

July 4, 1939.

G. GUANELLA

2,164,402

ELECTRICAL CIRCUIT

Filed Feb. 17, 1938

2 Sheets-Sheet 1

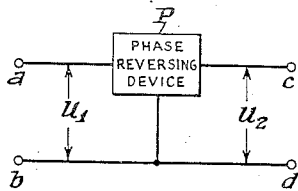


Fig. 1

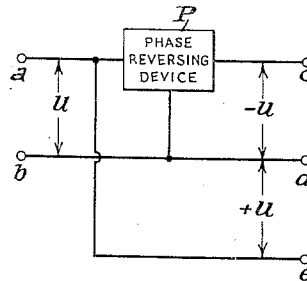


Fig. 2

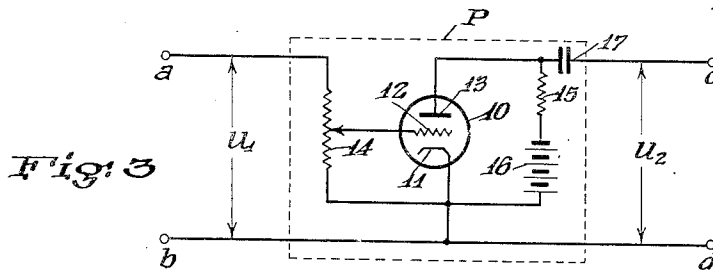


Fig. 3

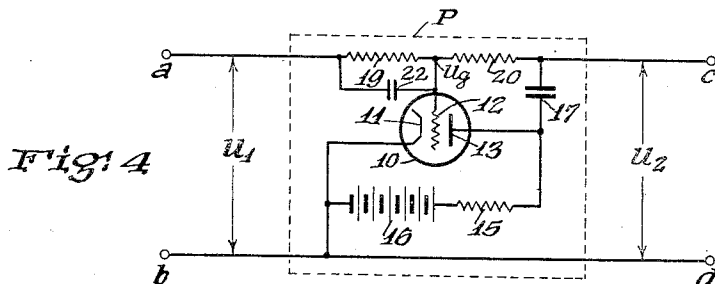


Fig. 4

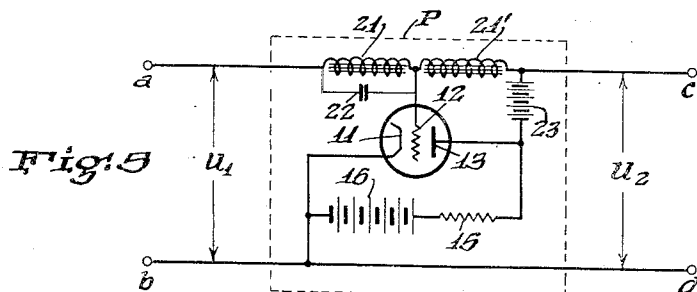


Fig. 5

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2 Sheets-Sheet 2

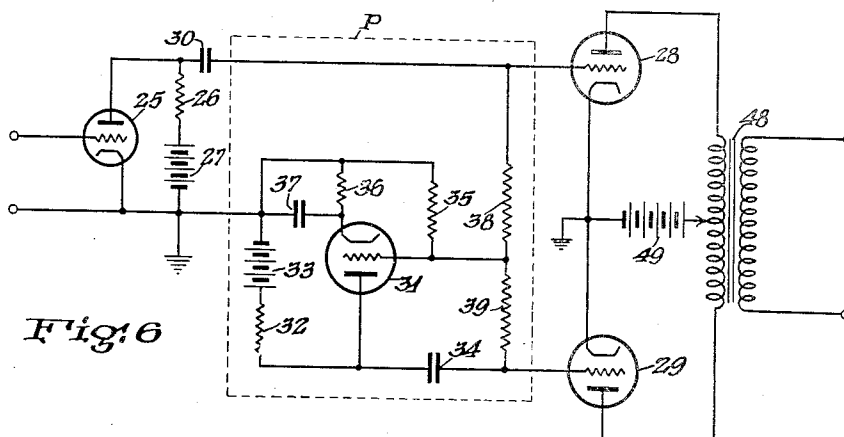


Fig. 6

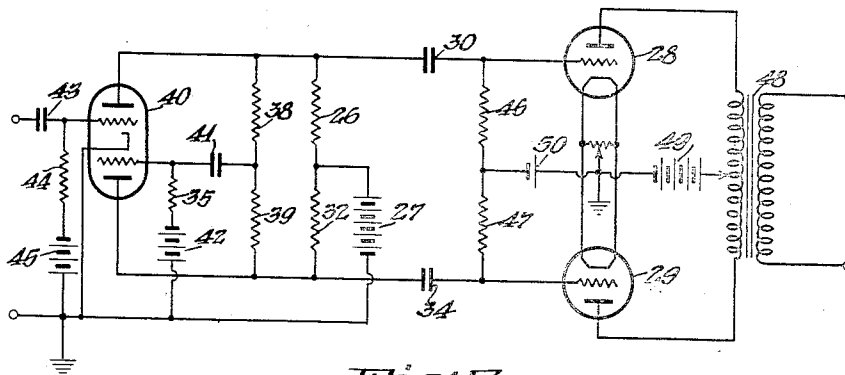


Fig. 7

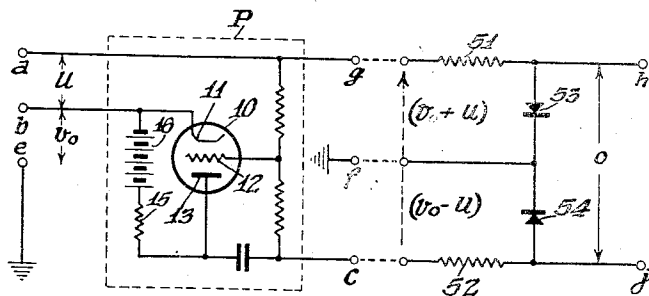


Fig. 8

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2,164,402

ELECTRICAL CIRCUIT

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9 Claims. (Cl. 172-238)

The present invention relates to phase or polarity reversing arrangements and a method of operating the same for use in either direct or alternating current systems.

An object of the invention is the provision of a phase reversing system which avoids the use of transformers and the distortions and other defects connected therewith.

Another object is the provision of a phase or polarity reversing system which is equally effective for both high and low frequencies as well as direct currents.

A further object is to provide a system for and a method of simultaneously reversing the phases by 180° of a large number of electric currents or potentials of different frequencies such as the frequency components of a current or potential signal wave.

Still another object is the provision of a phase reversing system embodying amplifying valves wherein the phase and amplitude of the reversed potential or current is substantially independent of the amplification and other constants of the valve and circuits used.

A further object is the provision of a push-pull modulating system constructed without the use of transformers or inductance coils.

Another object is the provision of a novel push-pull modulating system designed and operating without the use of transformers or choke coils.

Still another object is to provide a system for producing the sum and difference of alternating currents or potentials of like or different frequencies.

The above and further objects and advantages of the invention will become more apparent from the following detailed description taken in reference with the accompanying drawings forming part of this specification and wherein:

Figures 1 and 2 illustrate diagrammatically phase reversing devices known in the art,

Figure 3 shows a phase reversing network of known type employing an electron valve as a reversing element,

Figures 4 and 5 illustrate an improved phase or polarity reversing system employing an electron valve as a reversing element in accordance with the invention,

Figure 6 illustrates the employment of a phase reversing network according to the invention in a push-pull amplifier,

Figure 7 illustrates a push-pull system with a phase reversing system of the type according to the invention employing a multi-purpose electron valve,

Figure 8 illustrates a further embodiment of the invention as applied to a push-pull modulating circuit arrangement designed without the use of transformers.

Like reference numerals identify like parts throughout the different views of the drawings.

It is a common requirement in the electrical and radio arts to rotate the phase of an alternating or oscillating current or of a plurality of such currents or potentials by 180°. Various circuits for this general purpose are known. For example, there is shown in Figure 1 a known four terminal network comprising input terminals *a* and *b* and output terminals *c* and *d* of which terminals *b* and *d* are common. *P* is a phase reversing device by which the sign of the voltage u_1 applied between terminals *a* and *b* is reversed, so that if terminal *a* is at a potential $+u_1$ with respect to terminal *b*, terminal *c* will be at an opposite potential $u_2 = -u_1$ with respect to terminal *d*. The phase reversing arrangement at *P* might be a center tapped choke coil in series between *a* and *c* with its center tapping connected to the common terminals *b* and *d*. In some cases, especially where the input voltage at *a-b* is an alternating voltage of known predetermined frequency, *P* could be a network of the resonant type with inductance, capacity and resistance.

The problem of phase reversal also arises where a voltage which is varying in relation to earth or to some other fixed datum potential is required to be transformed into a symmetrical voltage, that is to say, where, referring to the accompanying Figure 2, one input terminal *a* varies in potential above a second, earthed or fixed potential input terminal *b* (voltage u) and it is required that two output terminals *c* and *e* shall vary equally and oppositely (voltage $+u$ and $-u$) with respect to a point *d* which is at earth or said fixed datum potential.

The accompanying Figure 3 shows within the chain rectangle *P* a known phase reversing arrangement which can be used for the device *P* of Figure 2. An example of a case requiring a network of the type of Figures 2 and 3 is where it is required to feed from an ordinary single valve thermionic valve amplifier into a push-pull valve amplifier stage. In this case, output voltage of the single valve or "straight" amplifier is applied to terminal *a*, while the control grids of the two valves in the push-pull stage are connected, respectively, to the terminals *c* and *e* of Figure 2. It is common practice of course to couple a straight stage to a push-pull stage by means of the usual push-pull input transformer which has

a secondary winding with an earthed center tap, but the use of these transformers involves practical disadvantages such as cost and liability to distortion and Figure 3 shows one known arrangement which has been suggested in order to avoid the use of transformers. In the latter, the phase reversal network includes a valve 10 comprising a cathode 11, grid 12 and anode or plate 13. The control grid 12 is connected to a tap on a voltage divider resistance 14 which is connected between terminals *a* and *b*. Item 15 is an anode or load impedance connected across the anode and cathode in series with a high tension supply source 16, and 17 is a coupling condenser connected between the anode 13 and output terminal *c*. If a voltage u_1 is impressed between *a* and *b* the voltage on the grid will be

$$\frac{r}{R} u_1$$

wherein *R* represents the entire resistance 14 and *r* the tapped portion thereof connected across the grid-cathode path of the valve. If *n* is the amplification of the valve, the output alternating voltage u_2 will be

$$-u_1 \frac{r}{R} n$$

By suitable choice of *r* it is therefore always possible to make u_2 (the voltage between *c* and *d*) equal to $-u_1$.

A disadvantage of this known circuit according to Figure 3 is the fact that small variations of valve amplification, such as produced by variations in the operating voltages or as a result of changing the valves have a large effect on the amplitude of u_2 with respect to the input voltage u_1 . For this reason the production and maintenance of symmetry is in practice difficult and the present invention seeks to overcome this defect.

Referring to Figure 4, there is shown a phase rotating arrangement according to the invention comprising a potential divider consisting of two series portions 19 and 20 connected between the terminals *a* and *c* with the junction point u_x between them connected to the grid 12 of the amplifier valve 10 whose cathode is connected to the earthed or fixed potential terminal *b*. Item 17 is a blocking condenser to block the anode potential source 16 from the grid 12. If the instantaneous voltage between *a* and *b* and impressed on the terminal *a* is u_1 the voltage u_2 at terminal *c* and between *c* and *d* is equal to $-u_1$ as will be seen later.

If u_x is the voltage at the junction between 19 and 20 impressed upon the grid 12, then, assuming the voltage divider 19 and 20 to be of sufficiently high impedance and the anode resistance 15 in series with the anode source 16 and the loading impedance connected to the terminals *c* and *d* also to be sufficiently high, the output voltage u_2 at the terminal *c* will be equal to $-u_x n$ where *n* is the amplification of the valve and the voltage u_x will be equal to

$$\frac{u_1 R_2 + u_2 R_1}{R_1 + R_2}$$

wherein R_1 and R_2 are the values of impedances 19 and 20, respectively.

From this it follows that

$$u_2 = -u_1 \frac{R_2}{R_1} \frac{1}{1 + \frac{R_2}{R_1} \frac{1}{n}}$$

assuming both impedance 15 and the load im-

pedance connected to terminal *c* to be sufficiently high. By suitable choice of

$$\frac{R_2}{R_1}$$

the result can be achieved that u_2 will substantially equal $-u_1$ even though *n* varies. If *n* is sufficiently large R_1 will be only slightly different from R_2 . It is possible to write the above formula with a high degree of approximation in the simpler form

$$u_2 = -u_1 \frac{R_2}{R_1} \left(1 - \frac{2}{n}\right)$$

From this it can be seen that the amplitude of the output voltage u_2 will, if there is a sufficiently high amplification, only depend to a very slight extent on the fluctuations in *n*. The elements 19 and 20 need not be pure ohmic resistances but if they are reactive impedances such as inductances or capacities the phase shifts introduced thereby should be equal. For example, Figure 5 is the same as Figure 4 except that a choke with a tapped portion 21 and 21' replaces the resistive divider 19, 20 of Figure 4.

It may be noted that the output voltage u_2 is in general of substantially the same amplitude as the voltage u_1 impressed on the input terminals *a*, *b*, no perceptible amplification occurring notwithstanding any amplification factor valve 10. This function of the inventive circuit may be further explained by the fact that a substantial amount of output energy is fed back from the plate 13 to the grid 12 through the condenser 17 and resistance 20 in inverse phase relation to the input energy thereby reducing the amplification of the valve. Thus while utilizing the effect of phase reversal between the grid and plate potential of a vacuum valve the invention provides a means for substantially suppressing undesired amplification by inverse feedback thereby avoiding the disadvantages and drawbacks incident thereto as pointed out hereinabove.

In practice, in order to facilitate adjustment it is advisable to make one or both the impedances 19, 20 or 21, 21' variable within limits. For example, one of these impedances can be constituted by a fixed relatively large impedance, such as a fixed resistance, fixed condenser or inductance in series with a relatively small variable supplementary impedance of the same character. Again the voltage divider can be constituted by two fixed impedances connected in series by a voltage divider element of low impedance which has a variable tapping constituting the point u_x .

Since in general it is required that 19 and 20, 21 and 21' be impedances of relatively high absolute values, it is possible that equalization may, in practice, be disturbed by the grid-anode capacity of the amplifier valve 10 which capacity is in parallel with 20 or 21' only. If difficulty occurs due to this it may be remedied by connecting a suitable capacity in parallel with impedance 19 or 21 as shown at 22 in Figures 4 and 5, respectively.

The blocking condenser 17 in Figure 4 can be replaced by a voltage source 23 as shown in Figure 5 giving a voltage equal and opposite to that from the source 16. If a battery or the like is provided in this manner the circuits become suitable for the phase reversal of voltages of very low frequency and for changing the sign of direct current voltages, in which latter case a high ohmic impedance potential divider 19, 20 is preferably used as shown in Figure 4.

Figure 6 shows an arrangement in accordance with the invention employed to couple a "straight" amplifier stage to a push-pull amplifier stage. In this figure, item 25 is a straight amplifier valve, 26 and 27 are its anode resistance and anode potential source, respectively. Items 28 and 29 are the push-pull valves, 30 is a coupling condenser, 31 is the phase reversing valve, and 32 and 33 its anode resistance and anode potential source, respectively. Item 34 is a blocking condenser, item 35 is a grid leak resistance for valve 31, and 36 is a self-bias resistance which is shunted by a condenser 37 and is inserted in the cathode lead to provide adequate grid biasing potential in a manner well known. This arrangement for producing grid bias can of course be replaced by any known method. Items 38 and 39 represent the voltage divider corresponding to items 19 and 20 or 21 and 21' in Figures 4 and 5 and may consist of any desired impedance elements as is understood from the above. The valve 25 can be of any type such as a multi-grid of the screen grid valve or pentode type, or it may be constituted by one of the electrode systems of a double or multiple purpose valve.

Figure 7 shows an arrangement of the latter type. Here a double triode 40 has one triode system (the upper section in the figure) which performs the function of the valve 25 of Figure 6 and another (the lower section) which performs the function of the valve 31 of Figure 6. There are shown several minor modifications in Figure 7 over Figure 6. The junction point of the voltage divider 38, 39 is connected to the grid of the phase reversing (lower) triode section of valve 40 through a coupling condenser 41 and the grid of this section is biased by a separate biasing source 42 connected in series with the grid leak 35. Items 43, 44 and 45 represent a coupling condenser, grid leak and biasing source for the upper or input triode section of the valve 40, while items 46 and 47 are grid leak resistances for the push-pull valves 28 and 29, respectively, the output of which is combined by means of a transformer 48 with a center tapped primary connected to ground or cathode through the high tension source 49 in a manner well known. Valves 28 and 29 may be indirectly heated valves in place of the directly heated type shown. Item 50 is a common grid biasing source for the valves 28 and 29 arranged in a known manner.

Another application of circuits as shown in Figures 6 and 7 is the production from an oscillatory voltage source having two terminals, one of which is connected to earth of a symmetrical control voltage for application to a pair of deflecting plates of a cathode ray tube such as a television reproducer type. A further application of a circuit in accordance with the invention is in place of a transformer arrangement of the push-pull type for coupling a two-wire line, one wire of which is earthed, such as a concentric high frequency cable, to a two-wire line, the conductors of which are to be symmetrical to earth. The circuits of this invention are particularly to be recommended in those cases where owing to the wide range of frequencies to be transmitted, such as in the case of television signals, the usual transformer arrangements are not satisfactory or convenient.

Figure 8 shows a modification wherein the potential on the datum terminal *b*, in relation to which the input voltage on the terminal *a* as well as the output voltage on the terminal *c* are meas-

ured, can be put at any desired potential in relation to earth potential. For example, if v_0 be a variable potential on the terminal *b* in relation to earth (terminals *e* and *f*) and $v_1 = v_0 + u$, the corresponding potential on the terminal *a*, then the potential v_2 on the terminal *c* is equal to $v_0 - u$. As will be obvious from the figure, the sum voltage $v_0 + u$ will be set up between the terminals *g* and *f* and the difference voltage $v_0 - u$ will occur between the terminals *c* and *f*. v_0 may, for example, be a modulating frequency alternating voltage, and u a high frequency carrier wave voltage which is to be modulated in accordance with v_0 . From the sum and difference voltages between the terminals *c* and *g*, respectively, and earth, a modulated frequency ω can be derived at terminals *h*, *j* by means of a push-pull modulation circuit as shown, in which 51 and 52 are resistances and 53 and 54 rectifiers which may be of any type, such as diodes or thermionic valves. Here again there is the advantage of elimination of transformers which, especially where the frequency range involved is wide, tend to be expensive and to introduce distortion.

As will be evident from the above, the invention is not limited to the specific circuits and methods disclosed and described herein for illustration and the underlying principle and inventive concept are susceptible of numerous variations and modifications differing from the embodiments illustrated and coming within the broader scope and spirit of the invention as defined in the appended claims. The specification and drawings are intended accordingly to be regarded in an illustrative rather than a limiting sense.

I claim:

1. A four-pole network having an input and an output, a potential divider connected between an input terminal and an output terminal of said network so as to be in series relation with both said input and output, an electron discharge device having at least a cathode, a grid and an anode, a coupling connection from an intermediate point of said potential divider to said grid, a connection from said anode to said output terminal, and a further connection from said cathode to both the remaining input and output terminals of said network.

2. A four-pole network having an input and an output, a potential divider connected between an input terminal and an output terminal of said network so as to be in series relation with both said input and output, an electron discharge device having at least a cathode, a grid and an anode, a coupling connection from an intermediate point of said potential divider to said grid, a load impedance and a high potential source in the anode circuit of said device, a capacitative connection from said anode to said output terminal, and a connection from said cathode to both the remaining output and input terminals of said network.

3. A four-pole network having an input and an output, a potential divider connected in series between an input and an output terminal of said network, an electron discharge device having at least a cathode, a grid and an anode, a coupling connection from an intermediate point of said potential divider to said grid, a load impedance and a high potential supply source in the anode circuit of said device, a conductive connection between the anode and said output terminal including a further high potential source connected in opposition to said first source, and a connec-

tion from said cathode to the remaining input output terminals of said network.

4. In a network as claimed in claim 1, including a condenser connected between said grid and said first mentioned input terminal.

5. In a network as claimed in claim 1, wherein said potential divider is comprised of a high ohmic resistance and said intermediate point forms approximately the center thereof.

6. In a network as claimed in claim 1, wherein said potential divider consists of a high ohmic inductance and said intermediate point is at approximately the center thereof.

7. A four-pole network having an input and an output, a potential divider connected in series between an input terminal and an output terminal of said network, an electron discharge device having at least a cathode, a grid and an anode, a coupling connection from an intermediate point of said potential divider to said grid, a connection from said anode to said output terminal, and a further connection from said cathode to both the remaining input and output terminals of said network, said intermediate point

being chosen in respect to the constants of the remaining circuit elements such that the phase of the output potential of said network is shifted by substantially 180° with respect to the phase of the impressed input potential and that the amplitude of the output potential is substantially independent of amplification constant of said valve.

8. A phase reversing system comprising an electron valve having an input and an output, means for impressing a potential upon said input, means for deriving a corresponding potential of reversed phase from said output, and means for substantially suppressing the effect of the amplification of said valve.

9. A phase reversing system comprising an electron valve having an input and an output, means for impressing a potential upon said input, means for deriving a corresponding potential of reversed phase from said output, and inverse feedback means for substantially suppressing the effect of the amplification of said valve.

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