

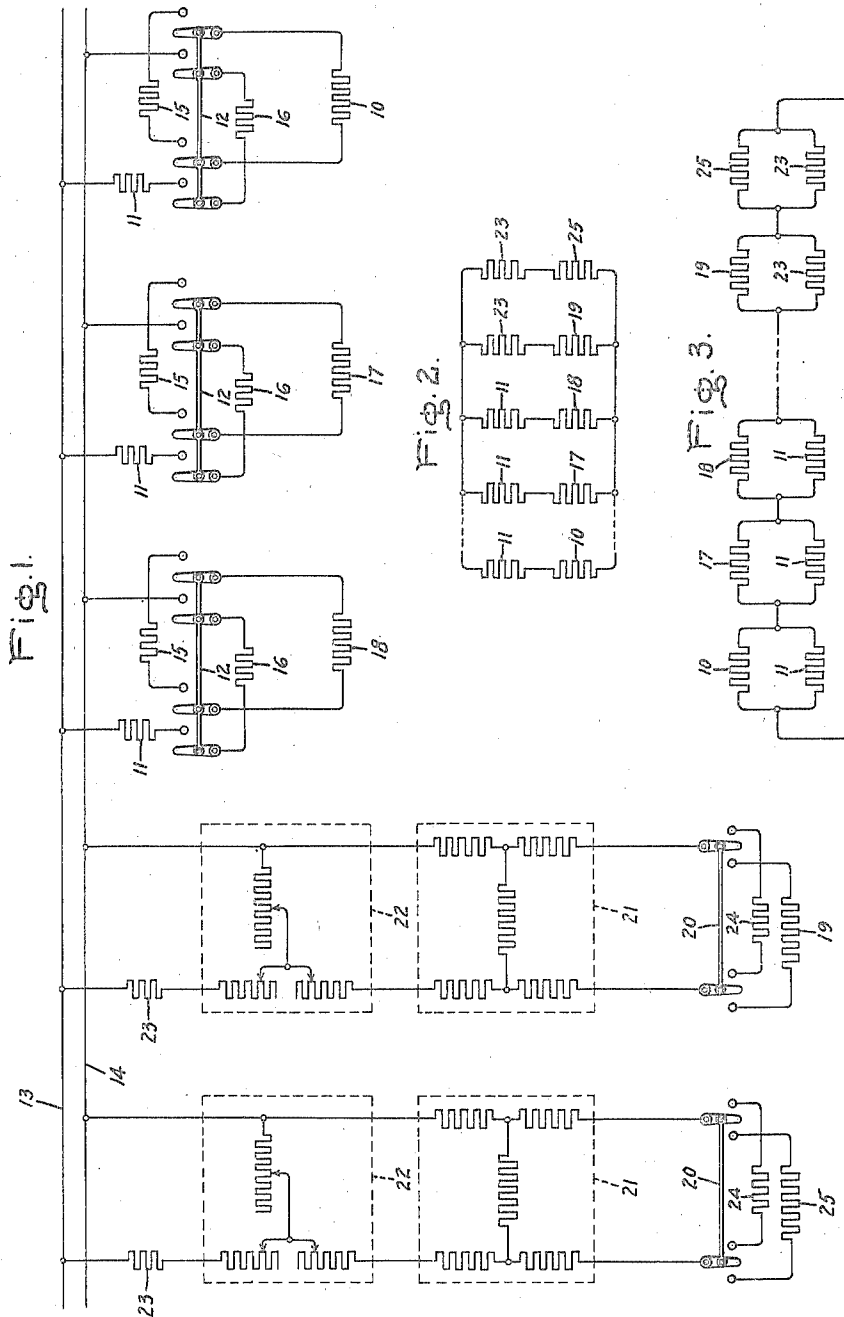
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MIXER CIRCUIT

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MIXER CIRCUIT

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This invention relates to a method and apparatus for interconnecting circuits and more particularly to an arrangement for interconnecting a plurality of input and output circuits.

It is frequently desirable in connecting two electrical devices together to arrange the impedance of each device, as measured at the connections to the other device, equal to the impedance of the other device. As is well known, this assures that power exchange will proceed at a maximum rate. It is an object of this invention to provide a method and means for interconnecting a plurality of power supplying and power consuming circuits in such a manner that each circuit is terminated in its characteristic impedance.

The features of my invention which I believe to be novel are set forth with particularity in the appended claims. My invention itself, however, both as to its organization and method of operation, together with further objects and advantages thereof may best be understood by reference to the following description taken in connection with the accompanying drawing, in which Fig. 1 represents a circuit arrangement embodying my invention, Fig. 2 is a simplified schematic diagram of the circuit shown by Fig. 1, and Fig. 3 shows an alternative arrangement.

In Fig. 1 a source 10 of alternating voltage is represented simply as an impedance. It may be a radio or carrier current transmitter or an audio frequency amplifier which is adapted to generate alternating voltage. This source 10 is connected in series with an impedance 11 by a switching means 12 in its operating position. The source 10 and the impedance 11 are connected in series across a pair of buses 13 and 14.

In the right hand position of the switch 12 the source 10 is entirely disconnected from the impedance 11 and the buses 13 and 14, and is loaded by an impedance 15. The impedance 11 and the buses 13 and 14 are entirely disconnected from the source 10 and are loaded or terminated by an impedance 16. It is desirable that the values of the impedances 15 and 16 be the same as the characteristic impedance of the source 10 and the same as the driving point impedance of the buses 13 and 14 as measured through the impedance 11. This is to insure that the various circuits are not disturbed in their normal operation by connection and disconnection of the source 10 and the buses 13 and 14.

Sources 17 and 18 of alternating voltage are similar to the source 10 and are connected to the buses 13 and 14 by means which are similar to the means connecting source 10 to the buses. The parts of this connecting means are similar to the parts in the connecting means for the source 10 and have like reference characters.

A device 19, represented simply as an imped-

ance, is adapted to consume power delivered from the buses 13 and 14 and is connected thereto by a switching means 20, a fixed attenuator 21, a variable attenuator 22, and a series impedance 23. The device 19 may be a radio or carrier current receiver or an audio frequency responsive device. The switching means 20 in its left hand position connects both ends of device 19 in series with fixed attenuator 21 which in turn is connected in series with variable attenuator 22. One side of the variable attenuator 22, which is shown as a T type attenuator, is connected directly to one of the buses 13 and 14 and the other side of the variable attenuator 22 is connected through impedance 23 to the other bus.

When the switch 20 is in its right hand position an impedance 24 is connected at both ends to fixed attenuator 21 and device 19 is entirely disconnected. The impedance 24 should have the same impedance as device 19. The driving point impedance at the terminals of the fixed attenuator 21 on the same side as switch 20 should also be of the same value.

A device 25, represented simply as an impedance, is connected to the buses 13 and 14 by means similar to the means connecting device 19 and in which like parts have like reference characters.

The value of impedance 11 is made such that the impedance into which the source 10 works is equal to the impedance of the source itself. If the switch 12 be moved to the right hand, or off position, the impedance 16, which is of the same value as source 10 is then connected in series with the impedance 11. The impedance, into which any other source 17 or 18 or device 19 or 25 works, thus remains unchanged. The source 10, when switch 12 is in the right hand position, is connected to impedance 15, whose value is the same as the impedance into which source 10 works when transferring power to the other sources and the devices 19 and 25. Hence it appears at the source 10 as though no change in connections had been made.

When the switch 20 is moved to the right hand or off position, the impedance 24 takes the place of the device 19 and hence it appears at the sources 19, 17 and 18 and at the device 25 as though no change had been made.

In Fig. 2, which is a schematic diagram corresponding to the circuit of Fig. 1, the impedance 10, 17, 18, 19, and 25 represent the devices between which it is desired to transmit power. One end of each of these impedances are connected together. The impedances 11 and 23, one of which is connected in series with each of the above-mentioned impedances are connected at one end into a common circuit which allows exchange of energy between any pair of the im-

pedances 10, 17, 18, 19 and 25. The value of the impedances 11 and 23 are such that the impedance, into which each of the devices 10, 17, 18, 19 and 25 works, is equal to the impedance of that device.

It is apparent that an impedance 11 or 23 may be divided into two equal parts, one being connected to either end of the corresponding device 10, 17, 18, 19 or 25. The operation of the circuit obviously is not altered by such a change, except that the voltage is distributed somewhat more advantageously in the power transfer circuit. In certain installations this is of advantage where it is desired to balance the voltage of each transmitter or receiver to ground to prevent cross talk.

Assuming that each of the impedances 10, 17, 18, 19, and 25 are equal and that each of the matching impedances 11 and 23 are equal, we may proceed to analyze this simplified network diagram to determine what value each impedance should have. Let R represent the impedance of impedances 10, 17, 18, 19 and 25. Let r be the numerical value of the impedances 11 and 23. Let n be the number of devices such as impedances 10, 17, 18, 19 and 25, which it is desired to connect together. Then the necessary condition that each impedance R be terminated by its characteristic impedance is:

$$R = r + \frac{R+r}{n-1}$$

Determining the proper value of r necessary to meet the imposed conditions:

$$r = R \left(\frac{n-2}{n} \right)$$

by the method described here it is possible to connect together any number of circuits whatever, assuring the termination of each in its characteristic impedance. The method is correct either if the impedances consist of pure resistance or if the impedances are adjustable in absolute magnitude but not in angle.

If it be desired to take account of more than the absolute values of impedance in arranging the network for condition of maximum power flow, it is necessary that the driving point impedance to which each device is connected and the impedance of the device be conjugates of each other. In other words, the resistive components must be equal and the reactive components equal in value and of opposite character. If the impedance of the devices 10, 17, 18, 19, or 25 be $R+jX$ and the series impedance 11, or 23, connected thereto be $r+jx$, the network must satisfy the following equation to provide maximum power transfer:

$$R-jX = r+jx + \frac{R+jX+r+jx}{n-1}$$

If the real quantities be equated, the same condition will be found necessary as was found when only the absolute value of impedance was considered above.

$$R = r + \frac{R+r}{n-1}$$

Or stated otherwise:

$$r = R \left(\frac{n-2}{n} \right)$$

Equating the imaginary quantities will show the condition necessary to be met by the reactive components:

$$-X = x + \frac{X+x}{n-1}$$

Solving for x :

$$x = -X$$

In other words, the reactive component of each impedance 11 or 23 must be equal in value and opposite in character to the reactive component in the impedance of the sources 10, 17, 18, or the devices 19 and 25.

In this last mentioned condition for maximum power flow, the reactances are, of course, equal but they are also conjugate. That is, if the source 10 be inductive in a certain amount, the impedance 11 connected in series must then be capacitive in equal amount. The impedance 11 must at the same time have the proper resistive component, which is that fraction of the resistive component of source 10 as is expressed by the ratio of two less than the total number of sources and devices to the total number thereof.

It is unnecessary to consider the reactive components in the usual communication network, since, if they are not purely resistive, they are made substantially so by tuning. However, certain cases may occur where the reactive components must be accounted for to obtain the maximum transfer of power.

It is of course evident that attenuation is least when the minimum number of devices are interconnected for power transfer. However, attenuation has been found not to be objectionably great even for a comparatively large number of circuits. It is, of course, important, if any volume control device be connected between a source 10, or a device 19, and the remainder of the network, that it have a characteristic such that its input and output impedance remain unchanged as its attenuation is varied. It is also obvious, as has been mentioned above, that the source 10, which has been represented by an impedance, may be suitably a carrier or radio transmitter having audio frequency or modulation superimposed upon its carrier wave. The device 25 may, of course, be a radio or carrier current receiver suitable for receiving signals such as emitted by the source 10. If the impedance of a source 10, or a device 19, happens to be unequal to the other impedances of the system, matching transformers may be used, if desired, to connect the source or device in place of the sources or devices as shown.

Referring to Fig. 3 an alternative connection of the devices 10, 17, 18, 19, and 25 is indicated. As illustrated by this schematic diagram these devices may be connected all in series. This type of connection may be desirable where it is not necessary to balance each circuit to ground. In this circuit the impedances 11 and 23 are each connected in shunt to the corresponding device. For example, an impedance 11 is connected in shunt to source 10 and an impedance 23 is connected in shunt to device 25. It is apparent to any one skilled in the art how the circuit of Fig. 1 should be modified to change it from the parallel type of circuit as shown by Fig. 2 to the series type of circuit as shown by Fig. 3.

If R , r , and n represent the same quantities as before, the necessary condition that each im-

pedance be terminated by its characteristic impedance is:

$$R = \frac{1}{\frac{1}{r} + \frac{R+r}{Rr(n-1)}}$$

Solving for r , we find:

$$r = R \left(\frac{n}{n-2} \right)$$

It is possible with the circuit of Fig. 3, as with that of Fig. 2, to take account of the angle of the impedances as well as the absolute values. Here, as before, to provide for maximum power flow, the driving point impedance and the impedance of the device to which it is connected must be conjugates. Allowing $R+jX$, $r+jx$, and n to retain their former meanings, the network of Fig. 3 must satisfy the following condition to provide maximum power flow.

$$R-jX = \frac{1}{\frac{1}{r+jx} + \frac{R+r+jX+jx}{(R+jX)(r+jx)(n-1)}}$$

If the real quantities be equated the same condition will be found necessary as was found when only the absolute value of impedance was considered:

$$r = R \left(\frac{n}{n-2} \right)$$

Equating the imaginary quantities will show the condition necessary to be met by the reactive components:

$$-jX = \frac{1}{\frac{1}{jx} + \frac{j(X+x)}{jXjx(n-1)}}$$

When this equation is solved, we find

$$x = -X$$

which is the same condition required in the type of circuit shown in Fig. 2.

While I have shown a particular embodiment of my invention, it will, of course, be understood that I do not wish to be limited thereto, since different modifications may be made both in the circuit arrangement and instrumentalities employed, and I contemplate by the appended claims to cover any such modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination with at least three electric translating devices, at least two of said devices being sources of electric energy and at least one of said devices being a load therefor, said devices being connected together for interflow of electric power, means for transferring power between said devices including an impedance connected with each of said devices, said impedance having a value such that the driving point impedance of the circuit connected across the terminals of each device is equal to the characteristic impedance of said device.

2. In combination with at least three electric translating devices, at least two of said devices being sources of electric energy and at least one of said devices being a load therefor, said devices being connected together for interflow of electric power, means for transferring power between said devices including impedance connected with each of said devices, said impedance having a value such that the driving point impedance of the circuit connected across the terminals of each device and the characteristic impedance of each device are conjugates.

3. In combination with at least three electric translating devices, at least two of said devices being sources of electric energy and at least one of said devices being a load therefor, said devices being connected together for interflow of electric power, electric connections for connecting said devices including impedance connected in series with each of said devices, said impedance having a value such that the driving point impedance of the circuit connected across the terminals of each device is equal to the characteristic impedance of said device.

4. In combination with at least three electric translating devices, at least two of said devices being sources of electric energy and at least one of said devices being a load therefor, said devices being connected together for interflow of electric power, electric connections for connecting said devices including impedance connected in shunt with each of said devices, said impedance having a value such that the driving point impedance of the circuit connected across the terminals of each device is equal to the characteristic impedance of said device.

5. In combination with at least three electric translating devices, at least two of said devices being sources of electric energy and at least one of said devices being a load therefor, said devices being connected together, electric connections between one end of each of said devices, an impedance connected to the other end of each of said devices adapted to connect into a common circuit, the value of each of said impedances being such that the impedance across which each of said translating devices is connected is substantially equal to the characteristic impedance of said translating device.

6. In combination, at least three electric translating devices, at least two of said devices being sources of electric energy and at least one of said devices being a load therefor, said devices being connected together, a first series of impedances connected to one end of each of said devices, a second series of impedances connected to the other end of each of said devices, common connections for the remaining ends of said first series of impedances, and common connections for the remaining ends of said second series of impedances, said impedances connected to the ends of one of said devices having such value that the impedance at the terminals of said device is substantially equal to the characteristic impedance of said device, whereby maximum power flow between said devices is obtained.

7. In combination, at least three electric translating devices of equal characteristic impedance, means for transferring power between said devices including impedance connected in series with each of said devices, the ratio of the value of each of said impedances to the impedance of the corresponding one of said devices being as the ratio of two less than the total number of devices to the total number of said devices.

8. In combination, at least three electric translating devices of equal characteristic impedance, means for transferring power between said devices including impedance connected in shunt with each of said devices, the ratio of the value of each of said impedances to the impedance of the corresponding one of said devices being as the ratio of the total number of devices to two less than the total number of said devices.

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