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2,303,862

OSCILLATION GENERATOR AND AMPLIFIER

Filed June 1, 1940

2 Sheets-Sheet 1

Fig. 1.

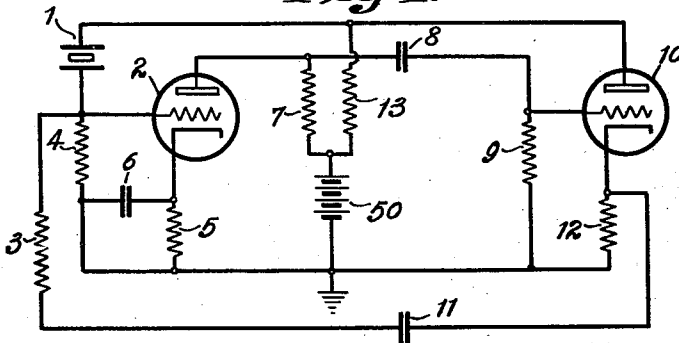


Fig. 2.

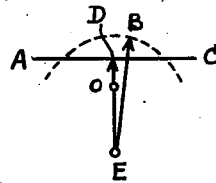


Fig. 3.

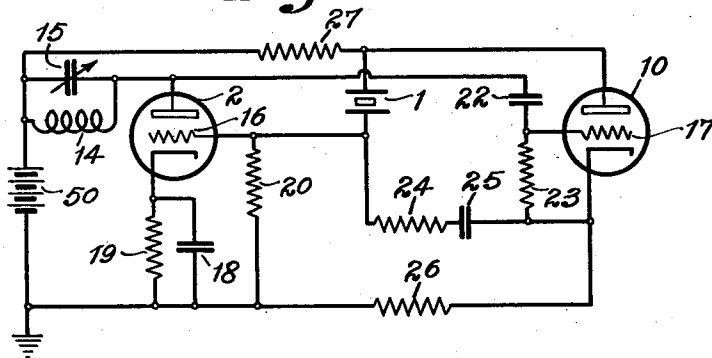
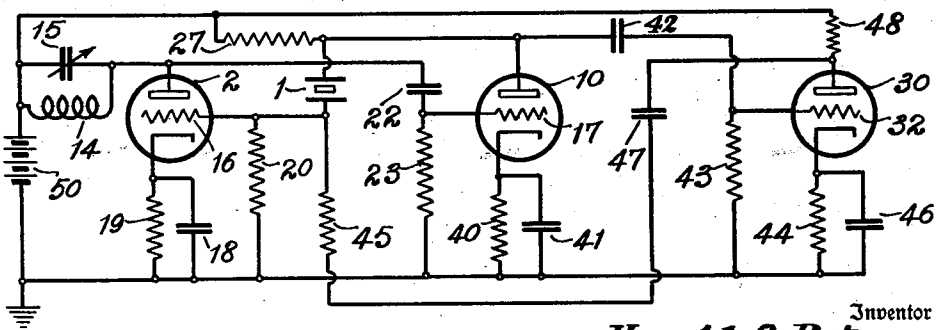


Fig. 4.



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Fig. 5.

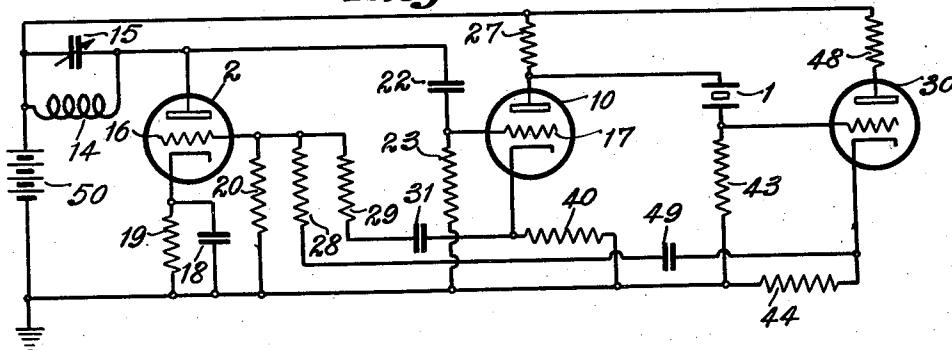


Fig. 6.

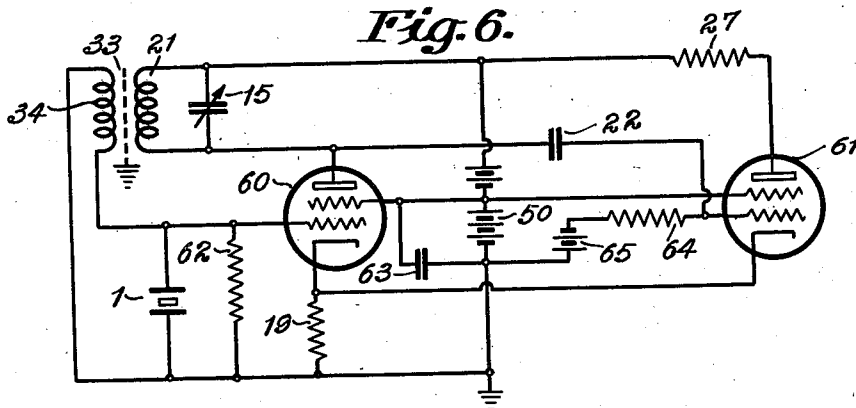
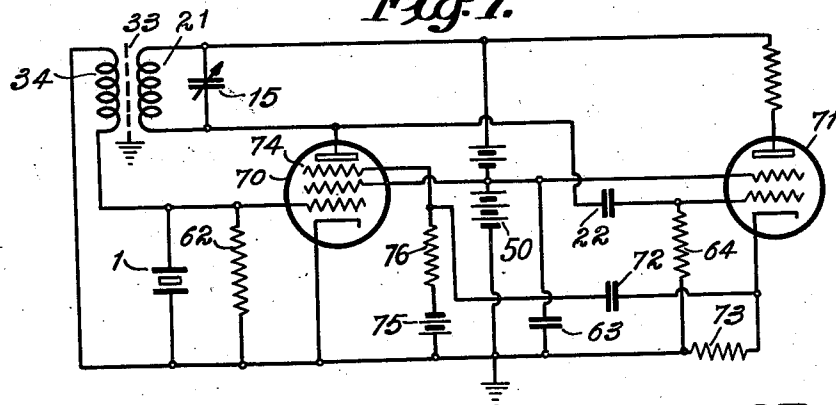


Fig. 7.



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OSCILLATION GENERATOR AND AMPLIFIER

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Application June 1, 1940, Serial No. 338,328

5 Claims. (Cl. 250—36)

This invention relates to oscillation generators and more particularly to circuit arrangements of the type which employ degeneration to improve their stability.

It is an object of my invention to provide means for improving the frequency stability of a crystal-controlled oscillator.

It is another object of my invention to provide a frequency stabilized oscillation generator of the crystal-controlled type wherein an inverse feed-back circuit is utilized to improve the frequency stability.

My invention is illustrated in the accompanying drawings which includes the following figures:

Figure 1 shows a circuit arrangement in which two electron discharge tubes are provided in combination with a piezo-electric frequency control device;

Fig. 2 is a diagram which is referred to in explaining the theory of operation of my invention;

Fig. 3 shows a modification of the system shown in Fig. 1;

Fig. 4 shows a second modification in which three discharge tubes are utilized;

Fig. 5 shows still another modification having three discharge tubes;

Figs. 6 and 7 show still further modifications in which multigrid tubes are utilized.

Referring to Fig. 1, two discharge tubes 2 and 10 are shown connected as resistance coupled amplifiers. The regenerative feed-back from the output of tube 10 to the grid of tube 2 is obtained through a path which includes the piezo-electric crystal resonator 1. An inverse feed-back circuit is also provided from the cathode of tube 10 to the grid of tube 2 through a resistance 3 and a series-capacitor 11. At the resonant frequency of the crystal 1 the impedance of this crystal is equivalent to a substantially pure resistance. The phase of the feed-back through the crystal tends to make the circuit oscillate. The phase of the feed-back through the capacitor 11 and the resistor 3, however, tends to prevent the circuit from oscillating. By making the constants of the circuit such that the feed-back through the crystal 1 is slightly greater than the inverse feed-back through resistor 3, the circuit can be made to oscillate but the frequency stability will be better than it would be without the stabilizing influence of the inverse feed-back.

This stabilizing effect will be better understood by reference to Fig. 2. Let OD represent

a small increment of voltage applied to the grid of tube 2. Let vector OE represent the inverse feed-back of this increment of voltage after it has been amplified. Let EB represent the feed-back through the crystal 1. It will be noted that EB is greater than OE by an amount slightly larger than the original increment of voltage OD. Therefore, the circuit will oscillate when the phase of the resultant feed-back is such that the point B will lie somewhere above a horizontal line AC to which the vector OD is perpendicular. Assume now that the oscillations generated tend to depart from the resonant frequency of the crystal. The vector EB would then change in phase and amplitude, as represented by the broken line which is a curve of phase and amplitude variations. Where this curve drops below the line AC the circuit will refuse to oscillate. In other words, since the condition of oscillation is dependent upon the difference between positive and negative feed-back, it follows that this difference will be such as to satisfy the requirement of oscillation over a relatively small range of frequencies. This range of frequencies is quite limited in respect to the phase variation through which the vector EB may be permitted to swing. Hence the positive feed-back is optimum for the condition of oscillation only at or near the frequency for which series-resonance through the crystal can be obtained.

Having explained the theory of operation of the circuit arrangement of Fig. 1, it may be well to describe in more detail the elements provided for the desired mutual cooperation between the tubes 2 and 10.

The cathode of tube 2 is connected to ground through a resistor 5, the by-pass capacitor 6 being in shunt with this resistor. The grid of tube 2 is resistively connected to ground through a grid leak resistor 4. Anode potential is supplied to tube 2 by a source 50, the anode circuit including a resistor 7. Another resistor 13 is used as a plate load circuit for tube 10.

The cathode of tube 10 is resistively connected to ground, the same as is the cathode of tube 2, cathode circuit resistors 12 and 5 being used. A grid leak resistor 9 is interposed between the grid of tube 10 and ground. The tube 10 is grid-controlled from potential variations on the anode of tube 2 whose output circuit is coupled to this grid across condenser 8.

The operation of the circuit arrangement shown in Fig. 1 may be well understood from the foregoing description and from an understanding

of conventional practice in resistance coupling of two amplifier stages.

In the embodiment shown in Fig. 3 the same two discharge tubes 2 and 10 are shown but these are inter-related in a somewhat different manner. The circuit arrangement includes a resonant tank comprising inductance 14 and a variable capacitor 15 both connected to the anode of tube 2. Anode potential from the source 50 is fed through the inductance 14 to the anode. The cathode circuit of tube 2 includes resistor 19 one end of which is grounded. Resistor 19 is shunted by a by-pass condenser 18. Grid 16 is provided with a grid leak resistor 20 connected to ground. Regenerative feed-back from the anode of tube 10 to the grid 16 of tube 2 is provided through the piezo-electric device 1. Direct current potential is supplied to the anode of tube 10 through resistor 27. Resistor 23 interconnects the grid 17 and the cathode in tube 10. Control potentials from the anode of tube 2 are applied through coupling condenser 22 to the grid 17.

Degenerative feed-back is derived from the cathode of tube 10 through coupling condenser 25 and resistor 24 connecting with the grid 16 of tube 2. A cathode circuit impedance 26, which may be purely resistive, is provided between the cathode of tube 10 and ground.

The circuit arrangement shown in Fig. 3, while somewhat more complicated than that of Fig. 1, has been found to be very stable in its action. The cooperation between the resonant circuit 14-15 and the piezo-electric device 1 tends to make the circuit arrangement more efficient. The principles of combined regenerative and degenerative feed-back, as followed in the design of this circuit, are substantially the same as those applied in Fig. 1.

Referring now to Fig. 4, I show a circuit arrangement including three electron discharge tubes 2, 10 and 30. The combined functions of these tubes and their inter-relationships are such that any desired phase relation between positive and negative feed-back branches may be obtained. Referring more particularly to the elements in combination, I show the tube 2 with its cathode circuit 18, 19 arranged substantially the same as in Fig. 3. The anode is also connected to a resonant circuit 14-15 and thence to a direct current source 50, the same as shown in Fig. 3. The grid 16 is also provided with a grid leak resistor 20 connected to ground. The regenerative feed-back circuit which interconnects the anode of tube 10 with the grid 16 of tube 2 includes the piezo-electric device 1. Resistor 27 serves as an anode load circuit for tube 10. The cathode circuit of tube 10 includes resistor 40 shunted by capacitor 41, each of these elements being grounded at one end. Grid leak resistor 23 is disposed between the grid 17 and ground, and corresponds to the like referenced element in Fig. 3. Control of tube 10 is also provided for by coupling condenser 22 between the anode of tube 2 and grid 17 of tube 10, the same as is shown in Fig. 3.

In the embodiment of Fig. 4 degenerative feed-back is obtained by means of a circuit which may be traced from the anode of tube 30 through coupling condenser 47 and thence through resistor 45 to control grid 16 of tube 2. The tube 30 is controlled through coupling condenser 42 which is interposed between the anode of tube 10 and the grid 32 of tube 30. This grid is provided with a grid leak resistor 43 connected to

ground. Anode potential is supplied to tube 30 through load resistor 48. The cathode circuit of tube 30 includes resistor 44 shunted by capacitor 46, each of these elements being grounded at one end. Due to the phase opposition between the conductive states of tubes 10 and 30 respectively, it will be seen that although feed-back energy is derived from the anodes of these tubes, one is opposed to the other and the circuit constants must, therefore, be so arranged that the feed-back from tube 10 will predominate over that which is derived from tube 30. It thus becomes important that the values of the resistors 45 and 48 shall be made subservient to this purpose.

Referring now to Fig. 5, I show another modification of the invention in which certain similarities will be observed between this circuit arrangement and Fig. 4 so that it is perhaps unnecessary to describe the circuit details other than where they are different from Fig. 4. This is especially true where like parts have been given the same reference numerals.

Referring more particularly to Fig. 5, I show how the anode of tube 10 may be coupled to the grid of tube 30 through a piezo-electric device 1. The stability of frequency control is thus introduced between these two tubes, although tube 2 is the oscillation generator per se. However, the control grid 16 of tube 2 is fed with both regenerative and degenerative potentials as follows: Regenerative potentials are impressed through capacitor 49 and resistor 28, which are in series between the cathode of tube 30 and the control grid 16 of tube 2. Degenerative potentials, however, are derived from the cathode of tube 10 and are impressed through capacitor 31 and resistor 29 to the control grid 16. The tube 10 is controlled by output energy from tube 2 impressed through coupling condenser 22 which is connected to the grid 17 of tube 10. Tubes 10 and 30, of course, work in phase opposition. Hence the regenerative and degenerative potentials derived from their respective cathodes become suitable for controlling the frequency of oscillation of the tube 2.

Referring now to Fig. 6, it is here shown that positive feed-back may be obtained through an inductively coupled circuit consisting of a transformer having a primary winding 21 and a secondary winding 34. The winding 21 is made parallel-resonant with the capacitor 15, both being connected to the anode of tube 60. An electro-static shield 33 is interposed between the primary 21 and the secondary 34.

The tube 60 is of the tetrode type. Its cathode is connected to ground through a resistor 19. The control grid is connected to ground across resistor 62. In shunt with resistor 62 is the piezo-electric device 1. This piezo-electric device is also in shunt with the terminals of the secondary winding 34. Tubes 60 and 61 are both of the screen grid type, the screen grids themselves being supplied with suitable positive potential from the source 50. The screen grids are also capacitively by-passed to ground through capacitor 63. The anode of tube 60 is coupled to the control grid of tube 61 through coupling condenser 22. The control grid of tube 61 may, if desired, be negatively biased by means of a source 65, potential from which is fed to the control grid through resistor 64. The positive terminal of source 65 is grounded. A load

resistor 27 is interposed between the source 50 and the anode of tube 61.

The circuit arrangement of Fig. 6 operates as follows:

Maximum current flows through the crystal 1 at its series-resonance frequency. The inverse feed-back is obtained by causing the plate current of tube 61 to flow through the cathode resistor 19, which is also common to the cathode of tube 60. Regenerative feed-back is supplied to the control grid of tube 60 by virtue of the intercoupling between the primary and secondary windings 21 and 34 respectively.

Referring now to Fig. 7, another alternative embodiment is shown having only two tubes 70 and 71. The tube 70 is of the pentode type, while tube 71 is a tetrode. The output circuit of tube 70 is substantially the same as that of tube 60 in Fig. 6. Also the piezo-electric device 1 is similarly disposed in shunt with the terminals of the transformer secondary 34. In Fig. 7, as in Fig. 6, the screen grids of the two tubes are supplied with suitable D. C. potential from the source 50. Both of these screen grids are capacitively coupled to ground across condenser 63. In tube 70 a suppressor grid 74 is provided, this grid being preferably negatively biased by means of a D. C. source 75, connecting through resistor 76.

The control of tube 70 is the same in Fig. 7 as in Fig. 6. Regenerative feed-back current from the anode of tube 70 flows through the transformer primary 21 and induces control potentials across the secondary 34 which is in circuit between the cathode and grid of tube 70. In Fig. 7, however, the negative feed-back is obtained from tube 71 by coupling its cathode through capacitor 72 to the suppressor grid 74. The feed-back potentials are obtained by virtue of the variable potential drop across a cathode load resistor 73, which provides a path to ground from the cathode of tube 71. The application of the negative feed-back to the so-called suppressor grid 74 is merely illustrative of a number of ways in which this degenerative action may be obtained in the tube 70. If one or more other grids were to be provided in the tube 70 any one of them might be selected for connection with the degenerative feed-back circuit. The suppressor grid has been found satisfactory for this purpose, however, in view of its control of the amplification, or transconductance, of the tube 70.

Small adjustments of the resonant frequency of any of the systems shown in the different circuit diagrams may be made by the provision of more or less reactance either positive or negative in series with the crystal resonator 1. The addition of such reactance has not been shown in the figures since its value is well understood by those skilled in the art.

I claim:

1. In combination, an oscillator including an electron discharge tube having a cathode, an anode and at least one grid, a resonant circuit connected between said cathode and said anode, two amplifier discharge tube stages connected in cascade with said oscillator, each amplifier tube having a control grid coupled to an anode of a preceding tube, a resonant regenerative feed-back circuit including a piezo-electric device

coupling the tube anode of the first amplifier stage to the control grid of the oscillator, a non-frequency selective degenerative feed-back circuit including series capacitance and resistance coupling the tube anode of the second amplifier stage to the control grid of the oscillator, and means for maintaining predominance of the regenerative potential over the degenerative potential.

2. In combination, an oscillator including an electron discharge tube having a cathode, an anode and at least one grid, a resonant circuit connected between said cathode and said anode, two amplifier discharge tube stages connected in cascade with said oscillator, the amplifier tube of the first stage having a control grid coupled to the anode of the oscillator tube, the amplifier tube of the second stage having a control grid coupled through a piezo-electric device to the anode of the first stage amplifier tube, a regenerative feed-back circuit including means having series resonance at the desired frequency for coupling the cathode of the second stage amplifier tube to the control grid of the oscillator, and a non-resonant degenerative feed-back circuit including series capacitance and resistance coupling the cathode of the first stage amplifier tube to the control grid of the oscillator.

3. A discharge tube oscillator comprising a first tube and a pair of subsequent stage tubes each tube having at least three electrodes and each having a cathode-to-grid circuit and an anode-to-cathode circuit, impedances in each of said circuits, means for coupling an anode of the first tube to a grid of the second tube, means for coupling an anode of the second tube to a grid of the third tube, means having series resonance at the desired frequency for applying regenerative energy to the grid of the first tube, this means being connected to a point on the impedance in the anode-to-cathode circuit of one tube of said pair, and non-resonant means for applying degenerative energy to the grid of the first tube, this means being connected to a point on the impedance in the cathode-to-anode circuit of the other tube of said pair.

4. A discharge tube oscillator comprising at least three tubes, each having a cathode, an anode and a grid, means for coupling the anode of the first tube to the grid of the second tube, means for coupling the anode of the second tube to the grid of the third tube, means for coupling the anode of the second tube to the grid of the first tube in a regenerative manner through a means which is series-resonant to the desired frequency, and non-resonant means for coupling the anode of the third tube to the grid of the first tube in a degenerative manner.

5. A discharge tube oscillator comprising at least three tubes, each having a cathode, an anode and a grid, means for coupling the anode of the first tube to the grid of the second tube, means for coupling the anode of the second tube to the grid of the third tube, means having series resonance for coupling the cathode of the third tube to the grid of the first tube in a regenerative manner, and non-resonant means for coupling the cathode of the second tube to the grid of the first tube in a degenerative manner.

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