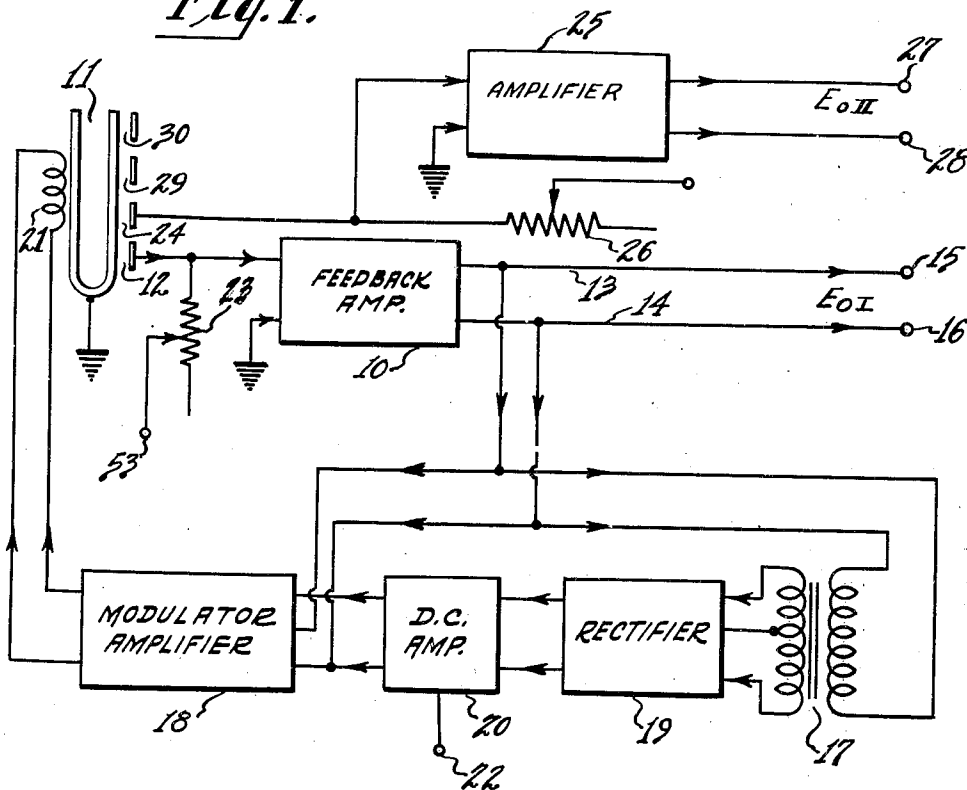


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Fig. 1.

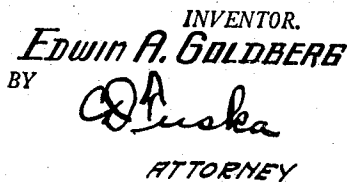


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UNITED STATES PATENT OFFICE

2,469,264

GENERATION AND MODULATION OF
ALTERNATING CURRENT SIGNALSEdwin A. Goldberg, Princeton, N. J., assignor to
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Application November 29, 1944, Serial No. 565,695

3 Claims. (Cl. 250—36)

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This invention relates to the generation and modulation of alternating current signals. It provides a stabilized generator which operates in response to an applied unidirectional voltage to deliver an alternating current signal of an amplitude which is proportional to the amplitude of the applied unidirectional voltage. It also provides modulating means whereby this generated alternating current signal may be combined with separate unidirectional voltages to produce alternating voltages, each of which is proportional to the product of the generated alternating current signal and a different one of the separate unidirectional voltages.

The illustrated form of the invention includes a high gain feedback amplifier which receives its input from a tuning fork and delivers at its output the generated alternating current signal. Connected between the output of the feedback amplifier and the tuning fork are: (1) a transformer, (2) a rectifier, (3) a direct current amplifier which functions to deliver a unidirectional voltage proportional to the difference between the amplitudes of the rectified voltage and that of the unidirectional voltage which determines the amplitude of the generated alternating current signal, (4) a modulator which responds to both the output of the feedback amplifier and the output of the direct current amplifier, and (5) an alternating current amplifier through which the tuning fork is excited from the modulator.

The tuning fork obviously may be replaced by any other suitable type of generator. While it is illustrated as provided with electrostatic pickups through which it is coupled to the feedback amplifier, it is apparent that these pickups may be replaced by magnetic pickups or the like.

Among the objects of the invention are to provide a stabilized generator which functions to deliver an alternating current signal of an amplitude which is proportional to that of a controlling unidirectional voltage; to provide a modulator which functions in response to an alternating current signal and a unidirectional voltage to deliver an alternating signal which is proportional to the product of such signal and voltage; and to provide an improved means and method of operation whereby there is made available both a generated alternating current signal of an amplitude proportional to that of a unidirectional control voltage, and one or more auxiliary alternating current signals, each of an amplitude proportional to the product of the generated alternating current signal and a different one of such unidirectional control voltages.

The invention will be better understood from

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the following description, considered in connection with the accompanying drawings, and its scope is indicated by the appended claims.

Figure 1 of the drawings is a schematic showing of the improved, stabilized signal generator and modulator, and

Figure 2 is a wiring diagram of the stabilized signal generating part of Figure 1.

In connection with these figures, it should be understood that the feedback amplifiers which perform the modulating functions are similar to the feedback amplifier which performs the signal generating function. For this reason, only the pickups to which the modulator feedback amplifiers are connected are shown in Figure 2.

The apparatus of Figure 1 includes a feedback amplifier 10, which receives its input from a tuning fork 11 through a pickup coupling 12 and delivers its output through leads 13—14. Connected to the leads 13—14 are the output terminals 15—16, a transformer 17 and one input circuit of the modulator 42 (Fig. 2) of a modulator-amplifier unit 43. The transformer 17 is connected through a rectifier 19 and a direct current amplifier 29 to another input circuit of the unit 43 and the output of this unit is applied to the driving coil 21 of the tuning fork 11.

Applied to the terminal 22 is a unidirectional voltage of an amplitude which determines the amplitude of the alternating signal delivered at the output of the amplifier 10. Applied through a resistor 23 to the pickup feeding the input of the amplifier 10 is a voltage which determines the amplitude of the vibration of the tuning fork 11, as hereinafter explained.

The input of a second feedback amplifier 25 is coupled through a pickup 24 to the tuning fork 11. The pickup 24 is connected through a resistor 26 to a source of unidirectional potential. The output delivered at the terminals 27 and 28 is an alternating voltage which has the same frequency as the tuning fork 11, and has an amplitude proportional to the product of the unidirectional voltages applied through the terminal 22 and through the resistor 26 and inversely proportional to the voltage applied through the terminal 53.

Additional pickups 29 and 30 may be provided to cooperate with other amplifiers in the same way that the pickup 24 cooperates with the amplifier 25.

In the wiring diagram of Fig. 2, the feedback amplifier 10 is shown as consisting of four stages 31, 32, 33 and 34. The first stage 31 is coupled to the tuning fork 11 through the pickup 12 and the last stage is connected to the primary winding of the transformer 17. The secondary wind-

ing of the transformer 17 delivers its output to the rectifier 19. The rectified voltage available at the output terminals of the rectifier is smoothed or filtered by a network 35 and applied to one control grid 36 of the direct current amplifier 20.

To the other control grid 37 of the direct current amplifier 20 is applied a bias potential determined by the potential drop of resistors 38 and 39. These resistors are connected between a lead 40 maintained at a positive potential of 300 volts and a lead 41 maintained at a negative potential of 300 volts. The potential developed across these resistors corresponds to the potential applied to the terminal 22 of Fig. 1 and is set at any desired value by suitable adjustment of the resistor 39.

The modulator 42, which forms part of the "modulator-amplifier" 18 of Fig. 1, is provided with two control grids 43 and 44. The potential of the grid 44 is determined by the potential drop of a resistor 45 connected in the right-hand plate circuit of the direct current amplifier 20. Since the potential drop of the resistor 45 is responsive to the potential of the grid 36, and this grid potential is determined by the output of the rectifier, it follows that the potential of the grid 44 is varied in accordance with the amplitude of the rectified voltage.

The left-hand plate circuit of the amplifier 20 is connected to a gaseous voltage regulator tube 57 which receives its operating current through the resistor 45'. The negative electrode of the regulator tube 57 is connected to the negative terminal of the 300 volt power supply. Also connected to the positive electrode of the regulator tube 57 is the cathode of the modulator tube 42. The D. C. potential of the second control grid of the modulator tube 42 is maintained at the cathode potential due to the D. C. return through the choke 46. Thus the regulator tube 57 maintains the left hand plate of the tube 20, the cathode of the modulator tube 42, and the second control grid of the modulator tube 42 at a fixed D. C. potential of +150 volts with respect to the negative terminal of the 300 volt power supply. There is applied to the grid 43 through a capacitor 47, a resistor 48 and an output lead 49 of the feedback amplifier 31—32—33—34 a part of the alternating current signal delivered by this feedback amplifier. With proper adjustments in the various parts of the circuit, the grids 43 and 44 function to make available at the output terminals of the modulator 42 alternating current of an amplitude which responds very closely to the potential drop of the resistors 38 and 39. Thus, the rectified unidirectional voltage is constantly compared with voltage drop of the resistors 38 and 39, so that the amplitude of the alternating current signal is stabilized at a value determined by the potential drop of these resistors.

The stabilized alternating current output of the modulator 42 is amplified by the amplifier 50 and supplied through leads 51—52 to the driving coil 21 of the tuning fork 11.

Potential (corresponding to that applied through the resistor 23 of Fig. 1) is applied through a lead 53, a potentiometer 54, and a resistor 23 to the pickup feeding the input of the amplifier 31—32—33—34. As previously indicated, adjustment of this potential determines the amplitude of the vibration of the tuning fork. Such adjustment is made by means of the potentiometer 54.

The gain of the loop, formed as outlined above, is determined by adjustment of a potentiometer

55 through which the modulator 42 is coupled to the amplifier 50.

The operation of the signal generator is readily understood, if it be assumed that the tuning fork 11 is vibrating and a unidirectional voltage is applied to the terminal 22 of Fig. 1, or across the resistors 38 and 39 of Fig. 2, and a unidirectional voltage is also applied to pickup 12 through resistor 23. Under these conditions, an alternating voltage of the fork frequency is applied to the input circuit of the feedback amplifier 31—32—33—34 (indicated by the reference numeral 10 in Fig. 1). The output voltage of this amplifier is stepped up by the transformer 17, is rectified, and is compared with the unidirectional voltage across the resistors 38—39. The difference between these unidirectional voltages is utilized to control the gain of the modulator 42 which is excited by alternating potential applied from the output of the amplifier 31—32—33—34 through the leads 49 to the grid 43. The modulator output is amplified and utilized to drive the tuning fork. Thus, the system operates so that the rectified voltage is always maintained very close to the voltage across the resistors 38 and 39.

How this result is achieved may appear more clearly from the theoretical considerations outlined below. In these considerations, the various reference characters are identified as follows:

- A = the fork amplitude of vibration,
- B = the value of the voltage applied to pickup 12 through the potentiometer 54, and resistor 23,
- C = the value of the voltage across resistors 38 and 39,
- E_{oi} = alternating voltage at output of amplifier 31—32—33—34 (amp. 10 in Fig. 1),
- E_{oi} = alternating voltage at output of amplifier 25 (Fig. 1),
- D = unidirectional voltage applied to pickup 24 through resistor 26,
- G_m = gain of amplifier 10 (Fig. 1),
- G_n = gain of amplifier 25,
- E_m = alternating voltage output of 42 (Fig. 2),
- k_1, k_2, k_3 , etc. = constants,
- E_{oDC} = rectified voltage.

For the sake of simplicity, it is assumed that the modulator 42, the tuning fork drive, etc. are linear. This, of course, is not essential to the operation of the system. It is apparent that the following relations are established:

$$E_{oi} = k_1 A B G_m \quad (1)$$

$$A = k_2 E_m \quad (2)$$

$$E_m = k_3 E_{oi} (C - E_{oDC}) \quad (3)$$

$$E_{oDC} = k_4 E_{oi} \quad (4)$$

$$E_m = k_3 E_{oi} (C - k_4 E_{oi}) \quad (5)$$

$$E_{oi} = k_1 k_2 E_m B G_m \quad (6)$$

$$E_{oi} = k_1 k_2 B G_m k_3 E_{oi} (C - k_4 E_{oi}) \quad (7)$$

$$E_{oi} = \frac{k_1 k_2 k_3 B C G_m - 1}{k_1 k_2 k_3 k_4 B G_m} \quad (7a)$$

If $k_1 k_2 k_3 B C G_m$ is large relative to 1 (meaning only that the loop gain is high), the -1 may be neglected and there results for practical purposes:

$$E_{oi} = \frac{C}{k_4} \quad (8)$$

This last equation shows that the output voltage E_{oi} of the generator feedback amplifier 31—32—33—34 is proportional to the voltage drop across the resistors 38 and 39. This shows that the voltage of the alternating current signal output is controlled by the voltage drop across the resistors 38 and 39.

From Equations 1 and 8 it is seen that:

$$E_{oI} = k_1 ABG_m = \frac{C}{k_4} \quad (9)$$

$$A = \frac{C}{k_1 k_4 BG_m} \quad (10)$$

From Equation 10 it is apparent that the amplitude of the vibration of the fork 11 is inversely proportional to the unidirectional voltage applied through the potentiometer 54, and resistor 23. It is, therefore, possible to control the fork amplitude by adjustment of this potentiometer without affecting the generator alternating output voltage E_{oI} .

In the operation of the system, the voltage drop of the resistors 38 and 39 is adjusted first to give the desired signal generator output voltage. The voltage applied through the potentiometer 54 and resistor 23 is then adjusted to give the proper vibration amplitude of the tuning fork.

If a unidirectional voltage is applied to the pickup connected to the input of the modulator feedback amplifier 25 (Fig. 1) through the resistor 26, there is made available at the output terminals of this amplifier an alternating voltage E_{oII} , which has the same frequency as the tuning fork and has an amplitude proportional to the product of this unidirectional voltage and the amplitude of the vibration of the tuning fork.

$$E_{oII} = K_1 ADG_m \quad (11)$$

There is thus made available a linear modulator having an alternating current output which is proportional to a unidirectional voltage. This linear modulator is, of course, not essential to the stabilized signal generator part of the apparatus but is a useful addition to the generator, especially where a number of separate unidirectional voltages are each to modulate the same alternating current signal. The phase of the output voltage of the linear modulator is a constant, or a constant plus 180° with respect to the output voltage of the signal generator. The constant depends upon the relative phase shifts through amplifiers 10 and 25 of Fig. 1, and the phase may be shifted 180° by reversing the polarity of the unidirectional voltage applied through resistor 25 with respect to the unidirectional voltage applied through resistor 23 of Fig. 1.

I claim as my invention:

1. The combination of alternating current supply means having input and output circuits, modulating means having a pair of control grids, an alternating current amplifier having its input connected to the output circuit of said supply means and having an output circuit, means for applying a fixed unidirectional potential, means connected to said amplifier output circuit and responsive to said fixed unidirectional potential for applying to one of said modulator grids a potential representative of the difference between said fixed unidirectional potential and the am-

plitude of the output potential of said amplifier, means for applying the output potential of said amplifier to the other of said modulator grids, and means for applying the output potential of said modulator to the input circuit of said supply means.

2. The combination of alternating current supply means having input and output circuits, modulating means having a pair of control grids, an alternating current amplifier having its input connected to the output circuit of said supply means and having an output circuit, means for applying a fixed unidirectional potential, means connected to said amplifier output circuit and responsive to said fixed unidirectional potential for applying to one of said modulator grids a potential representative of the difference between said fixed unidirectional potential and the amplitude of the output potential of said amplifier, means for applying the output potential of said amplifier to the other of said modulator grids, means for applying the output potential of said modulator to the input circuit of said supply means, means for adjusting the value of said fixed potential, and means for stabilizing said fixed potential at such adjusted value.

3. The combination of alternating current supply means having input and output circuits, alternating current rectifying means, an alternating current amplifier connected between said rectifying means and the output circuit of said supply means, a modulator having first and second control grids and an output circuit including a cathode and an anode, a direct current amplifier including first and second anodes and first and second control grids, means connecting the output of said rectifying means to the first of said direct current amplifier grids, means for applying a fixed potential to the second of said direct current amplifier grids, means connecting the first of said direct current amplifier anodes to the first of said modulator grids, means for stabilizing the cathode of said modulator and the second anode of said direct current amplifier at the same voltage, means for applying the output potential of said alternating current amplifier to the second of said modulator grids, and means connecting the output circuit of said modulator to the input circuit of said supply means.

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REFERENCES CITED

The following references are of record in the file of this patent:

UNITED STATES PATENTS

Number	Name	Date
1,869,331	Ballantine	July 26, 1932
2,103,619	Halimark	Dec. 28, 1937
2,138,138	Bruckner	Nov. 29, 1938
2,283,241	Van Cott	May 19, 1942
2,292,790	Millar	Aug. 11, 1942
2,294,171	George	Aug. 25, 1942

Certificate of Correction

Patent No. 2,469,264

May 3, 1949

EDWIN A. GOLDBERG

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows:

Column 6, list of references cited, under the heading "United States Patents", add the following—

2,343,207 *Schrader*

Feb. 29, 1944

and that the said Letters Patent should be read as corrected above, so that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 24th day of October, A. D. 1950.

[SEAL]

THOMAS F. MURPHY,
Assistant Commissioner of Patents.