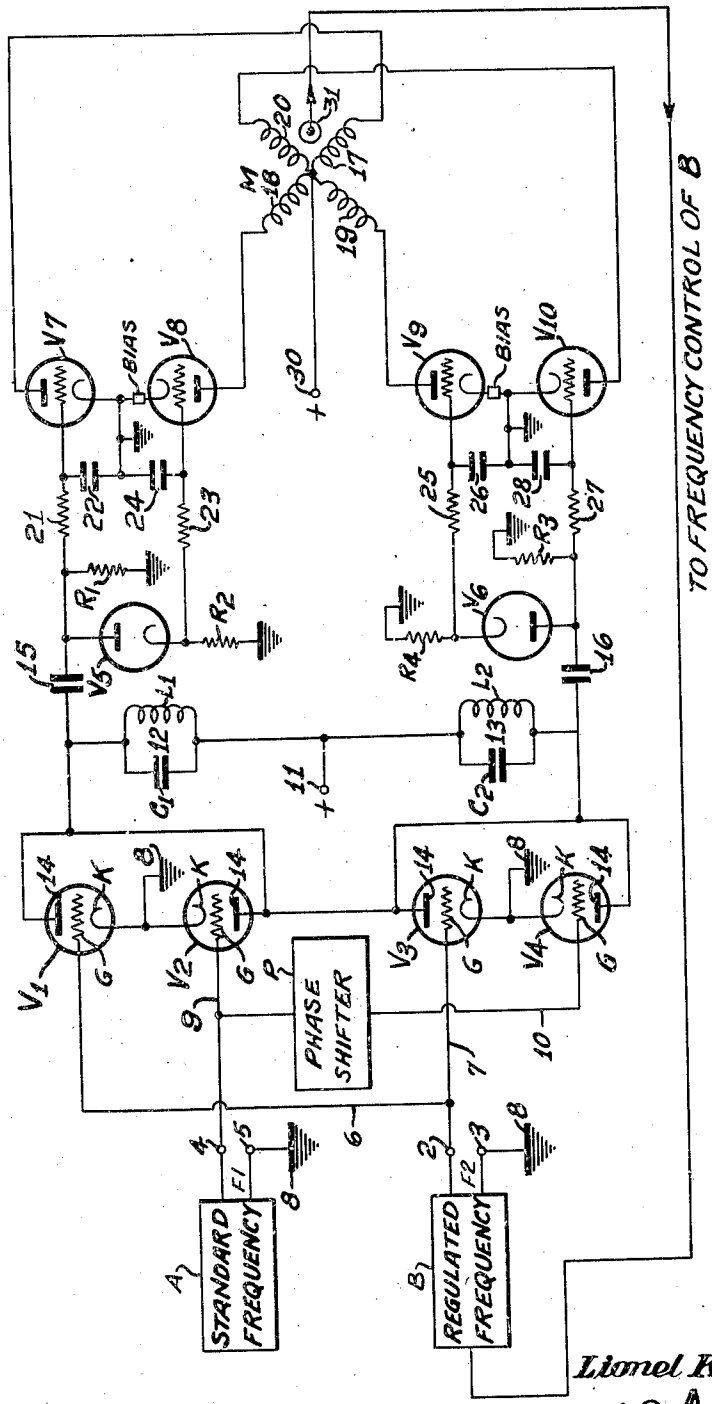
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FREQUENCY COMPARATOR

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FREQUENCY COMPARATOR

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This invention relates to frequency comparators and more particularly to frequency comparators of the electro-mechanical type.

Devices of the type referred to are usually employed for the purpose of indicating and/or utilizing any frequency difference which may occur between two independent frequency supply sources.

In most devices of the aforesaid type the frequency of an unstabilized frequency supply source is compared with a reference frequency derived from a stabilized frequency source such as a crystal controlled oscillator or the like, and any difference between the two utilized to control the frequency of the unstabilized source.

In one known system of this type the armature of a two phase motor is mechanically coupled to the frequency controlling element of the unstabilized frequency source. Alternating potentials from the stabilized and unstabilized frequency supply sources are mixed in a pair of split phase balanced modulators. The output beat frequencies from the balanced modulators are applied to the stator windings of the motor in such a manner as to produce a field which rotates at the beat frequency. The direction of field rotation is such that the armature of the motor is actuated to cause the frequency of the unstabilized source to be varied to a value such as will reduce the frequency of the beat in the output of the modulators to zero.

In the known system above referred to, the separate balanced modulators are fed through individual balanced transformers. These transformers are difficult to manufacture when the frequencies to be applied to them are high and particularly so when the balanced transformer is tuned.

The object of the present invention is to provide a frequency comparator of the electro-mechanical type in which the necessity for employing balanced transformers to feed the modulators is avoided.

The above objective is achieved by a frequency comparator in accordance with the present invention comprising in combination, a pair of resonant circuits, means for feeding alternating potentials from one frequency supply source to each of said resonant circuits in like phase, additional means for feeding, in phase, alternating potentials from a second frequency supply source to one of said resonant circuits and in phase quadrature to the other of said resonant circuits, separate rectifying means associated with each of said resonant circuits, means for deriving from the output of each of said rectifying means two separate potential of equal amplitude and opposite phase, means for utilizing said two separate potentials to produce a rotating magnetic field, and indicating and/or control means actuated by said rotating magnetic field, for the purpose hereinafter explained.

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For a more complete understanding of the invention and the manner in which it is to be carried out attention is now directed to the following description in connection with the accompanying drawing which illustrates one practical embodiment of the invention.

Referring to the drawing, independent frequency supply sources, generally indicated by the rectangles A and B, are connected to the terminal 4—5 and 2—3 respectively.

The source A provides alternating potential of substantially constant frequency F1 such as may be obtained for example from a crystal controlled oscillator. This source is the reference frequency and is hereinafter referred to as the standard frequency.

The source B provides alternating potentials of variable frequency F2 such as may be obtained for example from an unstabilized oscillator in a radio frequency transmitter or the oscillator of a heterodyne receiver.

The respective outputs F1 and F2 of the stabilized and unstabilized sources A and B may be of different frequencies but are preferably substantially equal so that when they are mixed a beat note is derived which may vary between say zero and 10,000 cycles per second.

Alternating potentials of frequency F2 from the high potential terminal 2 of the source B are fed in like phase to the control grids G of the valves V1 and V3 through the leads 6 and 7 respectively. The input circuits to the valves V1—V3 are completed by connecting the terminal 3 of the source B and the cathodes K of the valves V1—V3 to ground 8.

Alternating potentials of frequency F1 from the standard frequency source A are impressed in phase quadrature relationship between the control grid G and cathode K of the valves V2—V4. The high potential terminal 4 of the source A is connected to the grid G of the valve V2 through the lead 9 and to the grid G of the valve V4 through the lead 10 and a phase shifting device P which either advances or retards the phase by 90 degrees relative to the energy fed to the grid of the valve V3.

Any convenient form of phase shifting device P which will produce the desired quadrature relationship between the alternating potentials fed

from the source A to the grids G of the valves V2 and V4 may be employed at P. The input circuits of the valves V2—V4 are also completed by connecting the cathodes K of the valves and the terminal 5 of the source A to ground 8.

The anodes 14 of the valves V1—V2 are connected together and to the positive terminal 11 of the potential supply source (not shown) through a resonant circuit 12 comprising an inductance L1 and a parallel connected capacity C1.

The anodes of the valves V3—V4 are also connected together and to the positive terminal 11 of a potential supply source (not shown) through a resonant circuit 13 comprising the inductance L2 and the parallel connected capacity C2. The operating constants of the circuits 12 and 13 are such that each circuit is caused to resonate at a frequency equal to the output frequency F1 of the standard frequency source A. The negative terminal of the aforesaid potential supply source (not shown) is connected to the ground 8.

Output potentials of the valves V1 and V2 developed across the resonant circuit 12 are applied to a rectifying device such as the diode V5 through a coupling condenser 15. Output potentials of the valves V3 and V4 developed across the resonant circuits 13 are fed to a similar rectifying device V6 through the coupling condenser 16.

As the output potentials of the valves V1—V2 are developed across a common resonant circuit 12 any difference in the output frequencies F1—F2 from the sources A and B will appear as a beat frequency across the load resistors R1—R2 of the associated rectifier V5. A similar beat frequency displaced in phase 90 degrees with respect to that appearing across the load resistor of the valve V5 will also appear across the load resistors R3—R4 of the rectifier valve V6 associated with the resonant circuit 13.

Since the frequency F2 from the source B is applied to the control grids of the valves V1—V3 in phase, while the standard frequency F1 from the source A is applied to the control grids of the valves, V2—V4 in phase displaced relation the beat frequencies which appear in the output circuits of the rectifying valves V5—V6 will have a constant phase difference determined by the phase displacement produced by the phase shifting device P. The phase difference between these beat frequencies will never change assuming that it is set by circuit element dimensions, although the frequency of the beat frequencies may change as the frequency of the wave generated in B shifts with respect to the frequency of the wave produced by the standard frequency source A.

If the frequency of the source B is the same as the frequency of the standard source A the beat frequency in the output of the valves V5—V6 is zero. If the frequency of the wave energy from B shifts from one side of the frequency of the source A to the other the beat notes in the output of the rectifier valves V5—V6 will reverse in phase, i. e. there will be a relative phase reversal in the beat notes each time the frequency of the wave energy from the source B crosses the frequency of the wave energy from the standard source A.

In the usual rectifier circuits it is customary to employ only a single output load resistor. In these circumstances the beat frequencies appearing across the single output resistor of each valve would be applied either direct or through suitable amplifying means to separate stator windings of a two phase motor. Because of the quadrature phase relationship which exists between the beat

frequency outputs of the two rectifying valves a rotating magnetic field which rotates at the beat frequency will be set up in the stator windings of the motor. The frequency and direction of rotation of the rotating field will depend upon the direction and extent of the frequency difference existing between the frequencies F1 and F2 from the respective sources A and B.

The disadvantage associated with the above arrangement is that the magnetic flux produced would not be equally distributed. In order to obtain satisfactory operation of the apparatus over a wide range of beat frequencies down to zero beat it is essential that the magnetic flux set up by the current flowing through the stator windings be uniformly distributed between adjacent windings.

In known frequency comparators of the electro-mechanical type the use of split phase balanced modulators enabled quarter phase currents of the output beat frequency to be applied to individual stator coils to develop a rotating magnetic field with uniform distribution of the flux.

In order to achieve the same object in the frequency comparator system of the present invention it is necessary to obtain from the output appearing across the load resistance of each rectifying valve, two separate potentials of equal amplitude and opposite phase.

In the present example the two desired potentials of equal amplitude and opposite phase are obtained by connecting the centre point of the load resistance of each valve to a point of fixed potential such as earth. This effectively divides each load resistance into two parts R1—R2 in the case of the valve V5 and R3—R4 in the case of the valve V6.

With the above arrangement the output voltages at the anode and cathode of each rectifying valve are displaced in phase 180 degrees and with the quadrature phase relationship already existing between the total output voltages of each rectifying valve provide an effective source of quarter phase potentials of equal amplitude. It will be readily appreciated that each of the rectifying valves V5 and V6 may be replaced by a pair of rectifying valves having separate load resistors connected in series and adapted in known manner to rectify opposite half cycles of the applied signal energy.

The beat frequency potentials of opposite phase appearing at the anode and cathode ends of the resistors R1—R2 in the output circuit of the valve V5 are applied direct or through convenient amplifying valves V7—V8 to the outer ends of the serially connected stator coils 17—18 respectively.

Similarly the potentials appearing at the anode and cathode ends of the resistors R3—R4 in the output circuit of the valve V6 are respectively applied direct or through convenient amplifying valves V9—V10 to the serially connected stator coils 19—20.

The coils 17—18 are mounted with their common axis perpendicular to that of the coils 19—20.

In the present example the anode end of the resistor R1 is connected through a radio frequency filter network comprising the series resistor 21 and shunt capacitor 22 to the grid of the amplifying valve V7. The anode of the valve V7 is connected to the positive terminal 30 of a potential supply source (not shown) through the stator winding 17. The cathode end of the resistor R2 is connected to the grid of the valve

V8 through the radio frequency filter 23—24, and the anode of the valve V8 is connected to the positive terminal 30 of the potential supply source through the stator winding 18 of the motor M.

The anode and cathode ends of the resistors R3—R4 of the valve V6 are connected in a similar manner through the filter networks 27—28 and 25—26 to the valves V10—V9 to supply energizing beat frequency potentials of opposite phase to the stator windings 20—19 respectively.

Due to the fact that the control grids of the valves V8 and V9 are respectively connected to the cathode ends of the resistors R2 and R4 of the valves V5—V6 respectively which are positive with respect to ground, a source of biasing potential is included in the cathode circuit of valves V8 and V9 to obtain the correct operating conditions for these valves.

The quarter phase voltages applied to the windings 17—18, 19—20 set up a rotating magnetic field the flux of which is uniformly distributed between adjacent stator windings. As previously pointed out the frequency and direction of rotation of the rotating field will depend upon the direction and extent of the frequency difference existing between the frequencies F1 and F2 from the respective sources A and B.

An armature 31 of magnetizable material is arranged to have freedom of rotation about the intersection of the axes of the coils 17—18, 19—20.

When waves of different frequency F1—F2 emanate from the sources A and B the action of the system is such that the armature will rotate at an angular speed equal to one revolution per cycle of the difference frequency.

The direction of angular rotation of the armature depends upon whether the frequency F2 from the source B is higher or lower than the frequency F1 from the standard frequency source A.

The provision of a mechanical link 32 in any convenient manner between the armature and the frequency controlling element of the source B provides a ready means for automatically maintaining synchronism between the frequencies being compared.

The arrangement of the linkage should be such that the movement of the armature of the motor will produce an equivalent movement of the tuning element at the source B in a direction such as to cause its frequency to approach synchronism with the frequency of the standard source A.

In the present example the desired quarter phase voltages for energizing the stator windings of the motor are obtained by the use of divided load resistors in the output circuits of the rectifier valves. It is to be understood however that these quarter phase voltages may be obtained from the potentials in the output circuits of the rectifiers by the use of any conventional phase splitting arrangement either before or after amplification of said output potentials.

For example the output potentials from the separate rectifiers V5—V6 may be applied to individual phase splitting devices of the type described in Australian Patent 9,045/32 or by the use of conventional paraphase amplifiers.

The frequency comparator arrangement of the present invention has been described in its application to the maintenance of synchonism between two frequencies. It will be appreciated that the system provides a source of 2 phase currents which may be supplied to any suitable load circuit and used for any desired purpose.

Although the present example has been described with respect to the use of separate triode valves it is not to be restricted in this respect as any convenient type of valve may be employed, and the electrode systems of the valve pairs V1—V2 and V3—V4 may be housed in a common envelope. Also a single valve may be substituted for each pairs of valves V1—V2 and V3—V4 and the frequencies F1—F2 from the sources A and B applied to the control grid of each valve in the desired phase relationship in any convenient manner.

I claim as my invention:

1. The combination of a pair of circuits resonant to a predetermined frequency, means for applying two potentials to one of said circuits so that they are in phase and one of them is maintained at said predetermined frequency, means for applying said two potentials to the other of said circuits so that they are in quadrature, a pair of rectifiers each connected to respond to the potential of a different one of said circuits, and means for deriving from each of said rectifiers two potentials which are equal in amplitude and opposed in phase.

2. The combination of a pair of circuits resonant to a predetermined frequency, means for applying two potentials to one of said circuits so that they are in phase and one of them is maintained at said predetermined frequency, means for applying said two potentials to the other of said circuits so that they are in quadrature, a pair of rectifiers each connected to respond to the potential of a different one of said circuits, means for deriving from each of said rectifiers two potentials which are equal in amplitude and opposed in phase, and means responsive to said equal amplitude and opposed phase potentials for producing a rotating magnetic field.

3. The combination of a pair of circuits resonant to a predetermined frequency, means for applying two potentials to one of said circuits so that they are in phase and one of them is maintained at said predetermined frequency, means for applying said two potentials to the other of said circuits so that they are in quadrature, a pair of rectifiers each connected to respond to the potential of a different one of said circuits, means for deriving from each of said rectifiers two potentials which are equal in amplitude and opposed in phase, means responsive to said equal amplitude and opposed phase potentials for producing a rotating magnetic field, and means responsive to said magnetic field for regulating the frequency of the potential which does not have its frequency maintained at said predetermined frequency.

4. The combination of a pair of circuits resonant to a predetermined frequency, means for applying two potentials to one of said circuits so that they are in phase and one of them is maintained at said predetermined frequency, means for applying said two potentials to the other of said circuits so that they are in quadrature, a pair of rectifiers each connected to respond to the potential of a different one of said circuits, means for deriving from each of said rectifiers two potentials which are equal in amplitude and opposed in phase, and means including a plurality of windings having a common terminal and each responsive to a different one of said equal and opposed potentials for producing a rotating magnetic field.

5. The combination of a pair of circuits resonant to a predetermined frequency, means for applying two potentials to one of said circuits so that they are in phase and one of them is maintained at said predetermined frequency, means

for applying said two potentials to the other of said circuits so that they are in quadrature, a pair of rectifiers each connected to respond to the potential of a different one of said circuits, means for deriving from each of said rectifiers two potentials which are equal in amplitude and opposed in phase, means including a plurality of windings having a common terminal and each responsive to a different one of said equal and opposed potentials for producing a rotating magnetic field, and means responsive to said rotating magnetic field for producing an effect dependent on the frequency and rotational direction of said magnetic field.

6. The combination of a pair of circuits resonant to a predetermined frequency, means for applying two potentials to one of said circuits so that they are in phase and one of them is maintained at said predetermined frequency, means for applying said two potentials to the other of said circuits so that they are in quadrature, a pair of rectifiers each having a resistor connected in its cathode lead and a resistor connected in shunt to it and said cathode lead resistor and each responsive to the potential of a different one of said circuits, and means responsive to the voltage across the cathode lead and shunt resistors of each rectifier for producing potentials which are equal in amplitude and opposed in phase.

7. The combination of a pair of circuits resonant to a predetermined frequency, means for applying two potentials to one of said circuits so that they are in phase and one of them is maintained at said predetermined frequency, means for applying said two potentials to the other of said circuits so that they are in quadrature, a pair of rectifiers each having a resistor connected in its cathode lead and a resistor connected in shunt to it and said cathode lead resistor and each responsive to the potential of a different one of said circuits, means including one pair of amplifiers having their input circuits connected respectively to the cathode lead resistor and the shunt resistor of one of said rectifiers and another pair of amplifiers having their input circuits connected respectively to the cathode lead resistor and the shunt resistor of the other of said rectifiers for producing two pairs of potentials which are of equal amplitude and opposed phase.

8. The combination of a pair of circuits resonant to a predetermined frequency, means for applying two potentials to one of said circuits so that they are in phase and one of them is maintained at said predetermined frequency, means for applying said two potentials to the other of said circuits so that they are in quadrature, a pair of rectifiers each having a resistor connected in its cathode lead and a resistor connected in shunt to it and said cathode lead resistor and each responsive to the potential of a different one of said circuits, means including one pair of amplifiers having their input circuits connected respectively to the cathode lead resistor and the shunt resistor of one of said rectifiers and another pair of amplifiers having their input circuits connected respectively to the cathode lead resistor and the shunt resistor of the other of said rectifiers for producing two pairs of potentials which are of equal amplitude and opposed phase, and means including a plurality of coils having a common terminal and each connected to the anode of a different one of said amplifiers for producing a rotating magnetic field.

9. The combination of a pair of circuits resonant to a predetermined frequency, means for applying two potentials to one of said circuits so that they are in phase and one of them is maintained at said predetermined frequency, means for applying said two potentials to the other of said circuits so that they are in quadrature, a pair of rectifiers each having a resistor connected in its cathode lead and a resistor connected in shunt to it and said cathode lead resistor and each responsive to the potential of a different one of said circuits, means including one pair of amplifiers having their input circuits connected respectively to the cathode lead resistor and the shunt resistor of one of said rectifiers and another pair of amplifiers having their input circuits connected respectively to the cathode lead resistor and the shunt resistor of the other of said rectifiers for producing two pairs of potentials which are of equal amplitude and opposed phase, means including a plurality of coils having a common terminal and each connected to the anode of a different one of said amplifiers for producing a rotating magnetic field, and means responsive to said rotating magnetic field for producing an effect dependent on the frequency and rotational direction of said magnetic field.

10. The combination of a pair of circuits resonant to a predetermined frequency, means for applying two potentials to one of said circuits so that they are in phase and one of them is maintained at said predetermined frequency, means for applying said two potentials to the other of said circuits so that they are in quadrature, a pair of rectifiers each having a resistor connected in its cathode lead and a resistor connected in shunt to it and said cathode lead resistor and each responsive to the potential of a different one of said circuits, means including one pair of amplifiers having their input circuits connected respectively to the cathode lead resistor and the shunt resistor of one of said rectifiers and another pair of amplifiers having their input circuits connected respectively to the cathode lead resistor and the shunt resistor of the other of said rectifiers for producing two pairs of potentials which are of equal amplitude and opposed phase, means including a plurality of coils having a common terminal and each connected to the anode of a different one of said amplifiers for producing a rotating magnetic field, and means responsive to said magnetic field for regulating the frequency of one of said potentials which is not maintained at said predetermined frequency.

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