AUTOMATIC OSCILLATION CONTROL

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FIG. 1

FIG. 2

CRYSTAL CURRENT
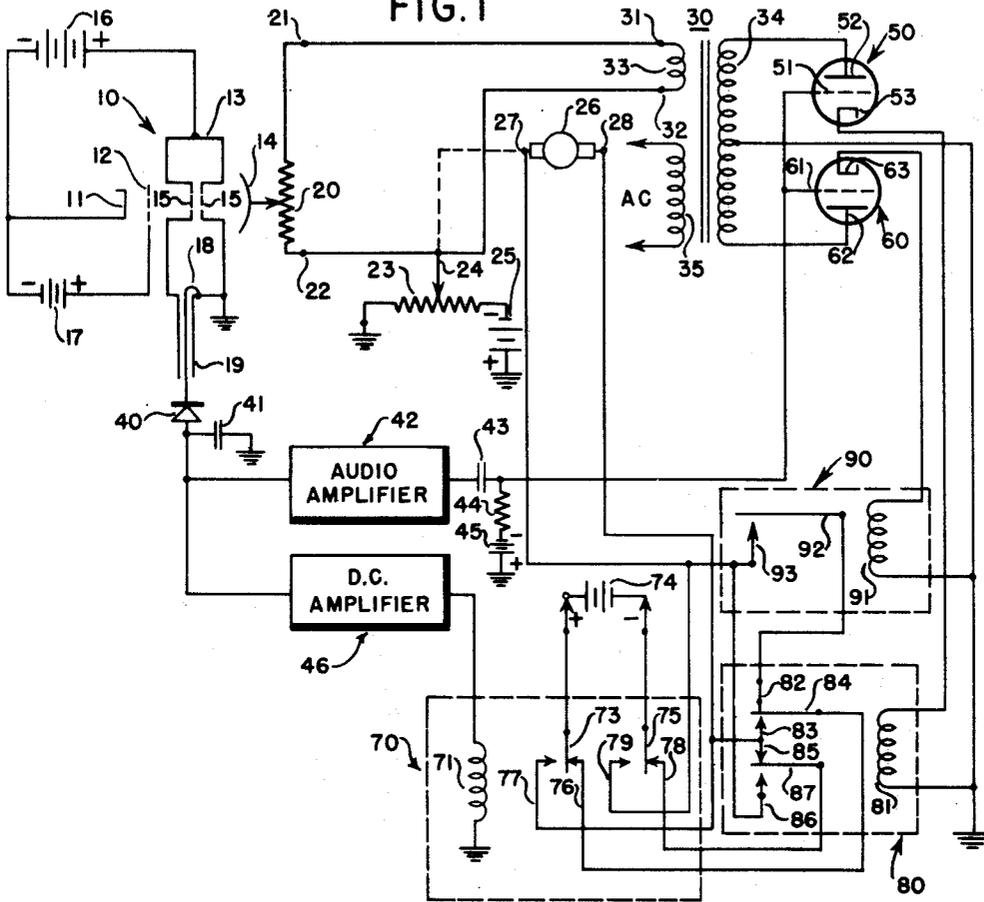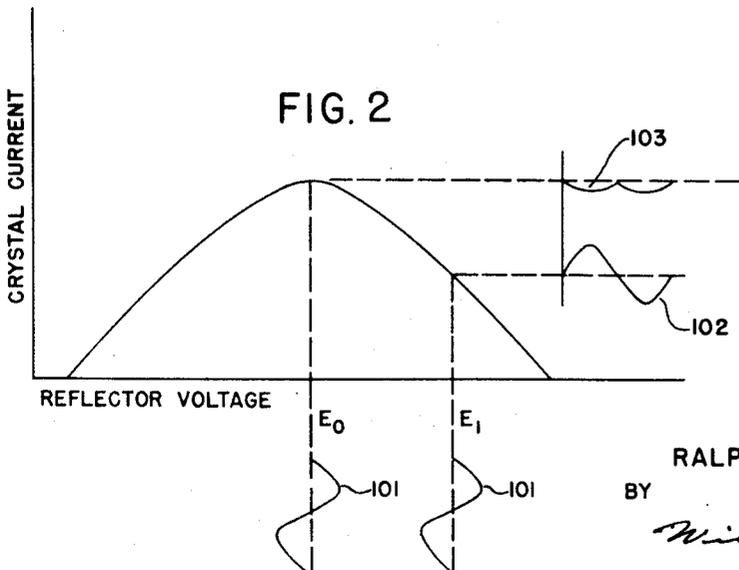
REFLECTOR VOLTAGE

E_0 E_1

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AUTOMATIC OSCILLATION CONTROL

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3 Claims. (Cl. 250—36)

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This invention relates generally to electrical apparatus and more particularly to means for automatically adjusting electron tube circuit parameters to obtain optimum operating conditions.

In certain oscillators where an ultra high radio frequency signal is to be generated use is made of a velocity-modulated vacuum tube of the reflex type. For a tube of this type to oscillate at a particular frequency whereby it furnishes maximum power output it is required that a critical voltage be applied to the reflector anode of the tube. Frequently the supply voltage for the reflector anode changes while the oscillator is in operation and sometimes when the oscillator is shut off for a while and then restarted. In certain applications where the reflector anode adjustment is not readily accessible, it may not be practical to depend on manual adjustment of the reflector anode voltage. In addition the operator may not be skilled in adjusting the reflector anode voltage properly. Accordingly, one object of the present invention is to provide a means whereby the voltage applied to the reflector anode of such a v-m tube is adjusted automatically so that oscillations will occur at a particular frequency.

Other objects, features and advantages of this invention will suggest themselves to those skilled in the art and will become apparent from the following description of the invention taken in connection with the accompanying drawings in which:

Fig. 1 is a schematic diagram of a circuit embodying the principles of this invention; and

Fig. 2 is a graph which will be used to explain the operation of this invention.

There is shown diagrammatically in Fig. 1 a reflex velocity-modulated oscillator tube 10, hereinafter referred to simply as the v-m tube 10. V-m tube 10 includes a cathode 11, control grid 12, cavity 13 and reflector anode 14. Cavity 13, which is represented in cross-section, includes two parallel grids 15 placed at right angles to the direction of flow of electrons through the tube. Customarily cavity 13 is grounded.

Battery 16 is connected between cavity 13 and cathode 11, its positive terminal being connected to cavity 13. Electrons leaving cathode 11 are thus accelerated towards the cavity grids 15 by virtue of this positive potential existing between the two elements. A second battery 17 is connected between control grid 12 and cathode 11, its positive terminal being connected to control grid 12. Control grid 12 regulates the total num-

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ber of electrons traversing between cathode 11 and cavity grids 15. The output power is taken from cavity 13 by means of a probe 18 projecting therein and leading to the external circuit through a coaxial line 19.

Reflector anode 14 is connected to the variable tap of a potentiometer 20. The ends 21 and 22 of potentiometer 20 are connected to the ends 31 and 32, respectively, of the secondary winding 33 of a transformer 30. End 22 of potentiometer 20 is connected also to the variable tap 24 of a potentiometer 23. The position of the variable tap 24 is governed by the angular displacement of a permanent-magnet (p-m) motor 26. P-m motor 26 has two input terminals 27 and 28. A battery 25 is connected across the potentiometer 23, the positive terminal of this battery being grounded. Battery 25 effectively supplies to reflector anode 14 a negative voltage with respect to cavity 13.

A portion of the output of the v-m tube 10 is taken from the coaxial output line 19 and applied to a crystal detector 40. By-pass condenser 41 is connected from one end of crystal 40 to ground.

Signals which appear in the crystal detector output are separated into alternating current (A.-C.) and direct current (D.-C.) components. The A.-C. component is amplified by a suitable audio frequency amplifier 42 and applied through a coupling network consisting of coupling condenser 43, grid resistor 44 and bias battery 45 to control grids 51 and 61 of vacuum tubes 50 and 60, respectively. The potential from bias battery 45 is sufficient to render vacuum tubes 50 and 60 nonconductive when no signal is applied to the control grids.

The D.-C. component of crystal current output is amplified by a suitable D.-C. amplifier 46 and applied to winding 71 of a D.-C. relay 70.

Anodes 52 and 62 of vacuum tubes 50 and 60, respectively, are connected to the ends of center-tapped secondary winding 34 of transformer 30. The center tap of secondary winding 34 is at ground potential. To primary winding 35 of transformer 30 is applied a suitable alternating voltage.

Cathodes 53 and 63 of vacuum tubes 50 and 60, respectively, are connected to windings 81 and 91, respectively, of reversing relays 80 and 90, respectively. The opposite ends of both windings 81 and 91 are returned to ground potential.

Movable contact 73 of D.-C. relay 70 is connected to the positive terminal of a battery 74. Movable contact 75 of D.-C. relay 70 is connected

to the negative terminal of battery 74. D.-C. relay 70 includes make-and-break fixed contacts 76 and 77 associated with movable contact 73. Relay 70 also includes make-and-break fixed contacts 78 and 79 associated with movable contact 75. When the relay is deenergized, movable contacts 73 and 75 are in contact with fixed contacts 76 and 78, respectively.

Relay 80 includes make-and-break fixed contacts 83 and 82 associated with movable contact 84, and make-and-break fixed contacts 85 and 86 associated with movable contact 87. When reversing relay 80 is deenergized, movable contacts 84 and 87 are in contact with fixed contacts 82 and 85, respectively.

Reversing relay 90 includes a movable contact 92 and a fixed contact 93. When reversing relay 90 is energized movable contact 92 is in contact with fixed contact 93.

Fixed contact 93 of reversing relay 90 is connected to terminal 27 of p-m motor 26, to fixed contact 79 of D.-C. relay 70 and to fixed contact 86 of reversing relay 80. Movable contact 92 of reversing relay 90 is connected to fixed contact 82 of reversing relay 80.

Fixed contact 83 of reversing relay 80 is connected to fixed contact 85 of reversing relay 80, to terminal 28 of p-m motor 26, and to fixed contact 77 of D.-C. relay 70. Movable contacts 84 and 87 of reversing relay 80 are connected to fixed contacts 76 and 78, respectively, of D.-C. relay 70.

The interconnections between the relays described above are such that when D.-C. relay 70 and reversing relay 90 are deenergizd and reversing relay 80 is energized, a voltage is applied to motor 26 to drive it in a forward direction. When relays 70 and 80 are deenergized and reversing relay 90 is energized, a voltage will be supplied to the motor 26 to cause it to rotate in a reverse direction. When D.-C. relay 70 is energized, the motor 26 will be driven in a forward direction regardless of the position of the other relays.

Operation of this circuit will be described first assuming that the reflector anode voltage is adjusted so that oscillations in the v-m tube 10 are not possible. Lack of oscillation will result in zero D.-C. output from the crystal detector 40. The D.-C. amplifier 46 and D.-C. relay 70 are arranged in such a manner that relay 70 will be energized. This effectively connects battery 74 directly to motor 28 and causes the latter to rotate in a forward direction. Variable tap 24 of potentiometer 23 is thereby moved and the voltage applied to the reflector anode 14 is changed accordingly. Potentiometer 23 is so constructed that variable tap 24 will rotate continuously through 360 degrees. Hence, a voltage will be reached which will allow the oscillator to become operative and supply power to the crystal detector. When such a condition occurs, D.-C. relay 70 is deenergized, the source of potential to the motor is interrupted, and the remainder of the circuit is allowed to come into operation.

When oscillations begin, the output is modulated by the small-amplitude A.-C. signal which is induced in secondary winding 33 and applied to reflector anode 14. The effects of the modulating voltage on the output of the oscillator is more clearly shown in Fig. 2. In Fig. 2 the power, as measured by D.-C. crystal current, is plotted against the reflector anode voltage. The power output curve is a resonance type curve with maximum power occurring for a reflector anode voltage of approximately E_0 volts. It is desirable that

the reflector voltage be adjusted to the optimum value of E_0 volts.

The operation of the circuit will next be explained when the reflector anode voltage, E_1, is a value greater than the optimum value, E_0 volts as indicated in Fig. 2. In Fig. 2 the sinusoidal A.-C. modulating voltage 101 has been shown superimposed upon the reflector anode voltage E_1. The resultant power output variation (indicated by the crystal current) is shown by the sinusoidal error signal curve 102.

The error signal 102 is amplified in audio amplifier 42 and applied to the control grids of vacuum tubes 50 and 60. As mentioned beforehand the bias voltage also applied to the control grids prevents either tube from conducting when the error signal is absent or of low amplitude. The vacuum tubes 50 and 60 together function as a phase detector, giving a first output when the error signal is of one phase and a second output when of the opposite phase in a manner to be described.

A sinusoidal alternating reference voltage of the same frequency as the error signal 102 is applied to the anodes of vacuum tubes 50 and 60 from secondary winding 34 of transformer 30. Since secondary winding 34 is center-tapped to ground the application of the sinusoidal alternating voltage to the plates of vacuum tubes 50 and 60 will result in voltages on these plates which are out of phase with each other. It will be assumed that for the first half-cycle of the error signal 102 the control grids of the vacuum tubes 50 and 60 are driven above cutoff, and furthermore, that the polarity of the reference signal on plate 52 is positive while that on plate 62 is negative. Under these conditions vacuum tube 50 will conduct and vacuum tube 60 will not conduct. On the other half-cycle of the error signal 102 the polarity of the signal on plate 62 will be positive and that on plate 52 negative. However, reference to Fig. 2 will show that the error signal 102 on the control grids now drives the grids below cut off. Therefore vacuum tube 60 will not conduct during either half-cycle for an error signal of the phase shown.

Reversing relay 80 is thus energized when tube 50 conducts and motor 26 is caused to rotate in a forward direction. The sense of the rotation is such as to alter the setting on potentiometer 23 so that the reflector anode voltage is decreased.

It should be evident to those skilled in the art that if the reflector anode voltage had been less than the optimum value E_0 volts, the error signal would have been reversed in phase, vacuum tube 60 of the phase detector would have conducted a current, relay 90 would have been energized, motor 26 would have rotated in a reverse direction, and the reflector anode voltage would have been increased accordingly.

As a result of this action the presence of an error signal from the crystal detector 40 will cause one of the vacuum tubes in the phase detector to conduct, and a difference of 180 degrees in phase will select which tube will conduct and hence which relay will operate.

When the reflector anode voltage reaches the proper value E_0, the error signal will be substantially of low amplitude, negative pulses as shown by curve 103 in Fig. 2. When the error signal is as shown by curve 103, neither tube 50 nor 60 of the phase detector will conduct, since neither grid is driven above cut off. Both reversing relays 80 and 90 remain deenergized, motor 26 does not

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rotate, and the reflector anode voltage is left at the optimum value of E_0 volts.

The foregoing has shown that the presence of the error signal automatically selects the proper direction for the variable tap on potentiometer 23 to travel to obtain optimum reflector anode voltage. It is only necessary for relays **80** and **90** in the plate circuits of the two phase detector vacuum tubes **50** and **60** to reverse the motor **26** in such a manner that it will adjust the reflector anode voltage in the proper direction. The circuit also provides for automatically adjusting the reflector anode voltage so that oscillations are possible.

It should be evident that the device herein disclosed may be adapted to control the operation of any specific device having a similar current-voltage characteristic.

While there has been described hereinabove what is at present considered to be a preferred embodiment of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the scope of the invention as set forth in the appended claims.

What is claimed is:

1. In combination with a reflex velocity-modulated vacuum tube including at least a reflector anode and a cavity, means for causing said velocity-modulated tube to oscillate and produce a radio frequency signal, means for modulating said radio frequency signal in a periodic manner, means for extracting the modulated radio frequency power from said cavity and producing therefrom a rectified direct-current component and an error signal alternating-current component proportional to said radio frequency power, a potentiometer, a motor acting in conjunction with said potentiometer for adjusting the value of direct voltage applied to said reflector anode, means responsive to the direct-current component in the output of said vacuum tube for energizing said motor when said direct-current component is zero, selective means for causing said motor to operate in a first direction when said error signal is of a first phase relative to the output of said modulating means, and other selective means for causing said motor to operate in a second direction when said a-c component of error signal is of a second phase relative to the output of said modulating means.

2. In combination with a vacuum tube oscillator for producing in its output a radio frequency

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signal and having at least a cavity and a reflector anode, means for modulating said radio frequency signal to produce a modulated radio frequency output signal, means for extracting a direct-current component and an alternating-current component from said modulated output signal, regulating means for adjusting the direct voltage applied to said reflector anode, means responsive to said direct voltage for actuating said regulating means to maintain said vacuum tube in a state of oscillation, and selective means sensitive to the phase of said alternating-current component relative to the output of said modulating means for causing said regulating means to operate in alternative directions depending upon such phase, to maintain the vacuum tube in a condition of maximum oscillation.

3. In combination with a radio frequency vacuum tube oscillator having at least a cavity and a reflector anode, the output frequency of said oscillator varying with the voltage applied at said anode and the output voltage reaching a maximum at the resonant frequency of said vacuum tube, direct current means for varying the voltage of the reflector anode, alternating current means in series with said direct current means for modulating the anode voltage and consequently the frequency of said oscillator, rectifier means responsive to the output of said oscillator for obtaining a direct voltage output proportional to the average oscillator output voltage and an alternating voltage output resulting from the modulation, means responsive to said direct voltage output for adjusting said reflector anode voltage to initiate or maintain oscillation and means responsive to the phase of said alternating voltage output component with respect to the phase of said modulating means to maintain the oscillations at maximum.

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