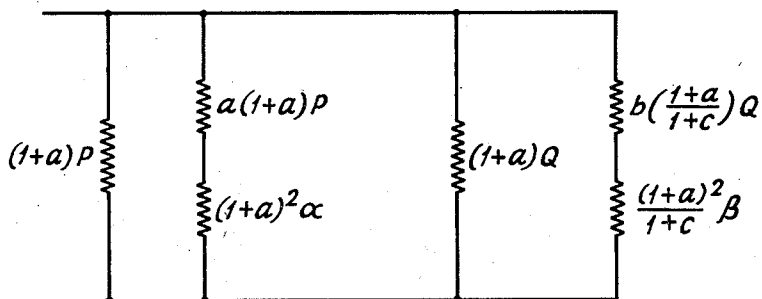
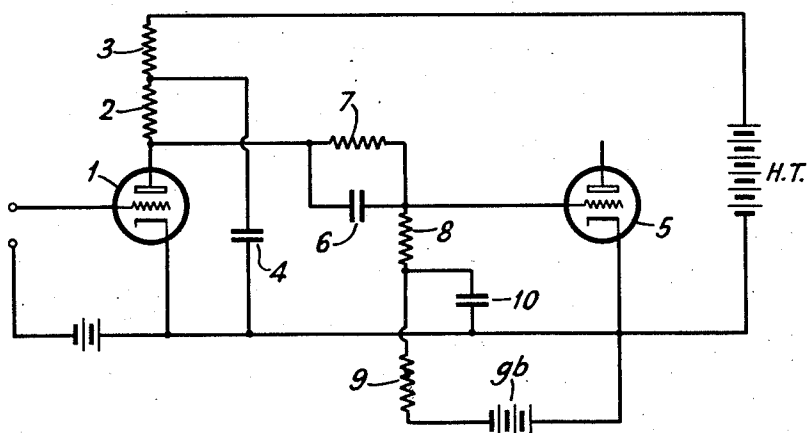


Fig. 18



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2,275,023

THERMIONIC VALVE CIRCUIT ARRANGEMENT

Filed May 9, 1940

5 Sheets-Sheet 3

Fig. 19

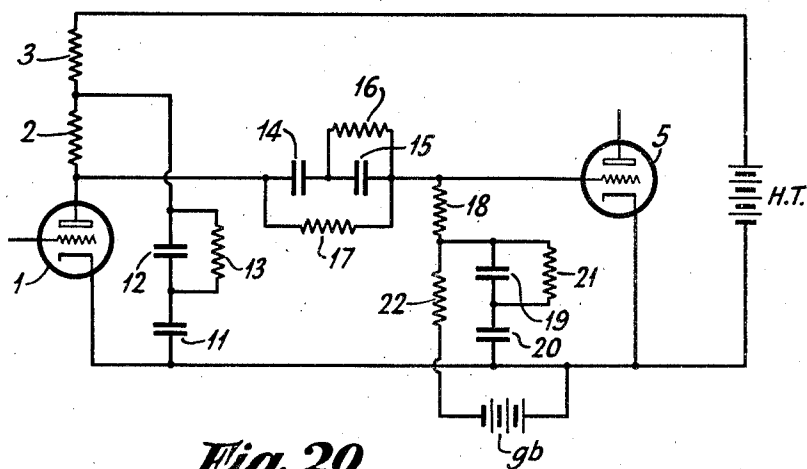


Fig. 20

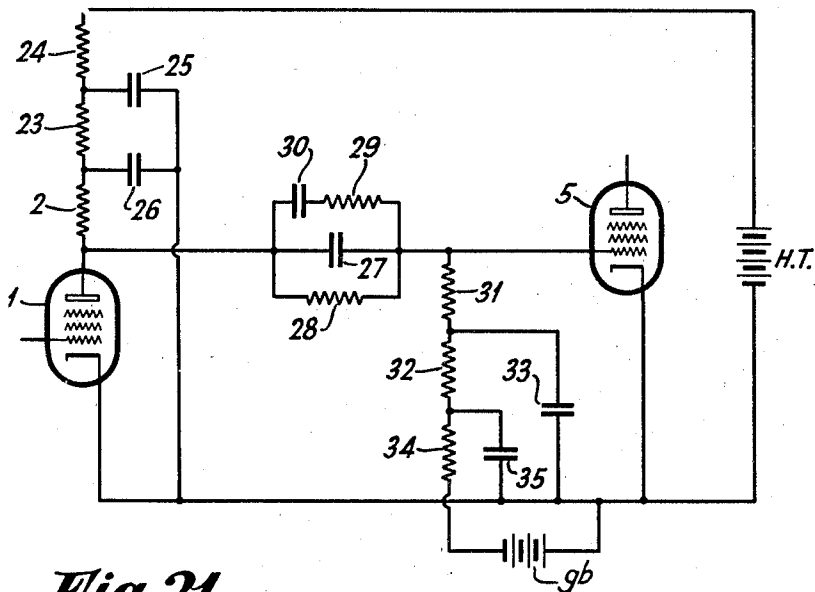


Fig. 21

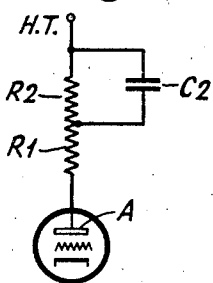
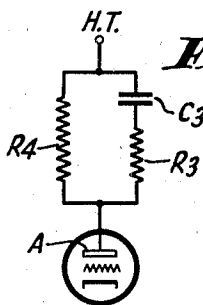


Fig. 22



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2,275,023

THERMIONIC VALVE CIRCUIT ARRANGEMENT

Filed May 9, 1940

5 Sheets-Sheet 4

Fig. 23

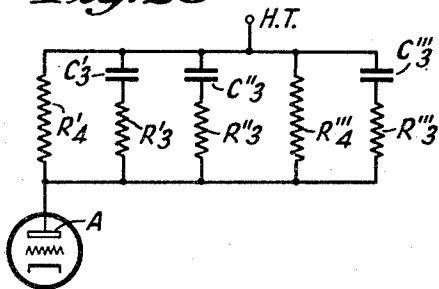


Fig. 24

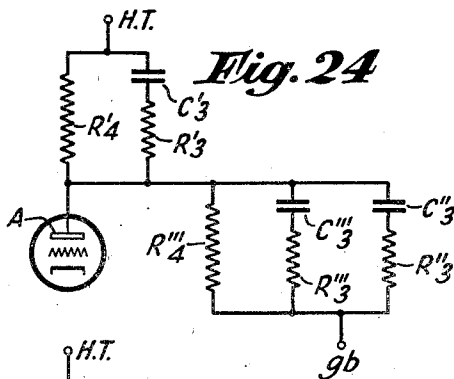


Fig. 25

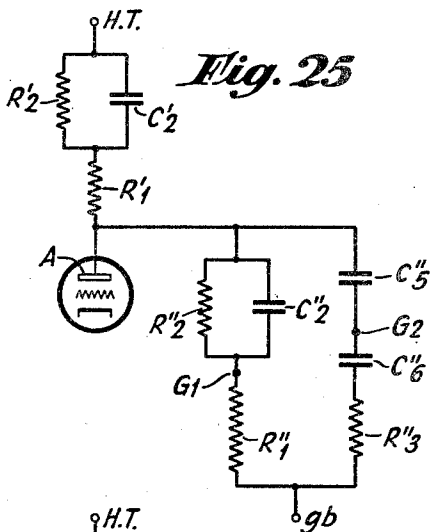


Fig. 26

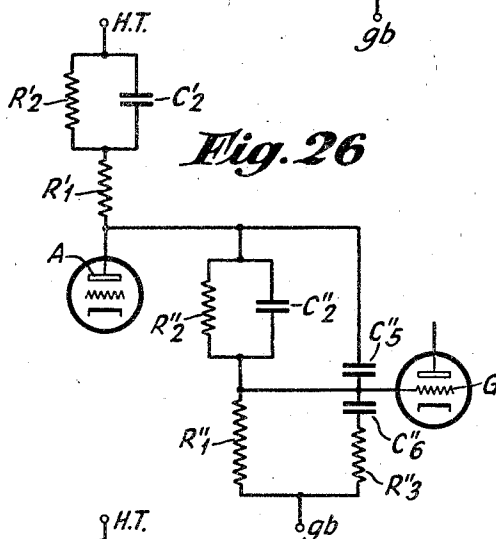


Fig. 27

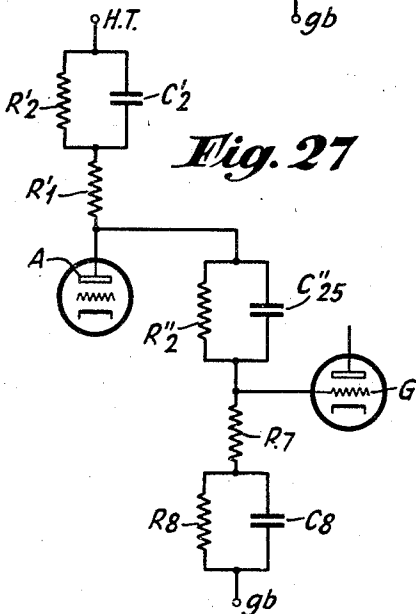
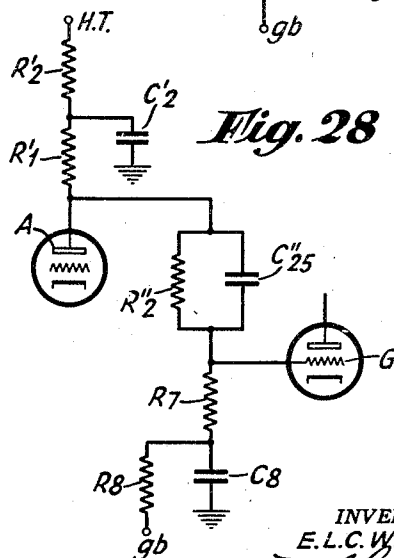


Fig. 28



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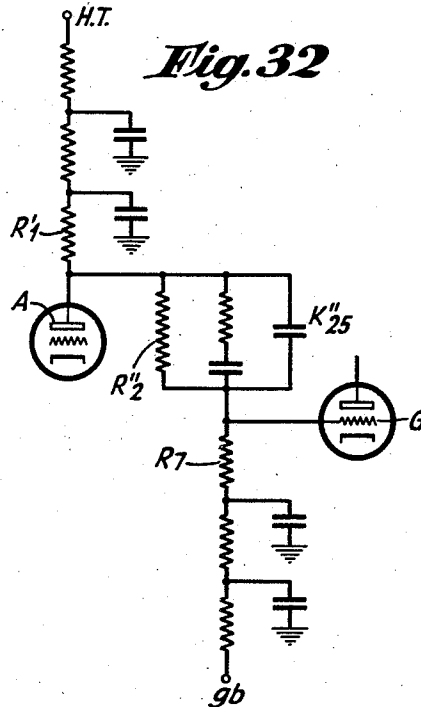
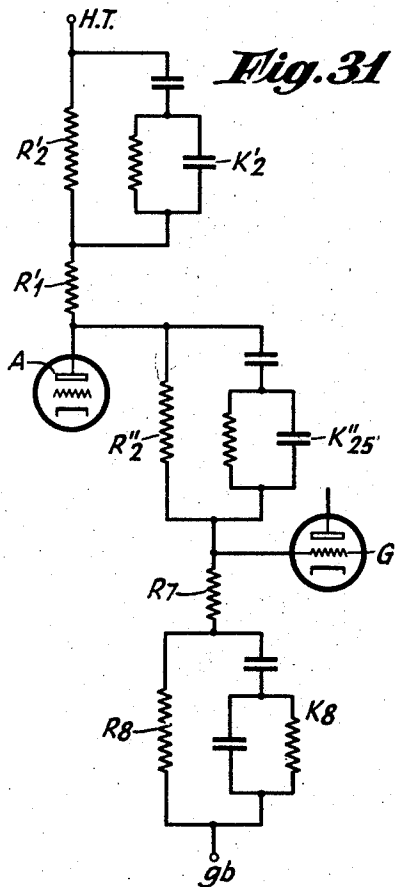
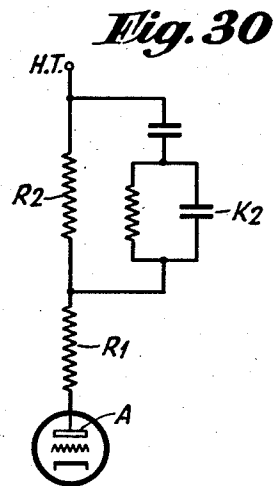
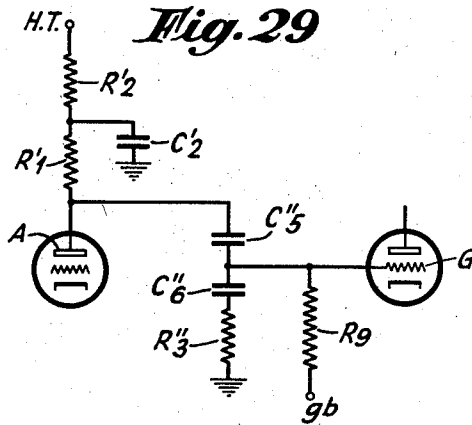
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THERMIONIC VALVE CIRCUIT ARRANGEMENT

Filed May 9, 1940

5 Sheets-Sheet 5



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Patented Mar. 3, 1942

2,275,023

UNITED STATES PATENT OFFICE

2,275,023

THERMIONIC VALVE CIRCUIT ARRANGEMENT

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Application May 9, 1940, Serial No. 334,157
In Great Britain May 10, 1939

13 Claims. (Cl. 179-171)

This invention relates to thermionic valve circuit arrangements and has particular reference to coupling networks between valves intended to pass with substantially equal attenuation all frequencies extending over a wide range from zero or direct current.

Coupling networks between valves designed to transmit direct current include a direct current path between the anode of one valve and the control grid of the next, and the problem presented by such networks is to design them so as not to discriminate between different frequencies, to provide for decoupling of the anode circuit of the first valve, and also to allow for a difference in potential between that anode and the following control grid suitable for their respective working ranges. Further, the direct current path usually includes a resistance shunted by a condenser which should be of large value compared with the stray capacities represented by the grid of the second valve so that a resistance connected in the anode lead of the first valve, the value of which is determined by these stray capacities shall be effective on the grid of the second valve, apart from the effect of any circuit elements such as coils, introduced between the anode and grid for the purpose of boosting high frequencies.

The specification of U. S. Patent No. 2,120,823 describes a direct coupled cascade amplifier for a wide range of frequencies in which the anode load impedance and anode impedance of a first valve can together be represented by a pure resistance R in series with an impedance Z and in which the first valve is coupled to a second valve through an impedance Z^1 and a leak resistance R^1 is provided between the grid and the cathode of the second valve, the relationship between these elements being such that the condition

$$\frac{Z^1}{Z} = \frac{R^1}{R}$$

is fulfilled.

The arrangement described in the patent above referred to provides a solution which is applicable to triode valves which have finite anode slope resistance and also to pentodes which have practically infinite slope resistance, but the patent does not describe arrangements for meeting the condition which arises when grid bias decoupling arrangements are employed.

The U. S. Patent 2,243,121 also describes a coupling arrangement for amplifiers operating over wide frequency bands with particular reference to and emphasis upon the problem of avoiding phase distortion particularly at low frequencies. In the arrangement described, the grid circuit of a valve coupled to a preceding valve has its constants for coupling capacity resistance and grid circuit resistance, as well as a grid bias filter, made to have a similar characteristic to

the anode circuit including the anode decoupling resistance and condenser of the preceding tube. By making the anode and grid circuit similar, phase distortion is substantially eliminated. Thus, while in the arrangement described in above Patent No. 2,243,121 account is taken of the grid bias decoupling arrangements, the solution applies only to triode valves.

The object of the present invention is to provide a coupling circuit from the anode of one valve to the grid of the next valve which will pass all frequencies down to zero with equal amplitude and substantially no phase shift, and which takes account of the decoupling arrangements for the anode supply and for the grid bias, the coupling circuit being applicable to valves of the triode or pentode type.

According to the present invention an electrical network for coupling a constant-current source of signals to a high impedance device comprises a pair of branches in parallel and fed with current from said source, the first of said branches comprising two parts connected in series, one part being formed by a resistance of magnitude P shunted by an impedance of value α , the other part being formed by a resistance of magnitude aP , the second of said branches comprising three parts connected in series, a first part formed by a resistance of magnitude Q shunted by an impedance of value β , a second part formed by a resistance of magnitude bQ , and a third part formed by a resistance of magnitude cQ shunted by an impedance of value $c\beta$, the quantities α , b , c being real numbers and satisfying the relation: $a=b+c$ and the quantities α , β being complex or purely imaginary and satisfying the relation:

$$\frac{aP}{\alpha} = \frac{bQ}{\beta}$$

and it is arranged that the sum of the potential differences developed across the second and third parts of said second branch are fed to said device and the network is so constructed that it transmits said signals over a wide range of frequencies substantially independently of the frequency. The magnitude Q may be large compared with the magnitude P but in a network in which the magnitude Q is not large compared with the magnitude P a resistance of magnitude

$$\frac{bQ}{c}$$

is connected so as to form a third branch in parallel with said pair of branches.

In a modification of a network embodying the last mentioned feature, the resistance of magnitude

$$\frac{bQ}{c}$$

is arranged to be present effectively by modifying the magnitudes of the elements of the second branch of the network.

In a further modification the resistance of magnitude

$$\frac{bQ}{c}$$

is arranged to be present effectively by modifying the magnitudes of the elements of the first branch of the network.

The source of signals may be constituted by a thermionic valve of high impedance such as a valve of the screen grid or pentode type, but in a modification the source of signals is constituted by a thermionic valve of low impedance such as a valve of the triode type and the magnitudes of the elements of either or both of the first and second branches are modified to allow for the finite impedance of said valve.

In particular forms of network embodying the invention the impedances of values α , β and $c\beta$ or of values modified therefrom are capacitative reactances, and those having the values α and $c\beta$, or values modified therefrom serve the purpose of decoupling.

In a modified electrical network embodying the invention, the impedance of value α or of value modified therefrom, is in conjunction with the resistance of magnitude P , or magnitude modified therefrom, the electrically equivalent circuit to a network comprising series resistances and shunt condensers serving for the purpose of decoupling.

In a further modification the impedance of value $c\beta$ or of value modified therefrom is in conjunction with the resistance of magnitude cQ or magnitude modified therefrom the electrically equivalent circuit to a network comprising series resistances and shunt condensers serving for the purpose of decoupling.

Any of the parts of the first and second branches formed by shunt combinations of impedance and resistance may be the electrically equivalent circuit to a network transformable to said equivalent circuit in accordance with the transformation equations to be referred to. Further modifications of networks embodying the invention and circuit arrangements including valves coupled by such networks and intended for operation over wide ranges of frequency including zero frequency or direct current and one arrangement for alternating current operation will be described in detail.

In order that the invention may be more clearly understood and readily carried into effect, the general theory underlying the alternative methods of designing networks in accordance with the invention will first be described and will be followed by particular examples of circuit arrangements including such networks.

Reference will be made to the accompanying drawings in which:

Figures 1 and 2 are explanatory diagrams,

Figures 3 to 15 are examples of network equivalents,

Figures 16 and 17 are further explanatory diagrams,

Figures 18, 19 and 20 are examples of circuit arrangements including particular forms of network,

Figures 21, 22 and 23 are further explanatory diagrams,

Figures 24 to 29 are further examples of arrangements including forms of network derived in accordance with an alternative method, and

Figures 30, 31 and 32 are examples of circuit arrangements including more complex elements.

Referring to Figures 1 and 2 of the drawings these show networks which are entirely equivalent if the impedances Z_1 , Z_2 , Z_3 , Z'_1 , Z'_2 and Z'_3 transform the one to the other according to the transformations

$$\begin{aligned} Z'_1 &= Z_1 + Z_2 & Z_1 &= \frac{Z'_1 Z'_2}{Z'_1 + Z'_2} \\ Z'_2 &= \frac{Z_1(Z_1 + Z_2)}{Z_2} & Z_2 &= \frac{Z'_1 Z'_2}{Z'_1 + Z'_2} \\ Z'_3 &= \frac{(Z_1 + Z_2)^2}{Z_2} \cdot Z_3 & Z_3 &= \frac{Z'_1{}^2}{(Z'_1 + Z'_2)^2} Z'_3 \end{aligned}$$

In particular it is to be noted that if Z_1 and Z_2 are real (i. e. resistances) Z'_1 and Z'_2 are also real (i. e. also resistances), while Z'_3 is identical with Z_3 , except that it has been multiplied by a real number (i. e. it has identical structure and form, but individual elements may have different values). Again, if Z_1 and Z_2 are purely imaginary and of like nature (i. e. like reactances) Z'_1 and Z'_2 are also purely imaginary and of like nature (i. e. like reactances). Thus the networks shown in Figures 3 and 4 can be chosen to be entirely equivalent; likewise the networks shown in Figures 5 and 6 can be chosen to be entirely equivalent. In the same way, the networks shown in Figures 10, 11, 12, 13, 14 and 15 are all equivalent. Conversions of this nature are explained in detail in the book entitled "Transmission Circuits for Telephonic Communications" by K. S. Johnson, 1935 edition, pages 267 to 280.

In these equivalences it is important to observe that a decoupling network, such as that shown in Figures 3, 7 and 10, can always be put in the form of two resistances in series and one of them shunted by an impedance. Thus the network shown in Figure 7 can be put in the form of the network shown in Figure 8 or 9, that shown in Figure 10 can be put in the form shown in Figure 13, 14 or 15, to which equivalent networks, other networks may be made to correspond by changing the order of the elements in a given branch.

The general coupling network underlying the applications of the invention can thus be drawn as shown in Figure 16 in which P , Q are resistances, a , b , c are real numbers and α and β are impedances of identical analytical form, but related by a multiplying factor which is a real number. This network is supposed to be driven from a constant current source and if the source is only of finite impedance it is supposed to be replaced by an infinite impedance source and its impedance effectively shunted across the network input by absorption in the resistances aP , P . Moreover a , b , c satisfy $b+c=a$, and α and β are related according to

$$\frac{bQ}{\beta} = \frac{aP}{\alpha}$$

These relations form the basis underlying all applications of the invention to coupling networks.

It is assumed that the P -branch is the anode circuit of a driving valve, the bQ , cQ , $c\beta$ part of the Q -branch is the grid circuit of the driven valve and the Q , β part of the Q -branch is the series coupling element between these circuits, the P , a and cQ , $c\beta$ parts of which may be interpreted as decoupling networks according to any of the equivalences described above. The decoupling is not limited to first, second and third order as shown.

Separate conditions arise when Q is large compared with P and when Q is not large compared with P . When Q is large compared with P , it is easily shown that the potential fed to the grid of the second valve due to a current i flowing into the network from the first valve, namely the potential:

$$i \left(aP + \frac{\alpha P}{\alpha + P} \right) \cdot \frac{bQ + \frac{c\beta Q}{\beta + Q}}{bQ \frac{(1+c)\beta Q}{\beta + Q}}$$

reduces simply to $i\alpha P$, which is independent of frequency.

When Q is not large compared with P , the above calculation of grid potential is not valid unless it so happens that the presence of the Q branch only modifies the current in the P branch in a constant ratio. In the circuit of Figure 16 this does not happen.

As described, networks including combinations of resistive, capacitive or inductive elements may, subject to the satisfaction of certain conditions, be each transformed into electrically equivalent networks in which the values and/or disposition of the elements may be varied. Thus, the arrangement of Figure 16 may be transformed to that shown in Figure 17.

With reference to Figure 17, it is easily shown that the impedance of the last branch is:

$$\frac{b}{1+c} \cdot \frac{Q}{aP} (a \cdot 1 + a \cdot P + 1 + a^2 \cdot \alpha)$$

so that the ratio of the fourth branch to the second branch is

$$\frac{b}{1+c} \cdot \frac{Q}{aP}$$

this is not the ratio of the third to the first—namely

$$\frac{Q}{P}$$

The last mentioned ratio can be transformed to:

$$\frac{b}{1+c} \cdot \frac{Q}{aP}$$

however, by shunting across the third branch a resistance of magnitude

$$\frac{bQ}{c}$$

If this is done the potential transferred to the grid of the second valve is proportional to $i\alpha P$, the value calculated in the first case, i. e. when Q is large compared with P .

Three possibilities arise in the second case, i. e. when Q is not large compared with P . The shunting resistance

$$\frac{bQ}{c}$$

may be left across the network; it may be absorbed into the first branch so modifying all the elements in the P -branch or it may be absorbed into the third branch. Any combination of these possibilities is allowable, of course.

Referring now to Figure 18 of the drawings, this shows an example of a coupling arrangement between two valves in which anode and grid bias decoupling networks of the first order are employed corresponding with Figure 3. The valve 1 is provided with an anode resistance 2, the P element, decoupling resistance 3 and decoupling condenser 4, the αP elements, and is coupled to the grid of valve 5 or other high impedance point, such as a modulating or deflect-

ing electrode of a cathode ray tube, through the βQ elements constituted by condenser 6 and resistance 7 in parallel. A bias potential from a battery gb is applied to the grid of the valve 5 through a leak resistance 8, the bQ element, a decoupling resistance 9 and decoupling condenser 10 the $c\beta$ elements, being provided.

Figure 19 shows two valves coupled by an arrangement including decoupling networks of the second order corresponding with Figures 7, 8 or 9. It will be seen that the impedance α of Figure 16 assumed to be a condenser, has in Figure 19 been replaced by a condenser 11 in series with a further condenser 12 shunted by a resistance 13. The βQ elements in Figure 19 are constituted by two condensers 14 and 15 in series, a resistance 16 being shunted across the condenser 15, and a further resistance 17 shunted across the combination. The bQ element is constituted by a resistance 18 and the $c\beta$ elements by two condensers 19 and 20 in series, the condenser 19 being shunted by a resistance 21. The cQ element is constituted by a resistance 22.

Figure 20 is a further example of a coupling arrangement between two valves employing anode and grid bias decoupling networks. The anode decoupling network αP , in Figure 20 includes resistances 23 and 24, and condensers 25 and 26. The βQ elements are constituted by the condenser 27 and shunting resistance 28, together with the additional series connected resistance 29 and condenser 30, also shunted across the condenser 27. The bQ element is constituted by resistance 31 and the $c\beta$ elements by resistance 32 and condenser 33. The cQ element is constituted by resistance 34 shunted by condenser 35.

An understanding of the application of the invention to circuit design will be further assisted by the following explanation of the derivation of D. C. coupling circuits including decoupling for the grid bias and also a derivation of an A. C. coupling which allows a low frequency time constant to be used very much longer than the normal limit set by the anode decoupling condenser and the anode decoupling resistance.

Figure 21 shows a typical anode circuit comprising an anode resistance R_1 , anode decoupling resistance R_2 , and decoupling condenser C_2 , which is shown as going to the H. T. but which can equally well go to earth. This circuit has an impedance

$$Z = R_1 + \frac{R_2}{1 + j\omega C_2 R_2}$$

and it is the object of the following derivation to provide circuits such as to give signal anode voltage equal to $Z I_{asc}$ where I_{asc} is the signal anode current which would be obtained for zero load in the anode and to provide a grid voltage to the following valve given by $R_1 I_{asc}$. The circuit shown in Figure 21 will only give the correct anode voltage if the anode impedance of the valve is infinite, but an allowance will later be made for a finite anode impedance. The circuit of Figure 21 can be converted to the circuit of Figure 22, following the conversions given in the previously mentioned book "Transmission Circuits for Telephonic Communications" by K. S. Johnson at pages 277 and 278.

Figure 23 shows the circuit of Figure 22 split up. The elements R_4''' , R_3''' and C_3''' are three elements identical in form but many times the impedance of R_4 , R_3 , and C_3 . The magnitudes of these elements are based on the drain of H. T. current which will ultimately be passed to the

grid bias source. For example, R_4''' and R_3''' may each be 100 times R_4 and R_3 , and C_3''' may be 100th the capacity of C_3 . The remnant elements are of such a size that combined with R_4''' , R_3''' and C_3''' , in parallel, they exactly make up the original impedance shown in Figure 22. The remnant portion of R_3 , C_3 is further broken up into two portions R_3' , C_3' and R_3'' and C_3'' . In general the portions R_3' , C_3' , will be very much higher in impedance than the remnant portion R_3' , C_3' and may as before be uniformly 100 times the impedance, as an example, though the whole order of this factor may be altered at will to give the desired final values of the circuit.

If now the anode impedance of the valve is not infinite, this may be allowed for by replacing R_4' by another resistance $\bar{R}_4'$ such that this new resistance in parallel with the anode resistance of the valve equals the previous R_4' . In Figure 24 such a replacement has been made so that allowance hereafter has been made for the finite anode resistance of the valve.

In Figure 24 only the circuit elements comprising R_4' and R_3' have been left connected to the high tension source. The remaining elements have been connected between anode and grid bias. Since the grid bias source, like the H. T. source, is ideally unaffected by signal potentials, this will not affect the signal potential on the anode.

In Figure 25 the elements R_4''' , R_3''' and C_3''' have been reconverted (as by the conversion methods referred to above) to elements R_1'' , R_2'' and C_2'' . Similarly elements $\bar{R}_4'$, R_3' and C_3' have been converted to elements R_1' , R_2' and C_2' . Element C_3'' has been converted to two condensers C_5'' and C_6'' whose values are such that, connected in series they give a resultant capacity equal to C_3'' and the ratios of capacity are such that the impedance of C_6'' compared with that of C_5'' is equal to the impedance of R_1 compared with R_2 . This gives

$$C_5'' = \left(1 + \frac{R_1}{R_2}\right) C_3''$$

and

$$C_6'' = \left(1 + \frac{R_2}{R_1}\right) C_3''$$

The potential of the anode A has been unchanged by all these modifications since the impedances are still the same as in Figure 24. Now the elements R_1'' , R_2'' and C_2'' are identical in form to, but uniformly a multiple of the impedance of the original R_1 , R_2 and C_2 . Hence the potential across R_1'' i. e., at the junction point G, is the potential that would have been obtained across R_1 in Figure 1, that is $R_1 I_{asc}$. Now the potential across the elements C_5'' , C_6'' and R_3'' is again $Z I_{asc}$ and a calculation based on the derivation of $R_3 C_3$ will show that the potential of the junction C_2 of C_6'' and C_5'' is again equal to $R_1 I_{asc}$. We now have two points G_1 and G_2 which both have the correct wanted signal voltage. Both of these points may therefore be connected to the grid of the following valve and such an arrangement is shown in Figure 26. The volts on the grid will now be exactly those required.

Figure 27 shows the capacities C_2'' and C_5'' combined in a single capacity C_{25}'' . Also the elements R_1'' , R_3'' , C_6'' have been converted (as by the conversion referred to in the reference above) to elements R_7 , R_8 and C_8 . These conversions will not alter the signal potential on the grid.

Figure 28 shows the elements C_2' and C_8 connected to earth instead of to the high tension and grid bias. If, as was hypothetically assumed, these potential sources are fixed as regards signal voltages, this change of connection will not alter the anode signal potential nor the grid signal potential. The circuit of Figure 28 therefore provides the required coupling system.

A variant on the above system is shown in Figure 29 wherein the impedance values selected for R_4''' , R_3''' and C_3''' in Figure 23 are all infinite. The remnant grid coupling circuit therefore only comprises C_5'' , C_6'' and R_3'' , the other impedances in parallel with these being now infinite. This coupling provides true D. C. coupling to the grid of the type described above, but does not provide any D. C. connection to the grid. In Figure 29 a grid leak R_9 is shown connected to the grid which provides the necessary D. C. connection and therefore converts the coupling system into a purely A. C. coupling. However, the time constant of this coupling is in practical cases approximately given by

$$(C_5'' + C_6'')$$

R_9 which can be given a value independent of the time constant R_2 , C_2 . The more conventional coupling where there is only a condenser between anode and grid such as C_5'' , has the time constant controlled by R_2 , C_2 , if the coupling condenser and grid leak are so fixed as to neutralise the low frequency boost, that would otherwise be given by R_1' in parallel with R_2' and C_2' .

More complex decoupling than that shown in Figure 21 may be used in the anode circuit and Figures 30, 31 and 32 correspond to Figures 1, 7 and 8 except that a more complex circuit is used. The method of deriving such a circuit is to replace the condenser C_2 in Figure 21 by a complex net of condensers K_2 in Figure 30. The whole method proceeds similarly, K_2 (considered as an admittance so as to change one value numerically in the same manner as C_2) becoming K_2' , K_{25}'' and K_3 in Figure 31. However, in deriving the final circuit, the conversion of R_2' in parallel with K_2' proceeds to give two separate decoupling resistances with two decoupling condensers as described in the book referred to above on page 278, for the conversion of Figure 20C to Figure 20B. The two condensers thus obtained connected to H. T. become connected to earth as previously described. A similar conversion is effected for R_8 and K_8 providing the double grid bias decoupling shown in Figure 32. Also K_{25}'' has been converted to a form requiring smaller total capacity.

It will be appreciated from the foregoing explanation and description of particular forms of circuit that the invention may be applied to the derivation of other forms of coupling network than those specifically mentioned.

I claim:

1. An electrical network for coupling a constant current source of signals to a high impedance device comprising a pair of branches in parallel and fed with current from said source, the first of said branches comprising two parts connected in series, one part being formed by a resistance of magnitude P shunted by an impedance of value α , the other part being formed by a resistance of magnitude αP , the second of said branches comprising three parts connected in series, a first part formed by a resistance of magnitude Q shunted by an impedance of value β , a

second part formed by a resistance of magnitude bQ , and a third part formed by a resistance of magnitude cQ shunted by an impedance of value $c\beta$, the quantities a, b, c being real numbers and satisfying the relation: $a=b+c$ and the quantities a, β being complex or purely imaginary and satisfying the relation:

$$\frac{aP}{\alpha} = \frac{bQ}{\beta}$$

wherein it is arranged that the sum of the potential differences developed across the second and third parts of said second branch are fed to said device and the network is so constructed that it transmits said signals over a wide range of frequencies substantially independently of the frequency.

2. An electrical network according to claim 1, wherein the magnitude Q is large compared with the magnitude P .

3. An electrical network according to claim 1, wherein the magnitude Q is not very large compared with the magnitude P and a resistance

$$\frac{bQ}{c}$$

is connected so as to form a third branch in parallel with said pair of branches.

4. An electrical network according to claim 1, wherein the magnitude Q is not very large compared with the magnitude P , and a resistance

$$\frac{bQ}{c}$$

is connected so as to form a third branch in parallel with said pair of branches, the latter resistance arranged to be present effectively by modifying the magnitudes of the elements of the second branch of said network.

5. An electrical network according to claim 1, wherein the magnitude Q is not very large compared with the magnitude P , and a resistance

$$\frac{bQ}{c}$$

is connected so as to form a third branch in parallel with said pair of branches, the latter resistance arranged to be present effectively by modifying the magnitudes of the elements of the first branch of said network.

6. An electrical network according to claim 1, wherein the impedance of said source of signals is finite and the magnitudes of the elements of said first and second branches are modified to allow for the finite impedance of said source.

7. An electrical network according to claim 1, wherein the impedances of value α, β and $c\beta$ are capacitive reactances, and those having the values α and $c\beta$ serve for the purpose of decoupling.

8. An electrical network according to claim 1, wherein the impedance of value α is in conjunction with the resistance of magnitude P the electrically equivalent circuit to a network comprising series resistances and shunt condensers serving for the purpose of decoupling.

9. An electrical network according to claim 1, wherein the impedance of value $c\beta$ is in conjunction with the resistance of magnitude cQ the electrically equivalent circuit to a network comprising series resistances and shunt condensers serving for the purpose of decoupling.

10. An electrical network according to claim 1, wherein any of the parts of said first and second branches formed by shunt combinations of impedance and resistance is the electrically equivalent circuit to a network transformable to said equivalent circuit.

11. An electrical network according to claim 1, wherein the second of said branches is composed of a pair of parallel branches, one of which includes a resistance connected in parallel with a condenser and a second resistance in series with that parallel combination, and the second of said parallel branches includes two condensers and a resistance in series, the arrangement being such that the junction point between said parallel combination and said second resistance is at the same potential as the junction point between said two condensers, one or the other of said junction points being connected to said high impedance device.

12. An electrical network according to claim 1, wherein the second of said branches is composed of a pair of parallel branches, one of which includes a resistance connected in parallel with a condenser and a second resistance in series with that parallel combination, and the second of said parallel branches includes two condensers and a resistance in series, the arrangement being such that the junction point between said parallel combination and said second resistance is at the same potential as the junction point between said two condensers, one or the other of said junction points being connected to said high impedance device and wherein the first of said pair of parallel branches is effectively absorbed in the first of said branches and said high impedance device is connected to said junction point of the second of said pair of parallel branches.

13. A circuit arrangement for amplifying substantially uniformly all signal frequencies within a wide range down to and including zero frequency, comprising two thermionic valves and a network interconnecting the anode of one with the control grid of the other, said network comprising a pair of branches in parallel and fed with current from the anode of said one valve, the first of said branches comprising two parts connected in series, one part being formed by a resistance of magnitude P shunted by an impedance of value α , the other part being formed by a resistance of magnitude aP , the second of said branches comprising three parts connected in series, a first part formed by a resistance of magnitude Q shunted by an impedance of value β , a second part formed by a resistance of magnitude bQ , and a third part formed by a resistance of magnitude cQ shunted by an impedance of value $c\beta$, the quantities a, b, c being real numbers and satisfying the relation: $a=b+c$ and the quantities a, β being complex or purely imaginary and satisfying the relation:

$$\frac{aP}{\alpha} = \frac{bQ}{\beta}$$

wherein it is arranged that the sum of the potential differences developed across the second and third parts of said second branch are fed to the control grid of said other valve.

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