Oct. 21, 1941. H. C. CURL 2,260,170

TRANSMISSION SYSTEM EMBODYING LOUD-SPEAKERS

Filed July 18, 1939 3 Sheets-Sheet 1

FIG. 1

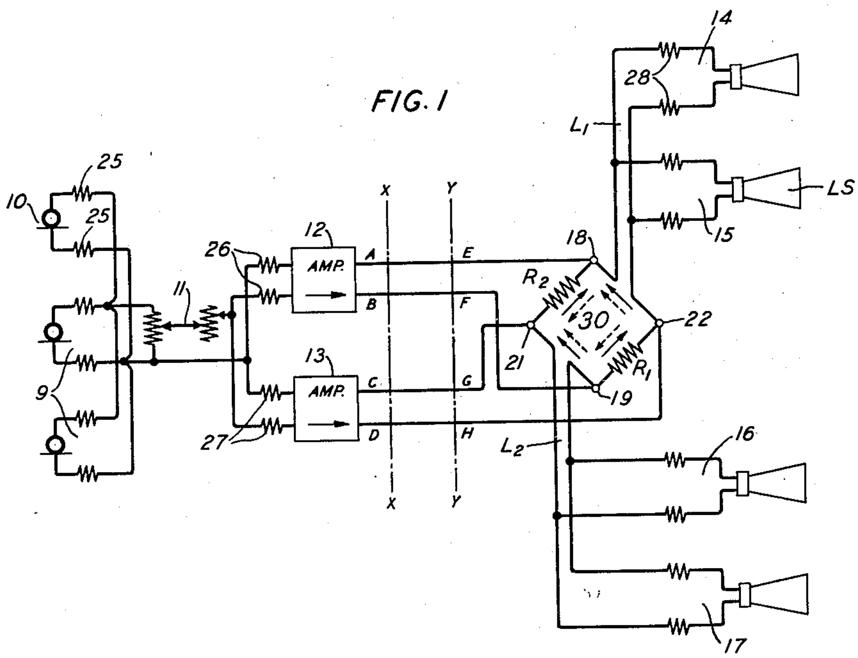

FIG. 1-A

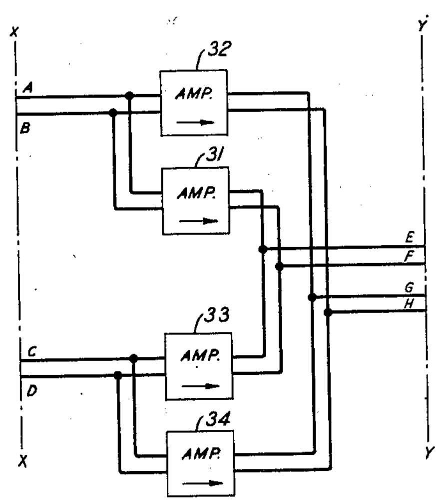

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FIG. 2

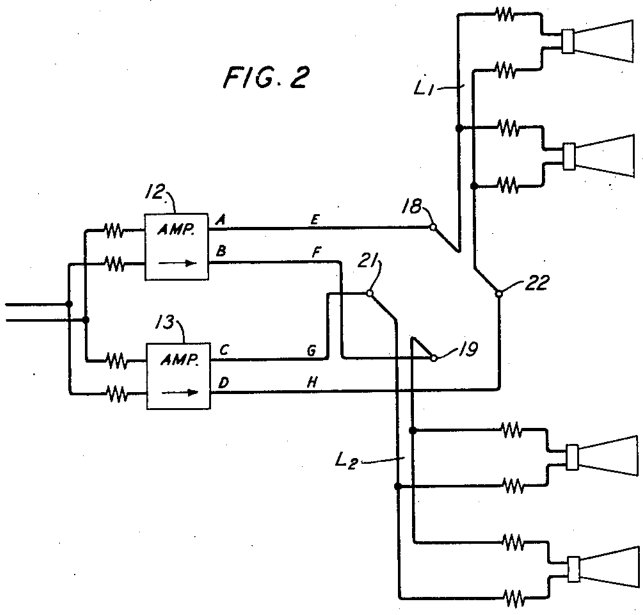


FIG. 3

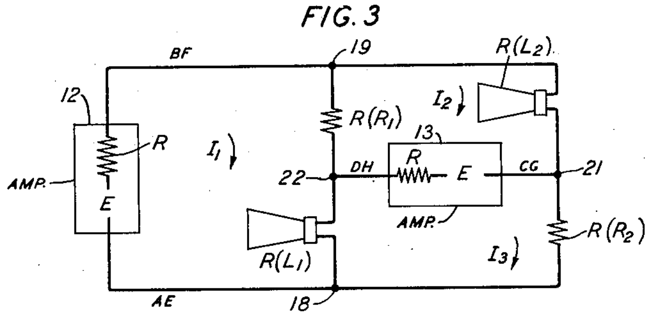
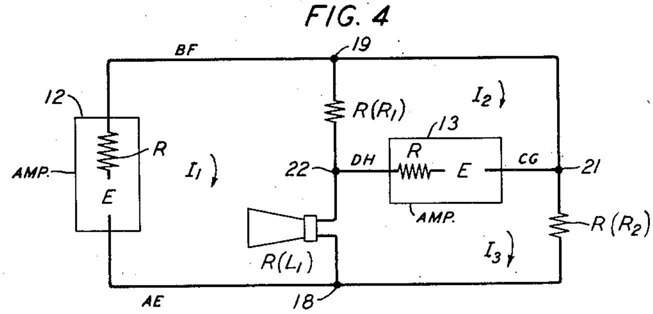


FIG. 4



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TRANSMISSION SYSTEM EMBODYING LOUD-SPEAKERS

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FIG. 5

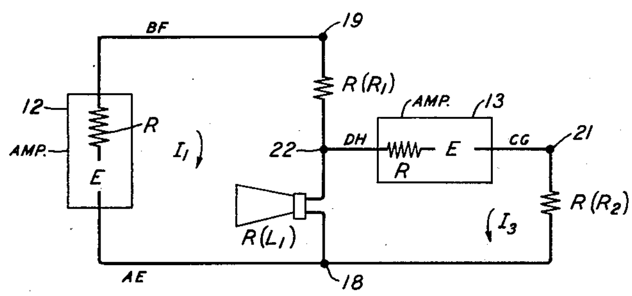


FIG. 6

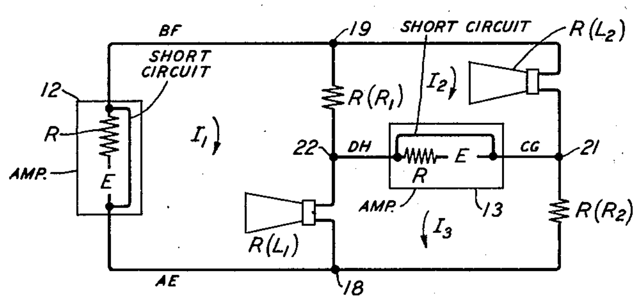
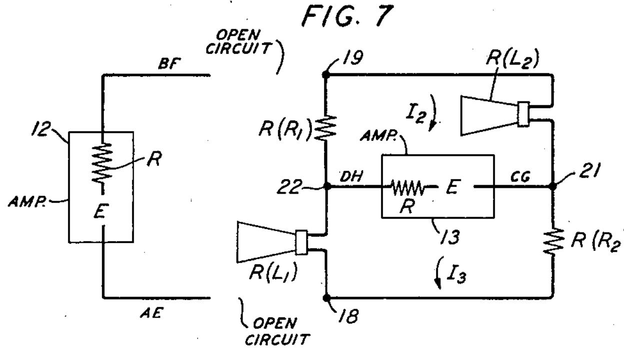


FIG. 7



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2,260,170

TRANSMISSION SYSTEM EMBODYING LOUD-SPEAKERS

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Application July 18, 1939, Serial No. 285,119

18 Claims. (Cl. 179—1)

This invention relates to transmission systems, and more particularly to such systems embodying a plurality of amplifiers supplying signaling energy to a plurality of remotely spaced loud-speakers.

In one type of transmission system used heretofore, it has been the practice to so utilize a pair of amplifiers that the outputs thereof are connected in parallel for supplying signaling energy to a plurality of remotely spaced loud-speakers. In such systems it has been found that a failure of one amplifier may occasion a failure of the entire system for the reason that a failure, say, for example, one involving a short circuit in the output of one amplifier, would divert the output of the operative amplifier therethrough so that substantially no signaling energy would be supplied to the loud-speakers. This invention contemplates in a transmission system a type of connection in which two amplifiers and a plurality of groups of loud-speakers are so effectively connected that the operation of the system is maintained substantially on a normal basis regardless of a disablement of one amplifier or one group of loud-speakers.

It is an object of the invention to obtain increased reliability in the operation of a plurality of amplifiers supplying signaling energy to different groups of loud-speakers in a transmission system.

It is another object of the invention to maintain in such system the normal operation of one group of loud-speakers when the other group of loud-speakers has been disabled.

It is a further object of the invention to provide in such system for the operation of all loud-speakers upon a failure of one of two input amplifiers.

It is a still further object of the invention to provide in such system an optimum impedance match between a signaling input and a plurality of loud-speakers and to maintain substantially such impedance match after one-half of the input has been disabled.

It is still another object of the invention to provide optimum impedance match between a signaling input and a load and to maintain such impedance match within a factor of 3 after one-half of the load has been disabled.

In a preferred embodiment of the invention, a network comprising a first pair of opposite arms each of which embodies a resistance, and a second pair of opposite arms each of which embodies a group of loud-speakers has applied to the terminals thereof the outputs of a pair of amplifiers so that normally the outputs are equalized between the arms embodying the loud-speakers, the network being preferably so arranged that optimum impedance match is established between each amplifier and each group of loud-speakers. The network provides that when one amplifier output has been disabled both groups of loud-speakers are supplied with signaling energy from the operative amplifier; and further that when one group of loud-speakers has been disabled, the operative group of loud-speakers is supplied with a normal amount of signaling energy from the outputs of both amplifiers.

A feature of the invention is that while the operation of a transmission system embodying it is maintained regardless of a disablement of one input amplifier or one group of loud-speakers in the manner aforementioned, such system operates in the normal condition without any loss of signaling power.

The invention will be more readily understood from the following description of a transmission system embodying it and by reference to the accompanying drawings in which:

Fig. 1 is a schematic circuit illustrating the invention;

Fig. 1A is a modification that may be incorporated in Fig. 1;

Fig. 2 is a schematic circuit illustrating the normal operation of Fig. 1; and

Figs. 3 through 7 are simplified schematic circuits delineating the operation of Fig. 1 under certain conditions.

Referring to Fig. 1, a plurality of parallel branches **9**, each of which embodies a suitable transmitter **10**, is applied through a volume control **11** to the bridged inputs of amplifiers **12** and **13**.

Load L_1 comprises branches **14** and **15** and load L_2 consists of branches **16** and **17**, each of which branches includes at least one loud-speaker LS. It is to be understood that each branch may comprise one or more subbranches of various series-parallel combinations in each of which may be connected one or more loud-speakers.

The two sides of each of the branches **9** embody series resistances **25, 25** which serve the purpose of preventing an accidental short circuit in any one of the transmitters **10** from materially affecting the transmission of the others, as any loss occasioned in these resistances is negligible. Similarly, the inputs of the amplifiers **12** and **13** embody the respective pairs of series resistances 26, 26 and 27, 27 which serve the purpose of preventing an accidental short circuit in the input of one amplifier from materially affecting transmission to the other, as any loss to these resistances is negligible.

Also, the branches 14 and 15, and 16 and 17 of the respective loads L_1 and L_2 embody similar pairs of series resistances 28, 28 which serve to prevent an accidental short circuit occuring in any one of the branches in either load L_1 or load L_2 from materially impairing the operativeness of the other loud-speakers in the load in which the fault occurs. In other words, a short circuit occurring in the loud-speakers in branch 14 would not affect the operation of the loud-speakers in branch 15 to any appreciable extent, depending on the value of the resistances 28, 28, and vice versa; and also a short circuit occurring in the loud-speakers in branch 16 would not affect the operation of the loud-speakers in branch 17 to any appreciable extent, depending on the value of the resistances 28, 28 and vice versa.

Resistance arrangements similar to those mentioned above are disclosed in the patent of H. S. Hamilton et al., No. 1,900,106, granted March 7, 1933.

In accordance with the invention a network 30 is utilized for connecting the outputs of the amplifiers 12 and 13 to the loads L_1 and L_2, and comprises one pair of opposite arms, one of which embodies resistance R_1 and the other resistance R_2, and another pair of opposite arms one of which embodies the loud-speaker load L_1 and the other the loud-speakers load L_2. The output of the amplifier 12 is applied by leads AE and BF to diagonally opposite network terminals 18, 19 while the output of the amplifier 13 is connected by leads CG and DH to diagonally opposite network terminals 21, 22.

The impedance of each of the four arms of the network is substantially the same, that is, $R_1=R_2=L_1=L_2$. Theoretically, arms R_1 and R_2 should be impedance elements which simulate the actual impedance of the respective loads L_1 and L_2 over a predetermined frequency range. Empirically, it has been found that resistances equal in value to about the average value of the impedance of the loads L_1 and L_2 approximate the theoretical condition to such extent that an operating condition suitable for practical purposes is provided. Also, the internal impedance R of each of the amplifiers 12 and 13 is substantially the same and is preferably made to have such value as to provide optimum impedance relation between the amplifiers and the loud-speaker loads, such relation being that obtaining in a normal circuit, that is, a circuit which does not embody the network. Therefore, the internal impedance of each amplifier is assumed such that $R_{12}=R_{13}=R_1=R_2=L_1=L_2$. It is to be understood that the equality of R_{12} and R_{13} to the other network impedances is not essential to satisfactory operation: and further that such equality is assumed for purposes of analysis to be explained subsequently, as it approximates the usual operating condition. Also, the impedances of all network elements have been taken as pure resistances to simplify the analysis, since in practical applications the loads L_1 and L_2 may be impedances, in general.

Normal operation—Figs. 1, 2 and 3

Normally no current flows in the arms R_1 and R_2 as the network is balanced so that the output of the amplifiers 12 and 13 is equalized between the loads L_1 and L_2. In such case the arms R_1 and R_2 may be considered as non-existent, as no potential is developed thereacross; and both amplifiers and loads are effectively connected in series in the manner illustrated in Fig. 2 which will be subsequently explained.

Referring to Fig. 1, output current of amplifier 12 tends to flow in a two-branch parallel circuit comprising in one branch lead BF, network terminal 19, arm R_1, network terminal 22, load L_1, network terminal 18 and lead AE, and in the other branch network terminal 19, load L_2, network terminal 21, arm R_2, network terminal 18 and lead AE. Output current of amplifier 13 tends to flow in a two-branch parallel circuit comprising in one branch lead DH, network terminal 22, arm R_1, network terminal 19, load L_2, network terminal 21 and lead CG, and in the other branch network terminal 22, load L_1, network terminal 18, arm R_2, network terminal 21 and lead CG.

It is to be noted that the output current of amplifier 12 tends to flow in the network arms in the directions indicated by the solid arrows while the current of amplifier 13 tends to flow in the network arms in the directions indicated by the dotted arrows. Thus, the output current of the amplifiers 12 and 13 tends to flow in the arms R_1 and R_2 in opposite directions thereby producing across the network terminals 19 and 22 and across the network terminals 18 and 21 potentials which have the same sign and substantially the same value. Consequently, no current flows in the arms R_1 and R_2, Fig. 1. Therefore, a balanced condition is provided in the network.

Inasmuch as no current flows in the arms R_1 and R_2, these arms may be omitted and the circuit of Fig. 1 may be simplified to that shown in Fig. 2. In the latter it will be observed that both amplifiers and loads are effectively connected in series. Further, it will be assumed that E is the voltage generated by each amplifier in series with its internal impedance R.

The normal circuit of Figs. 1 and 2 may be further simplified to that illustrated in Fig. 3 which will now be analyzed.

Inasmuch as the impedances of the amplifiers, loud-speaker loads, and bridge arms are assumed to be equal as previously mentioned, then R may represent the impedance of each amplifier and network arm, and the impedance of each loud-speaker load. The reference characters shown in parentheses and associated with certain reference characters in Fig. 3 are merely for the purpose of readily identifying corresponding elements in Figs. 1, 2 and 3, and therefore they may be omitted in the following calculations.

The equations for Fig. 3 are:

$$E=I_1(3R)-I_2R-I_3R$$
$$E=-I_1R+I_2(3R)-I_3R$$
$$E=+I_1R+I_2R-I_3(3R)$$

Solving for I_1, I_2 and I_3

$$I_1=\frac{E}{2R} \quad (1)$$
$$I_2=\frac{E}{2R}$$
$$I_3=0$$

The current in the bridge arms is:

$$I_1-I_2=0, \text{ the current in arm } R\ (R_2) \quad (2)$$
$$I_3=0, \text{ the current in arm } R\ (R_1) \quad (3)$$

Current in the loudspeaker loads is:

$$I_1-I_3=\frac{E}{2R}, \text{ the current in load } R\ (L_1) \qquad (4)$$

$$I_2=\frac{E}{2R}, \text{ the current in load } R\ (L_2) \qquad (5)$$

It is obvious from Equation 1 that amplifier 12 is operating into a matched impedance load; and similarly from the current delivered by amplifier 13, that is,

$$I_2-I_3=\frac{E}{2R}$$

that the latter is also working into a matched impedance load, as the current from each amplifier

$$I_{amp}=\frac{E}{2R}=\frac{E}{R+R} \qquad (6)$$

in which the first R in the denominator is the internal impedance of each amplifier and the second R therein is the impedance of the effective load for each amplifier.

From the above it is seen that:

(a) No current flows in the network arms, Equations 2 and 3, and therefore Figs. 1 and 2 operate in the normal condition substantially without any loss of signaling power;

(b) The same current

$$\frac{E}{2R}$$

flows in each loud-speaker load, Equations 4 and 5, and

(c) The impedance of each amplifier is matched to the impedance of each loud-speaker load, Equation 6, that is, optimum impedance match is established between both amplifiers and loads.

Short circuit of one loud-speaker load—Figs. 1 and 4

The occurrence of a short circuit in all loud-speakers in one load would have substantially no effect on the operation of the loud-speakers in the other load, and the current flowing in the operative load would be substantially the same as that flowing therein under normal operation.

Assuming a short circuit of the load L_2, or across the network terminals 19 and 21 in Fig. 1, the output current of amplifier 12 would flow in a circuit comprising lead BF, network terminal 19, arm R_1, network terminal 22, load L_1, network terminal 18 and lead AE. As the output current of amplifier 12 divides at the network terminal 19, a portion of this current would also flow in a circuit including network terminal 19, short circuit across the network terminals 19 and 21, network terminal 21, arm R_2, network terminal 18 and lead AE. The output current of amplifier 13 would flow in a circuit comprising lead DH, network terminal 22, load L_1, network terminal 18, arm R_2, network terminal 21 and lead CG. As the output of amplifier 13 divides at the network terminal 22, a portion thereof would also flow in a circuit including network terminal 22, arm R_1, network terminal 19, short circuit across network terminals 19 and 21, network terminal 21 and lead CG.

Assuming a short circuit of the load L_1, or across the network terminals 18 and 22 in Fig. 1, the output current of amplifier 12 would flow in a circuit comprising lead BF, network terminal 19, arm R_1, network terminal 22, short circuit across network terminals 22 and 18, network terminal 18, and lead AE. As the output of amplifier 12 divides at the network terminal 19, a portion of this current would also flow in a circuit including network terminal 19, load L_2, network terminal 21, arm R_2, network terminal 18 and lead AE. The output current of amplifier 13 would flow in a circuit comprising lead DH, network terminal 22, short circuit across network terminals 22 and 18, network terminal 18, arm R_2, network terminal 21 and lead CG. As the output current of amplifier 13 divides at the network terminal 22, a portion thereof would also flow in a circuit including network terminal 22, arm R_1, network terminal 19, load L_2, network terminal 21 and lead CG.

The circuit of Fig. 1 including, for example, the short circuit of the load L_2 mentioned above may, therefore, be represented by the simplified circuit shown in Fig. 4 which will now be analyzed.

It is to be understood that the impedances of the amplifiers, bridge arms and loud-speaker loads may be represented as indicated above with regard to Fig. 3.

The equations for Fig. 4 are:

$$E=I_1(3R)-I_2R-I_3R$$

$$E=-I_1R+I_2(2R)-I_3R$$

$$E=I_1R+I_2R-I_3(3R)$$

Solving for I_1, I_2 and I_3

$$I_1=\frac{3E}{4R}$$

$$I_2=\frac{E}{R}$$

$$I_3=\frac{E}{4R}$$

Then, the current in the operative loud-speaker load R (L_1) is:

$$I_1-I_3=\frac{3E}{4R}-\frac{E}{4R}=\frac{E}{2R} \qquad (7)$$

The current supplied by amplifier 12 is

$$I_1=\frac{3E}{4R}=\frac{E}{\frac{4}{3}R}=\frac{E}{R+\frac{R}{3}} \qquad (8)$$

and the current supplied by amplifier 13 is

$$I_2-I_3=\frac{E}{R}-\frac{E}{4R}=\frac{3E}{4R}=\frac{E}{R+\frac{R}{3}} \qquad (9)$$

As the first R in the denominator of Equations 8 and 9 may be taken to be the internal impedance of the respective amplifiers and the second R therein may be taken to be the impedance of the effective load, it is therefore obvious that each amplifier is operating into one-third of its internal impedance.

From the above it is seen that:

(a) The current

$$\frac{E}{2R}$$

Equation 7, flows in the operative load L_1 in Fig. 1 and it is the same as that flowing therein under normal operation, Equations 4 and 5, and

(b) Each amplifier is working into one-third normal load impedance, Equations 8 and 9.

Thus, a short circuit of the load L_2 in Fig. 1 would not impair the normal operation of the load L_1 in Fig. 1.

It is to be understood that while the above calculations are based on the assumption that the load L_2 in Fig. 1 is short-circuited and load L_1 in Fig. 1 is operative, the same calculations would also apply to the assumed circuit condition in Fig. 1 in which the load L_1 is short-circuited and the load L_2 is operative.

Open circuit of one loud-speaker load—Figs. 1 and 5

The occurrence of an open circuit of one loud-speaker load in Fig. 1 would have substantially no effect on the operation of the other loud-speaker load, and the amount of current flowing in the operative loud-speaker load would be the same as that flowing therein under normal operation

Assuming an open circuit of the loud-speaker load L_2 in Fig. 1, the output current of amplifier 12 would flow in a circuit consisting of lead BF, network terminal 19, arm R_1, network terminal 22, load L_1, network terminal 18 and lead AE; and the output current of amplifier 13 would flow in a circuit comprising lead DH, network terminal 22, load L_1, network terminal 18, arm R_2, network terminal 21 and lead CG. Thus, the output current of amplifier 12 would flow in the arm R_1 and load L_1 in series while the output current of amplifier 13 would flow in the load L_1 and arm R_2 in series. Hence, equal amounts of output current of each amplifier would flow in each network arm and loud-speaker load.

Assuming an open circuit of the loud-speaker load L_1 in Fig. 1, the output current of amplifier 12 would flow in a circuit including BF, network terminal 19, load L_2, network terminal 21, arm R_2, network terminal 18 and lead AE; and the output current of amplifier 13 would flow in a circuit including lead DH, network terminal 22, arm R_1, network terminal 19, load L_2, network terminal 21 and lead CG. Thus, the output current of amplifier 12 would flow in the load L_2 and arm R_2 in series while the output current of amplifier 13 would flow in the arm R_1 and load L_2 in series. Hence, equal amounts of output current of each amplifier would flow in each network arm and loud-speaker load.

The circuit of Fig. 1 including, for example. the open circuit of the load L_2 mentioned above may, therefore, be represented by the simplified circuit shown in Fig. 5 which will now be analyzed:

It is to be understood that the impedances of the amplifiers, bridge arms and loud-speaker loads may be represented as indicated above with regard to Fig. 3.

The equations for Fig. 5 are:

$$E=I_1(3R)+I_3R$$

$$E=I_1R+I_3(3R)$$

Solving for I_1 and I_3

$$I_1=\frac{E}{4R}=\frac{E}{R+3R} \qquad (10)$$

$$I_3=\frac{E}{4R}=\frac{E}{R+3R} \qquad (11)$$

$$I_1+I_3=\frac{E}{2R}, \text{ the current in load } R\ (L_1) \qquad (12)$$

As the first R in the denominator of Equations 10 and 11 may be taken to be the internal impedances of the respective amplifiers and the second R therein may be taken to be the impedance of the effective load, it is therefore obvious that each amplifier is operating into three times its internal impedance.

From the above it is seen that:

(*a*) The current

$$\frac{E}{2R}$$

Equation 12, flows in the operative load L_1 in Fig. 1 and it is the same as that flowing therein under normal operation, Equations 4 and 5, and

(*b*) Each amplifier is working into three times normal load impedance, Equations 10 and 11.

Thus, in Fig. 1 an open circuit of the load L_2 would not impair the normal operation of the load L_1.

It is to be understood that while the above calculations are based on the assmuption that the load L_2 in Fig. 1 is open-circuited and the load L_1 in Fig. 1 is operative, the same calculations would also apply to the assumed circuit condition of Fig. 1 in which the load L_1 is open-circuited and the load L_2 is operative.

Short circuit or open circuit in one amplifier—Figs. 1, 6 and 7

The occurrence of a short or open circuit in either amplifier 12 or 13 in Fig. 1 would cause a 6 decibel loss in all loud-speakers in the loads L_1 and L_2 relative to normal operation. In such case the output of the operative amplifier would be (1) divided between the loads L_1 and L_2 thereby involving a 3 decibel loss, and (2) applied through the arms R_1 and R_2 to the loads L_1 and L_2 thereby involving a further 3 decibel loss.

Assuming the occurrence of a short circuit in the output of amplifier 12, it is noted that this would be the same as a short circuit across the network terminals 18 and 19. In such case the output of amplifier 13 would flow in a circuit comprising lead DH, network terminal 22, load L_1, network terminal 18, arm R_2, network terminal 21 and lead CG. As this current divides at the network terminal 22, a portion thereof would also flow in a circuit including network terminal 22, arm R_1, network terminal 19, load L_2, network terminal 21 and lead CG. No current would flow in the short circuit across the network terminals 18 and 19 as both of the latter would have the same potential, or, in other words, there is no difference of potential thereacross to cause a flow of current therebetween.

Assuming the occurrence of a short circuit in the output of amplifier 13, it is noted that this would be the same as a short circuit across the network terminals 21 and 22. In such case the output of amplifier 12 would flow in a circuit embodying lead BF, network terminal 19, arm R_1, network terminal 22, load L_1, network terminal 18 and lead AE. As this current divides at the network terminal 19, a portion thereof would also flow in a circuit consisting of network terminal 19, load L_2, network terminal 21, arm R_2, network terminal 18 and lead AE. No current would flow in the short circuit across the network terminals 21 and 22 as both thereof would have the same potential.

Thus, in the case of a short-circuit disablement of one amplifier, the output of the operative one would be supplied through the network arms R_1 and R_2 to the loads L_1 and L_2 thereby involving the 6 decibel loss mentioned above. This may be readily seen by referring to Fig. 6 which is a simplified circuit of Fig. 1 when one amplifier say, for example, amplifier 12, is short-circuited.

Assuming the occurrence of an open circuit in the output of amplifier 12, then the output of the operative amplifier 13 would be supplied through the arms R_1 and R_2 to the loads L_1 and L_2. Likewise, the occurrence of an open circuit in the output of amplifier 13 would cause the output of the operative amplifier 12 to be supplied through the arms R_1 and R_2 to the loads L_1 and L_2. This may be readily understood by referring to Fig. 7 which is a simplified form of Fig. 1 when one amplifier say, for example, amplifier 12, is open-circuited.

In the case of either a short or an open circuit occurring in the manner aforedescribed, the loss of 6 decibels may be reduced by approximately 3 decibels by short-circuiting each of the network arms and disconnecting the disabled amplifier so as to allow the output of the operative amplifier to be equalized directly between the loads L_1 and L_2. Thus, the net loss in each load would be limited to about 3 decibels (a mismatch loss of 0.5 decibel will occur).

Therefore, it is observed that when one amplifier is disabled by a short or open circuit, the operative amplifier works into the normal load impedance since the four equal impedance arms of the bridge are in series parallel. Consequently, the bridge serves to substantially maintain an impedance match between both loads L_1 and L_2 during intervals when both amplifiers are operative and also during intervals when one is disabled and the other is operative.

The circuit of Fig. 1 including say, for example, the short circuit or open circuit of amplifier 12, may be represented by the respective simplified circuits of Figs. 6 and 7 both of which are obviously identical, in so far as a flow of current is concerned, and therefore they may be analyzed together as follows:

It is to be understood that the impedances of the amplifiers, bridge arms and loud-speaker loads may be represented as indicated above with respect to Fig. 3.

The mesh equations for Figs. 6 and 7 are:

$$O=I_1(2R)-I_2R+I_3R$$

$$E=-I_1R+I_2(3R)+I_3R$$

$$E=+I_1R+I_2R+I_3(3R)$$

Solving for I_1, I_2 and I_3

$$I_1=0$$

$$I_2=\frac{E}{4R} \tag{13}$$

$$I_3=\frac{E}{4R} \tag{14}$$

The current supplied by the amplifier 13 is

$$I_2+I_3=\frac{E}{2R}=\frac{E}{R+R} \tag{15}$$

As the first R in the denominator of Equation 15 may be taken to be the internal impedance of the amplifier 13 and the second R therein may be taken to be the effective load, it is therefore apparent that amplifier 13 is operating into a matched load impedance.

From the above it is seen that:

(a) The same current

$$\frac{E}{4R}$$

is supplied by the operative amplifier to each of the load L_1 and L_2 in Fig. 1, Equations 13 and 14, and

(b) The internal impedance of the operative amplifier 13 is matched to the effective load, Equation 15, and such impedance match is the same when both amplifiers are operative, Equation 6.

Thus, failure of one amplifier output in the manner aforedescribed would not impair the operation of the loads L_1 and L_2.

It is to be understood that while the above calculations are based on the assumption of a short or open circuit of the amplifier 12 in Fig. 1, the same calculations would also apply to the assumed circuit condition in Fig. 1 in which the short or open circuit occurred in the amplifier 13.

Modification—Figs. 1 and 1A

The modification illustrated in Fig. 1A which may be substituted for the portion between the dot-dash line X—X and Y—Y shown in Fig. 1 comprises a first pair of power amplifiers 31 and 32 and a second pair of power amplifiers 33 and 34 whose bridged inputs are supplied to the outputs of the respective input amplifiers 12 and 13. The outputs of the amplifiers 31 and 33 are connected in parallel and impressed on one diagonal of the network, and also the outputs of the amplifiers 32 and 34 are connected in parallel and applied to an opposite diagonal of the network. Thus, the input terminals A, B, C and D and the output terminals E, F, G and H of the power amplifiers are connected to the similarly characterized leads in Fig. 1.

The occurrence of a short circuit in the bridged outputs of either power amplifiers 31 and 33, or 32 and 34 would cause a 6 decibel loss relative to normal operation in all loud-speakers in both loads L_1 and L_2, as the output of the operative pair of power amplifiers would be (1) divided between the loads L_1 and L_2 thereby involving a 3 decibel loss and (2) impressed on the loads L_1 and L_2 through the network arms R_1 and R_2 thereby involving an additional 3 decibel loss. The 6 decibel loss may be reduced to 3 decibels by short-circuiting the arms R_1 and R_2 and disconnecting the disabled pair of amplifiers so as to allow the output of the operative pair of power amplifiers to be directly applied to the loads L_1 and L_2. This is similar to the operation of Fig. 1 when an open or a short circuit occurs in either amplifier 12 or 13.

In Fig. 1A a disabling of one of the input amplifiers 12 and 13 would involve only a 3 decibel loss, plus a slight loss due to change in impedance match, in all loud-speakers in both loads L_1 and L_2 for the reason that the output of the operative input amplifier would be applied through the bridged amplifiers associated therewith to the opposite diagonals of the network. As the latter maintains a balanced condition due to the fact that the potential across the diagonal 18, 19 is substantially the same as that across the diagonal 21, 22, the loss occasioned in this manner is limited to 3 decibels. Thus, if amplifier 12 were to be disabled the output of operative amplifier 13 would be applied through bridged amplifiers 33 and 34 to the opposite diagonals of the network; and if amplifier 13 were to be disabled the output of operative amplifier 12 would be applied through bridged amplifiers 31 and 32 to the opposite diagonals of the network. Due to the fact that the network is balanced, the current flow in the two loads L_1 and L_2 would be equalized.

What is claimed is:

1. In combination, a source of signals, a pair of amplifying means whose inputs are connected

to the signaling source, a pair of load circuits, and means for connecting the outputs of the amplifying means to the load circuits comprising a network having a pair of opposite arms each of which embodies an impedance and a pair of opposite arms each of which embodies one load circuit, the output of each amplifying means being connected to a different diagonal of the network, the network applying the outputs of the amplifying means to the load circuits such that the potentials across opposite diagonals thereof are substantially the same during intervals when both amplifying means are operative and one diagonal has zero potential difference thereacross while the opposite diagonal has the potential of one amplifying means thereacross during intervals when only one amplifying means is operative.

2. In combination, a source of signals, a pair of amplifying means whose inputs are connected to the signaling source, a pair of load circuits, and means for connecting the outputs of the amplifying means to the load circuits comprising a network having a first pair of opposite arms each of which embodies an impedance and a second pair of opposite arms each of which embodies one load circuit, the output of each amplifying means being applied to a different diagonal of the network, the network applying the outputs of both amplifying means directly to both load circuits during intervals when both amplifying means are operative and applying the output of one amplifying means through the impedance arms to both load circuits during intervals when the other amplifying means is disabled.

3. The combination according to claim 2 in which the network applies the output of the operative amplifying means to a two-branch parallel circuit comprising in each branch in series one impedance arm and one load circuit.

4. In combination, a source of signals, a pair of amplifiers connected to the signaling source, a pair of load circuits, and means for providing an optimum impedance match between the amplifier outputs and the load circuits comprising a network having a first pair of opposite arms each of which embodies a resistance and a second pair of opposite arms each of which embodies one load circuit, the output of each amplifier being connected to a different diagonal of the network, the impedance matching means providing substantially optimum impedance match between the amplifiers and the load circuits during an interval when both amplifiers are operative and also during an interval when only one amplifier is operative.

5. In combination, a source of signals, a pair of amplifiers whose inputs are connected to the signaling source, a pair of load circuits, a network comprising a first pair of opposite arms each of which embodies an impedance and a second pair of opposite arms each of which embodies one load circuit, circuit connections for applying the output of each amplifier to a different diagonal of the network, the network supplying the outputs of both amplifiers directly to both load circuits during an interval when both load circuits are operative and supplying the outputs of both amplifiers through the impedance arms to one load circuit during an interval when the other load circuit is disabled so as to maintain substantially constant the amount of signaling energy supplied to both load circuits when both thereof are operative and to the one load circuit when the other load circuit is disabled.

6. In combination, a source of signals, a pair of amplifiers whose inputs are connected thereto, a pair of load circuits, and means for connecting the amplifier outputs to the load circuits comprising a network having a first pair of opposite arms each of which embodies an impedance and a second pair of opposite arms each of which embodies one load circuit each amplifier output being applied to a different diagonal of the network, the network supplying both amplifier outputs directly to both load circuits during intervals when both load circuits are operative and supplying both amplifier outputs through the impedance arms to one load circuit during intervals when the other load circuit is disabled thereby equalizing the potentials across the different network diagonals when both load circuits are operative and also when one load circuit is operative and the other is disabled.

7. In combination, a source of signals, a first input amplifier, a second input amplifier, the inputs of the first and second input amplifiers being connected to the signaling source, a first pair of power amplifiers whose inputs are connected in parallel to the output of the first input amplifier, a second pair of power amplifiers whose inputs are connected in parallel to the output of the second input amplifier, the outputs of the first pair of power amplifiers being bridged with the outputs of the second pair of power amplifiers so as to provide two bridged power outputs each of which includes one amplifier of each pair of power amplifiers, a pair of load circuits, and means for connecting the two bridged power outputs to both load circuits comprising a network having a first pair of opposite arms each of which embodies an impedance and a second pair of opposite arms each of which embodies one load circuit, each bridged power output being applied to a different diagonal of the network, the network directly applying both bridged power outputs to both load circuits during intervals when both bridged power outputs are operative and applying one bridged power output through both impedance arms to both load circuits during intervals when the other bridged power output is disabled.

8. The combination according to claim 7 in which the network applies directly both bridged power outputs to both load circuits during an interval when both input amplifiers are operative and also during an interval when one input amplifier is operative and one input amplifier is disabled.

9. In combination, a pair of amplifying means, a pair of load circuits, and means to connect the outputs of said amplifying means to said load circuits, comprising a network having a first pair of opposite arms each of which embodies an impedance and a second pair of opposite arms each of which embodies one of said load circuits, and the output of each amplifying means connected to different terminals of said network.

10. In combination, a first input amplifier, a first pair of power amplifiers, circuit means to connect in parallel the inputs of said first pair of power amplifiers to the output of said first input amplifier, a second input amplifier, a second pair of power amplifiers, circuit means to connect in parallel the inputs of said second pair of power amplifiers to the output of said second input amplifier, circuit means to connect the outputs of said first and second pairs of power amplifiers

to provide two independent bridging outputs each of which embodies one amplifier of each of said first and second pairs of power amplifiers, a pair of load circuits, and circuit means to connect said two independent bridging outputs to said load circuits, comprising a network having a first pair of opposite arms each of which embodies an impedance and a second pair of opposite arms each of which embodies one of said load circuits, and each independent bridging output connected to different terminals of said network.

11. In combination, a pair of amplifying means, a pair of load circuits, and means to apply the outputs of said amplifying means to said load circuits such that said outputs and said load circuits are effectively connected in series in one circuit.

12. In combination, a pair of amplifying means, a pair of load circuits, and means to connect effectively the outputs of said amplifying means and said load circuits in series, comprising a network having a first pair of opposite arms each of which embodies an impedance and a second pair of opposite arms each of which embodies one of said load circuits, and the output of each amplifying means connected to different terminals of the network and the potential across the terminals of each impedance arm being substantially equal and having the same sign so that substantially no amplified current flows therein.

13. In combination, a pair of amplifying means each of whose outputs possesses substantially the same impedance, a pair of load circuits each of which possesses substantially the same impedance, the impedances of each output and each load circuit being substantially equal, and means to provide substantially optimum impedance match between said outputs and said load circuits, comprising a network having a first pair of opposite arms each of which embodies an impedance whose amount equals substantially each output or load circuit impedance and a second pair of opposite arms each of which embodies one of said load circuits, and each output connected to different terminals of said network so that substantially the same amount of amplified current flows in each load circuit.

14. In combination, a pair of amplifying means, a pair of load circuits, and means to apply effectively the outputs of said pair of amplifying means to said pair of load circuits such that a certain amount of amplified signaling current flows in each of said pair of load circuits when both thereof are operative and said certain amount of amplified signaling current flows in an operative load circuit when the other load circuit is disabled.

15. In the combination according to claim 13 in which said matching means connects effectively the output of each amplifying means substantially to one-third optimum load impedance when one load circuit is operative and the other load circuit is short-circuited.

16. In the combination according to claim 13 in which said matching means connects effectively the output of each amplifying means substantially to three times optimum load impedance when one load circuit is operative and the other load circuit is open-circuited.

17. In the combination according to claim 13 in which said matching means effectively connects the output of one operative amplifying means substantially to optimum load impedance when the output of the other amplifying means is either short-circuited or open-circuited.

18. In combination, a source of signals, a pair of amplifying means connected to said signaling source, a pair of load circuits, and means for effectively connecting the outputs of both amplifying means to both load circuits and maintaining such connection during an interval when one amplifier is disabled and also during an interval when one load circuit is disabled, said connecting means comprising a network having a first pair of opposite arms each of which embodies an impedance and a second pair of opposite arms each of which embodies one load circuit, and circuit means to apply each output to a different diagonal of said network.

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