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G. L. USSELMAN

2,452,811

FREQUENCY DIVIDER

Filed June 30, 1944

2 Sheets-Sheet 1

Fig. 1

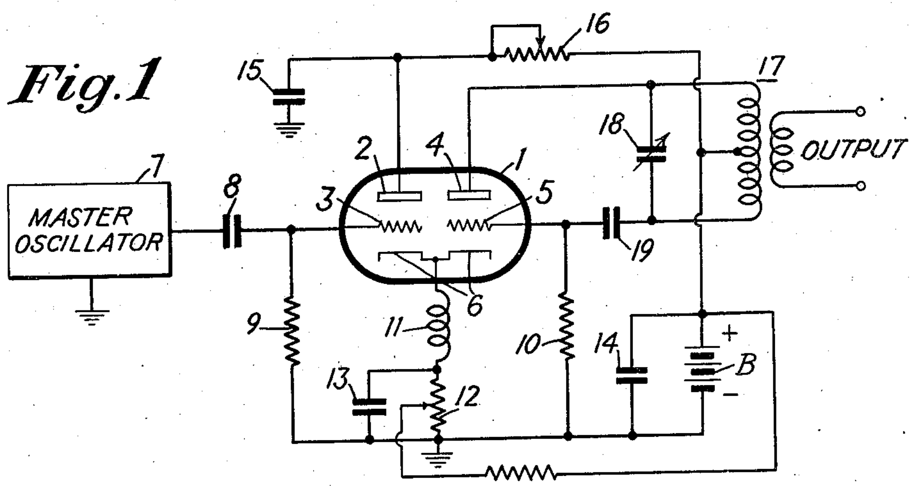

Fig. 2

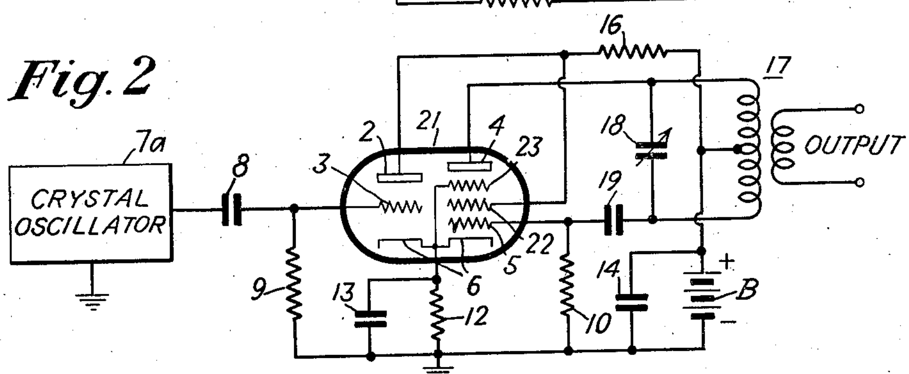

Fig. 3

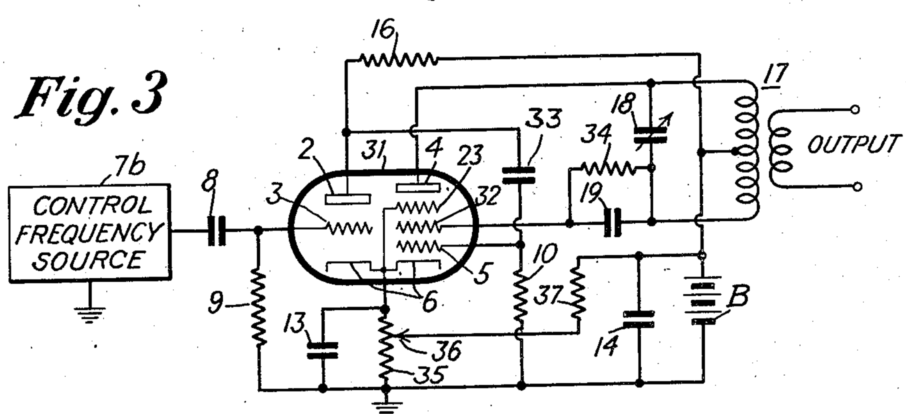

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Fig. 4

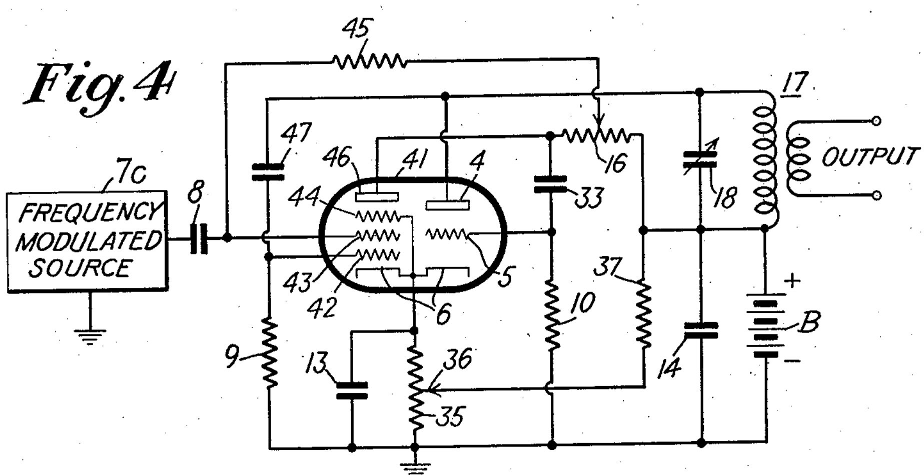
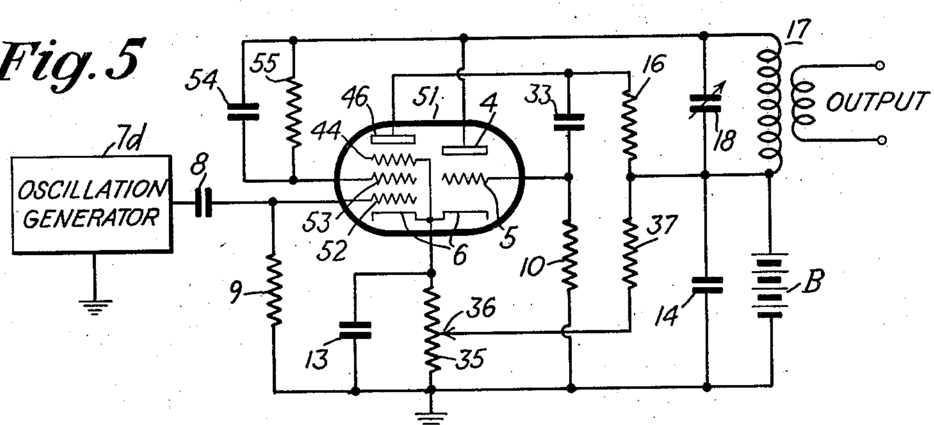


Fig. 5



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UNITED STATES PATENT OFFICE

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FREQUENCY DIVIDER

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12 Claims. (Cl. 250—36)

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This invention relates to frequency divider circuits and is adapted for general use in various electronic devices including monitoring circuits, frequency modulation transmitting apparatus, and also frequency modulation receivers.

It is an object of my invention to provide a frequency divider capable of control by an external source of alternating current where such source is that of a constant frequency oscillator or a modulated wave.

It is another object of my invention to provide a frequency divider suitable for use in monitoring a high frequency alternator.

Still another object of my invention is to provide a frequency divider having general utility, such, for example, as in a monitoring system for a frequency modulation transmitter, or again in a heterodyne receiving circuit for frequency modulated waves.

Other objects of my invention, will be inferentially brought out in the specification to follow. Essentially this invention comprises a frequency divider circuit arrangement wherein the divided frequency output is controlled by a harmonic frequency input which may be either constant or variable within a desired range of modulation frequencies.

My invention will now be described in more detail, reference being made to the accompanying drawings, in which:

Fig. 1 shows a circuit arrangement having electronic means controlled by an external source of alternating current and further electronic means coupled thereto for producing a sub-harmonic frequency output; and

Figs. 2, 3, 4, and 5 show alternative circuit arrangements for carrying out the objects of my invention.

Referring first to Fig. 1, I show therein a discharge tube 1 having two triode sections. The left-hand section includes anode 2 and control grid 3; the right-hand section includes anode 4 and control grid 5. The cathode 6 is common to both sections. A source of alternating current control potentials 7 is indicated as a master oscillator. In place of such an oscillator, however, any suitable source of control potentials, whether constant or variable, may be used. Alternative types of control potentials are, therefore, indicated as derived from units 7a, 7b, 7c, and 7d in the different figures of the drawing. The output of the source 7 is coupled across capacitor 8 to the input circuit for the left-hand section of tube 1. This input circuit includes a resistor 9 connected between the control grid 3 and ground.

The right-hand section of tube 1 has its control grid 5 connected to ground through resistor 10. There is a common cathode circuit impedance connected to ground, this impedance including

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preferably an inductance 11 in series with a resistor 12. A capacitor 13 is in shunt with resistor 12.

Anode potential is supplied to the two anodes 2 and 4 from a source of direct current B. This source is bypassed for alternating current by capacitor 14. Capacitor 15 provides an alternating current path to ground from the anode 2. The D. C. potential for anode 2 is made adjustable by means of a potentiometer 16. D. C. potential is fed to the anode 4 through one part of the primary winding of an output transformer 17. This primary has an intermediate tap connected to the battery circuit.

A variable capacitor 18 is in shunt with the primary winding of transformer 17 and forms therewith a parallel resonant circuit tuned to the divided frequency which is wanted for output. The secondary winding of transformer 17 is connected to the output leads. Feedback potentials are supplied to the grid 5 from the lower terminal of the resonant circuit, grid 5 being coupled thereto across capacitor 19.

In the operation of the circuit arrangement shown in Fig. 1, input potentials of the control frequency are supplied to the grid 3. The left-hand section of tube 1 operates as an amplifier. It develops variable potentials on the cathode 6 due to the impedance of the circuit between the cathode and ground. Since cathode 6 is common to both sections of the tube 1, control potentials are applied to the right-hand section of this tube which cause its oscillations to be locked in step with the frequency of the external source. The right-hand section of tube 1 is, however, included in a resonant circuit tuned to the divided frequency, and for this reason the output frequency is maintained in predetermined sub-harmonic relation to the input frequency. The function of the inductance 11 will be readily understood, therefore, as that of a coupling device between the two sections of the tube 1. The impedance of this inductance is low for the oscillator current of the right-hand tube section, and it is high for the amplifier current in the left-hand tube section. The choice of inductance value for the element 11 is, therefore, suitable for maintaining frequency stability in the output circuit. Capacitor 15 serves to sharpen the peaks of the amplifier current so as to increase its efficiency as a frequency controlling means.

The circuit arrangement shown in Fig. 1 has been found to possess very desirable operational characteristics, since the sub-harmonic frequency of output is readily locked in step with the control frequency, even though such frequency bears a harmonic relation thereto.

Referring to Fig. 2, the modification therein shown includes a discharge tube 21 having a triode section and a pentode section. The tube has a common cathode 6 for the two sections. In the left-hand section the anode 2 and control grid operate in the same manner as shown in Fig. 1, being controlled by input potentials through capacitor 8 and grid resistor 9. This left-hand section of the tube, therefore, operates as an amplifier.

Oscillations are generated in the right-hand section of the tube 21 where the anode 4 is in circuit with a parallel resonant circuit composed of the primary winding in transformer 17 and the adjustable capacitor 18. The control grid 5 derives feedback potentials from the resonant circuit, these potentials being fed through capacitor 19 to the grid 5, the same as in Fig. 1.

The pentode tube section includes a screen grid 22 connected to the anode 2 of the triode section, and a suppressor grid 23 connected to the common cathode 6.

The other components of the circuit arrangement of Fig. 2 are similar to those having the same reference numerals in Fig. 1 and need not, therefore, be further described. The functions of the screen grid and suppressor grid in the pentode section are conventional. However, the connection of the screen grid 22 to the anode 2 constitutes a cross-coupling means between the two sections of tube 21 and this adds to the cross-coupling effect which is inherent in the use of a common cathode. It should be noted, however, that in the circuit arrangement of Fig. 2 the inductance 11 of Fig. 1 has been omitted. There is, of course, a certain amount of voltage swing in the cathode 6 of Fig. 2 which results from the presence of the cathode resistor 12 in shunt with the capacitor 13.

The circuit arrangement shown in Fig. 3 is somewhat similar to that of Fig. 2. The functions of the control grid and the screen grid in the right hand section of tube 31 of Fig. 3 are reversed, however, with respect to the functions of these grids in Fig. 2. That is to say, control grid 5 in tube 31 is capacitively coupled across condenser 33 to the anode 2 in the amplifier section of this tube. The screen grid 32 derives feedback potentials from the parallel resonant circuit composed of the primary in transformer 17 and the adjustable capacitor 18. The feedback circuit includes capacitor 19 in shunt with a resistor 34, which supplies positive bias potential to the screen grid 32.

The cathode impedance 35 (in shunt with capacitor 13) is in the form of a voltage divider having a tap 36 thereon which connects through a resistor 37 with the positive terminal of the D. C. source B.

In the operation of the circuit arrangement shown in Fig. 3, input potentials are amplified in the left-hand (triode) section of tube 31 and are applied as control potentials across capacitor 33 and resistor 10 to the control grid 5 in the right-hand (pentode) section of tube 31. This pentode section is in circuit with a parallel resonant circuit which is tuned to the sub-harmonic frequency of the input potentials and produces the desired sub-harmonic frequency, although this frequency is locked in step with the input frequency. The operation is, therefore, quite similar to that of the circuits shown in Figs. 1 and 2.

In the circuit arrangement of Fig. 4, I show a discharge tube 41 comprising a pentode section and a triode section. For generating sub-harmonic frequency oscillations the two tube sections (or their equivalent) are disposed in a cascade-connected circuit. In tube 41 there is a common cathode 6. In the left-hand section, I show a control grid 42, a screen grid 43, and a suppressor grid 44. In the right-hand section of tube 41, I show anode 4, and control grid 5. Other components of the circuit arrangement shown in Fig. 4, if they correspond with components of the figures previously described, are given like reference numerals.

A capacitor 47 is disposed in a feedback circuit between the anode 4 and the control grid 42. Positive bias for the screen grid 43 is obtained by a connection through a portion of potentiometer 16 and resistor 45. The terminals of potentiometer 16 are respectively connected to the anode 46 and to the positive side of source B. The anode 4 in the triode section is connected to the parallel resonant circuit composed of the inductance in the primary of transformer 17 in shunt with adjustable capacitor 18. This resonant circuit is, of course, tuned to the desired sub-harmonic frequency. The feedback voltages through capacitors 33 and 47 are in phase opposition, and hence there is no need to develop a voltage swing at more than one end of the tank circuit 17, 18. The screen grid 43 derives control potentials from the frequency stabilizing or frequency modulated source 7c. The operation of the circuit arrangement shown in Fig. 4 will be readily understood, since it will be seen that the two sections of tube 41 are cross-coupled so as to deliver feedback potentials from one to the other in phase opposition, and the frequency of the triode section is controlled by the resonant circuit. Furthermore, the pentode section, although aperiodic, is nevertheless locked in step with the input potentials derived from the source 7c.

Fig. 5 is similar to Fig. 4 with the exception that the functions of the first and second grids in the pentode section of tube 51 are reversed as compared with their functions in Fig. 4. That is to say, the control grid 52 is coupled to the source of input potentials, while the screen grid 53 is coupled to the anode 4 in the triode section through capacitor 54 in shunt with resistor 55. The other components of the circuit arrangement are coordinated similarly to corresponding components in the circuit arrangement of Fig. 4, and need not, therefore, be described. The operation of the circuit shown in Fig. 5 will also be understood to be such as to lend itself to frequency stabilization in a divider circuit arrangement.

I claim:

1. A frequency dividing circuit comprising two cooperating electron discharge devices, A and B, each having a cathode, an anode, and at least one grid, a common cathode impedance connecting said cathodes to ground, means including a source of direct current connected negatively to ground and positively to said anodes for producing electronic emission in said discharge devices, aperiodic input circuits connected between one grid of each device and ground, means including input terminals coupled to a grid in device A whereby the emission in this device is controlled by alternating potentials from a given source, a parallel resonant circuit coupled between the anode of device B and a point of fixed reference potential, said resonant circuit being broadly tuned to a band of frequencies including the output frequency from said dividing circuit, means coupling the output circuit of device A to the input circuit of the device B, and feedback means for coupling the output circuit of device B to a grid in device

A, said dividing circuit being further characterized in that oscillations in the two devices A and B are maintained in harmonic relation one to the other.

2. A frequency dividing circuit according to claim 1 in which device A is of the pentode type; the first grid therein is coupled to the output circuit of device B; the second grid therein is biased as a screen grid and is controlled by alternating potentials from said given source; and the third grid is a suppressor grid.

3. A frequency divider circuit subject to control by alternating potentials from an external source, said circuit comprising a pair of electron discharge devices each having a cathode, an anode and at least one grid, means for controlling the emission in the first of said devices in accordance with the alternating potentials of said external source, a frequency determining circuit coupled to the anode in the second of said devices and to a point of fixed reference potential, an aperiodic input circuit connected between ground and a grid in each of said devices, and a common cathode impedance connected between said cathodes and ground and constituting means for locking in step the oscillations generated in the second said device and the controlled oscillatory emission in the first said device, whereby the output from the second device is maintained in sub-harmonic relation to the frequency of said external source.

4. A frequency divider circuit according to claim 3 wherein said common cathode impedance possesses a frequency discriminating characteristic such that it offers a relatively high impedance to the oscillatory potentials of the first said device and a relatively low impedance to the oscillatory potentials of the second said device.

5. A frequency divider circuit according to claim 3 and including means for applying an adjusted D. C. bias potential to the cathodes of said devices with respect to ground potential.

6. In a frequency divider circuit to be controlled by oscillatory energy of fundamental frequency, a pair of electron discharge systems each including an electron source, an anode and a control electrode, biasing circuits connected between the electron source and control electrode of each system, connections to the anode and electron source of each system for maintaining the anodes electro-positive relative to the electron source, connections for applying said oscillatory energy to the control electrode of one system, a circuit tuned to resonance at a sub-harmonic frequency coupled to the anode of the other system, connections to the electrodes of the other system such that the same generates oscillatory energy in said resonant circuit of a sub-harmonic frequency and a common impedance connected between the electron source of both of said systems and the control elcetrode of both systems, said common impedance being high with respect to current of said fundamental frequency and constituting means for locking in step the oscillations of sub-harmonic frequency generated in said second system and the oscillatory energy fed to the control electrode of said first system.

7. In a frequency divider circuit to be controlled by oscillatory energy of fundamental frequency, a pair of electron discharge systems each including an electron source, an anode, and a control electrode, biasing circuits including a common impedance connecting the control electrode of each system to the electron source of each system, connections to the anode and electron source of each system for maintaining the anodes electro-positive relative to the electron source, connections for applying said oscillatory energy to the control electrode of one system, a circuit tuned to resonance at a sub-harmonic frequency coupled to the anode of the other system, a feed back coupling between said resonant circuit and the control electrode of said other of said systems such that oscillations of said sub-harmonic frequency are generated in said resonant circuit, said common impedance constituting means for locking in step the oscillations generated in said second system and the oscillatory energy fed to the control electrode of said first system.

8. A frequency divider as recited in claim 6 wherein said common impedance is an inductor.

9. A frequency divider as recited in claim 7 wherein said common impedance is a resistor adjustably connected to a source of direct current.

10. In a frequency divider circuit to be controlled by oscillatory energy of fundamental frequency, a pair of electron discharge systems each including an electron source, an anode and a control electrode, an additional grid-like electrode in one of said systems, biasing circuits connected between the electron source and control electrode of each system, connections to the anode and electron source of each system for maintaining the anodes electro-positive relative to the electron source, connections for applying said oscillatory energy to the control electrode of the other of said systems, a circuit tuned to resonance at a sub-harmonic frequency coupled to the anode and additional electrode of said one system and a connection between the anode of the other system and said control electrode of said one system so that said one system generates oscillatory energy in said resonant circuit of a sub-harmonic frequency and a common impedance connected between the electron source of both of said systems and the control electrode of both systems, said common impedance being high with respect to current of said fundamental frequency and constituting means for locking in step the oscillations of sub-harmonic frequency generated in said one system and the oscillatory energy fed to the control electrode of said other system.

11. In a frequency divider circuit to be controlled by oscillatory energy of fundamental frequency, a pair of electron discharge systems each including an electron source, an anode, and a grid-like electrode, one of said systems having an additional grid-like electrode, biasing circuits including a common impedance connecting a grid-like electrode of each system to the electron source of each system, connections to the anode and electron source of each system for maintaining the anodes electro-positive relative to the electron source, connections for applying said oscillatory energy to a grid-like electrode of one system, a circuit tuned to resonance at a sub-harmonic frequency coupled to the anode of the other system, cross couplings between the anode of each system and a grid-like electrode of the other system, the arrangement being such that oscillations of said sub-harmonic frequency are generated in said resonant circuit, said common impedance constituting means for locking in step the oscillations generated in said other system and the oscillatory energy fed to the grid-like electrode of said one system.

12. In a frequency divider circuit to be controlled by oscillatory energy of fundamental frequency, a pair of electron discharge systems each including an electron source, an anode, and a

control electrode, an additional grid-like electrode in one system, biasing circuits including a common impedance connecting the control electrode of each system to the electron source of each system, connections to the anode and electron source of each system for maintaining the anodes electro-positive relative to the electron source, connections for applying said oscillatory energy to the additional electrode of said one system, a circuit tuned to resonance at a sub-harmonic frequency coupled to the anode of the other system, a coupling between the anode of said one system and the control electrode of said other of said systems, a coupling between the anode of said other system and the control electrode of said one system, the arrangement being such that oscillations of said sub-harmonic frequency are generated in said resonant circuit, said common impedance constituting means for locking in step the oscillations generated in said other system and the oscillatory energy fed to the additional electrode of said one system.

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