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H. CHIREIX

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DEPHASING OR PHASE-SHIFTER CIRCUIT

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Fig. 1

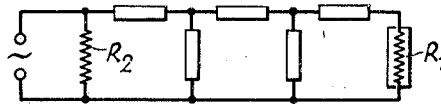


Fig. 2

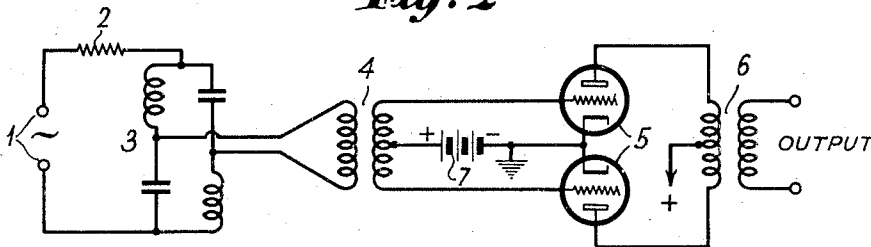


Fig. 3

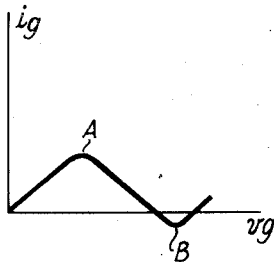


Fig. 4

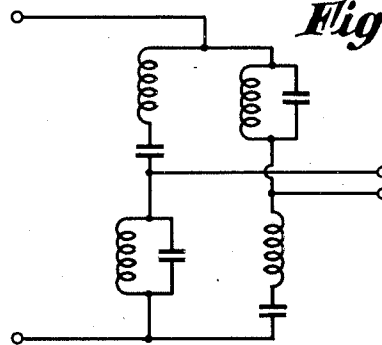


Fig. 5

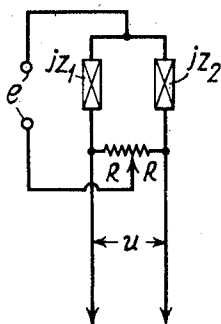
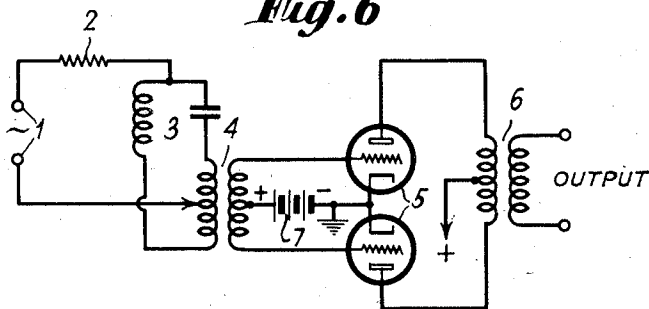


Fig. 6



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DEPHASING OR PHASE-SHIFTER CIRCUIT

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2 Claims. (Cl. 178-44)

It is known in the prior art that the iterative impedance in the band-pass of an electric filter is a real quantity. It is for this reason that the filter is terminated generally by a pure resistance having a value equal to the iterative impedance of this filter for a particular value of the frequency contained in the band-pass. In view of this fact, the phase of the voltage at the output end is caused progressively to lag with respect to the input voltage in a measure as the frequency increases within the band-pass width. It is easy to see in the light of the equations underlying filters that it is possible to obtain the opposite result, that is, an advancing or leading shift of the phase of the output voltage by choosing for the output impedance a negative resistance without altering the cut-off limits or the width of the band-pass filter.

Such a resistance may be formed by different ways and means basically known in the art, that is, either by means of multi-electrode tubes predicated upon secondary-emission phenomena or on negative or reverse coupling (dynatron, electron-oscillation or retarding-field tubes) or by employing magnetrons of the split-anode type, or else by using electron multipliers, etc.

In these conditions, however, the input impedance of the filter inside the band-pass also is found to be a negative resistance. Thus, in order to avoid an unstable state, a positive resistance (sufficiently high when in series, or sufficiently low when in parallel) is inserted at the input end of the filter in order that the total apparent resistance may be positive.

For a better understanding of the invention, reference will be had to the accompanying drawing, wherein Fig. 1 is a schematic representation of a filter circuit embodying the present invention, Fig. 2 is a circuit of a particular embodiment of the invention, Fig. 3 is the characteristic curve of a negative resistance device utilized in the invention, Fig. 4 is an alternative bridge circuit capable of use in Fig. 2, Fig. 5 is a modified bridge circuit, and Fig. 6 is the circuit of Fig. 2 transformed to include the bridge circuit of Fig. 5.

In the circuit scheme of Fig. 1 showing a T-type filter of ladder structure R_1 is a negative resistance employed in the output of the filter according to the invention and R_2 is a positive resistance at the input end of the filter in order that the total apparent resistance may be positive thereby avoiding the instability. A more particular embodiment shall now be given in more detail, namely, that of a dephaser or phase shifter whose band-pass extends from zero frequency to infinite frequency. Such a dephaser resulting in a phase lag at the output end may be formed by using one or more meshes in a

Wheatstone bridge whose arms are formed by pure reactances, for instance, two self inductances and two capacities.

The band-pass of such a filter, in fact, is determined by the space or interval in which the two groups are of opposite signs, that is, in the present instance from zero to infinity, and the iterative impedance by

$$Z_0 = \sqrt{L/C}$$

The iterative impedance is thus constant for all frequencies and the filter may be terminated by a resistance R in such a manner that $R^2 = L/C$, or

$$R = \sqrt{L/C}$$

The output voltage is thus equal to the input voltage for all frequencies, but undergoing a progressive backwards or lagging phase shift as the frequency increases.

Also according to the present invention $R^2 = L/C$, whereas

$$R = -\sqrt{L/C}$$

that is by employing a negative resistance.

In this case the output voltage is still equal to the input voltage for all frequencies, but it is dephased gradually in a leading sense when the frequency increases. The input impedance, besides, will be equal to

$$-\sqrt{L/C}$$

and thus be negative, and a positive resistance is necessary to stabilize the whole arrangement or assembly. Thus, the circuit scheme in Fig. 2 is obtained which just represents a particular or exemplified embodiment.

The source of current 1 by way of a positive resistance 2 feeds the bridge 3. Across the other diagonal of the bridge there is preferably connected a step-up transformer 4 which in turn is connected to two triodes (or multi-electrode tubes) 5 symmetrically arranged. The output is delivered to the secondary of transformer 6. The negative resistance is simply obtained by employing the secondary emission of the grid in the region where the grid is negative. In fact it is known in the prior art that with many triodes, characteristics $i_g = f(v_g)$ such as shown in Fig. 3 can be obtained, that is characteristics having a negative slope between A and B. Thus by the aid of the source of current 1, the operating point is chosen so as to be situated in the straight part of this region or range A-B.

The transformer 4 is not liable to cause appreciable disturbances if it is properly calculated for the range of desired frequency band (low leakage, low magnetizing current). Besides, it has the advantage of adapting or matching more easily the (high) negative resistance to the

iterative impedance of the network, which is generally much lower.

Naturally, there are conceivable numerous other ways and means adapted to design circuit organizations of the same nature. For instance, a symmetric arrangement is not indispensable, although preferable; neither is the provision of the transformer 4.

Also the negative resistance may be obtained in a different manner. The bridge itself may be designed in a different way, for instance, in a manner as shown in Fig. 4, where two arms are formed by a resonant circuit and the two other arms by an anti-resonant circuit, the resonant and anti-resonant frequencies coinciding. With such an organization a constant iterative impedance is again obtainable for all frequencies and a range extending from zero frequency to infinite frequency, while the total rotation of the phase is doubled.

The invention is particularly advantageous when applied in amplifiers where reverse feedback is employed in order to increase the stability of amplification or to reduce distortion. It is known in the prior art that the use of negative feedback is limited by the rotation or shift of the phase introduced by the amplifier, such phase rotation causing oscillating. By introducing a dephaser of a nature such as described, causing a shift in a leading sense in the path of the negative feedback, it is possible to more or less completely compensate the dephasing caused by the amplifier. Another modified embodiment which is more economical so far as circuit material is concerned, is as follows:

A network in the form of a complete bridge containing two reactances jZ_1 and two reactances jZ_2 may be replaced by a half bridge scheme, according to Fig. 5, which contains only one reactance jZ_1 and another reactance $jZ_2 (j=\sqrt{-1})$.

There thus results the expression

$$\frac{e}{u} = \frac{(Z_1 + Z_2) + j \left[\frac{Z_1 Z_2}{R} - R \right]}{Z_2 - Z_1} \sqrt{\frac{(Z_1 + Z_2)^2 + \left[\frac{Z_1 Z_2}{R} - R \right]^2}{(Z_1 + Z_2)^2 - 4Z_1 Z_2}}$$

It is seen from this expression that for $R^2 = -Z_1 Z_2$ $e/u = 1$.

The band-pass is always defined by $Z_1 Z_2 < 0$, but the output voltage is more constant when R^2 differs from $-Z_1 Z_2$ than in the case of a complete network fed by a constant voltage.

On the contrary, it will be seen that the dephasing as given by the expression

$$\tan \phi = \frac{\frac{Z_1 Z_2}{R} - R}{Z_2 + Z_1} \quad 10$$

changes its sign when R changes its sign, all other things remaining equal.

Thus everything being taken into account, Fig. 2 changes into Fig. 6 where the same reference numerals designate the same elements. One of the input leads is connected to the mid-point of the primary of transformer 4; also here the resistance 2 plays the part of a stabilizing resistance.

If it is desired, besides, to obtain a reduction of amplitude in the low-frequency and in the high-frequency ranges, a network may be constructed in the form of a band-pass filter comprising reactances jZ_1 and jZ_2 , for instance, in the form of two anti-resonant circuits tuned, respectively, to the cut-off frequencies.

What I claim is:

1. A circuit for shifting the phase of the output voltage with respect to the input voltage comprising input and output terminals, a series resistance connected to one of the input terminals, a series resonant circuit including an inductance and a capacity connected between said resistance and the other input terminal, a second series resonant circuit in parallel to the first series circuit with its inductance and capacity in reversed relation with respect to the corresponding elements of the first circuit, a transformer having its primary connected to each junction point of the inductance and capacity of the respective resonant circuits, and a negative resistance device connected between the transformer secondary and the output terminals.

2. A circuit as defined in claim 1 wherein the negative resistance device comprises a pair of push-pull electron discharge tubes, the grids of which are positively biased.

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