

Feb. 14, 1950

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2,497,202

ELECTRONIC RELAY

Filed Dec. 30, 1944

2 Sheets-Sheet 2

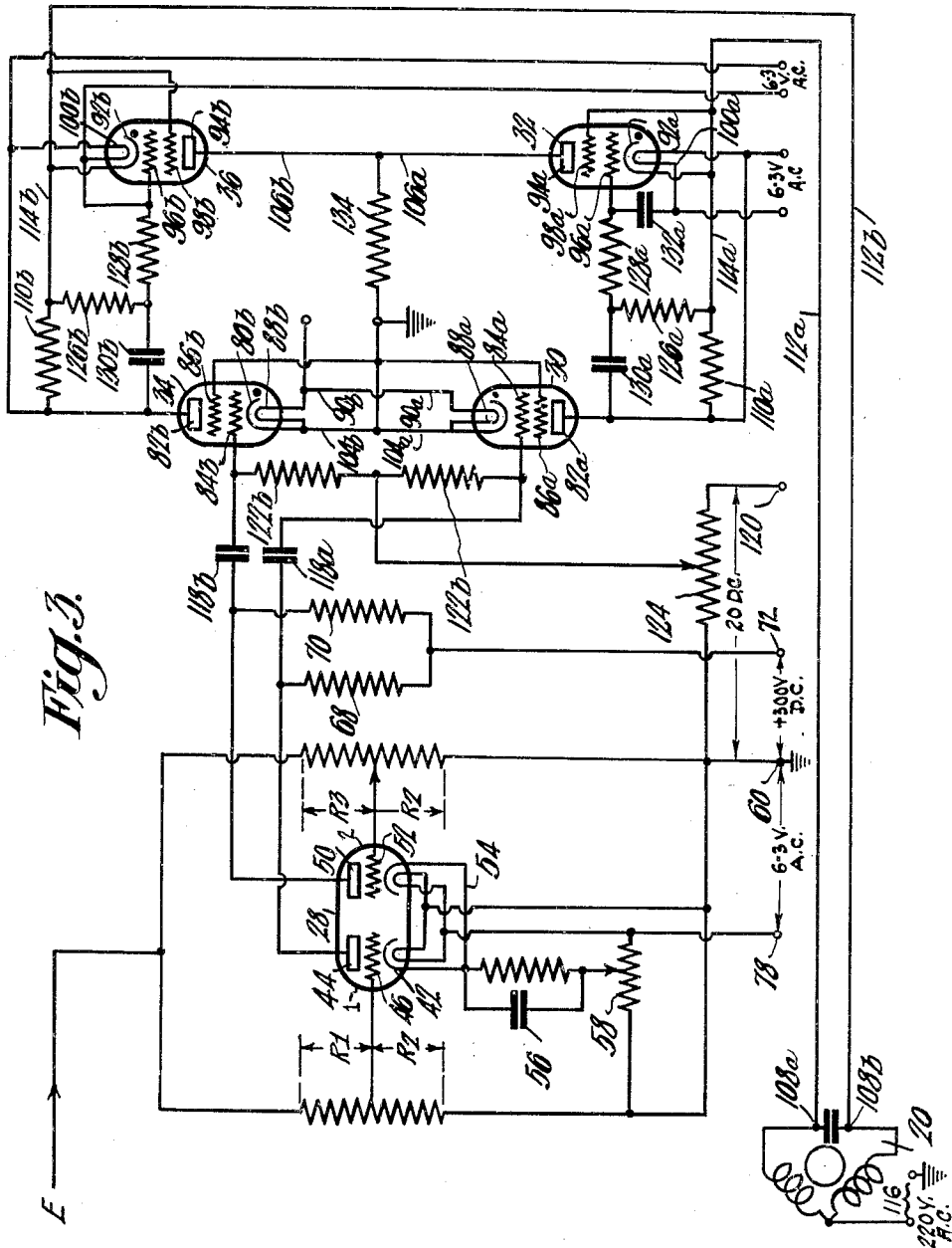


Fig. 3.

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2,497,202

ELECTRONIC RELAY

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Application December 30, 1944, Serial No. 570,706

6 Claims. (Cl. 315—194)

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This invention relates to an electronic relay and motor control system. Among its objects is the provision of an improved relay which is free from the defects of prior art relays employing mechanical contacts and which is, in particular, more sensitive and less critical of adjustment than relays of the prior art, and which maintains its adjustment over a substantial period. Further objects include the provision of sensitive and efficient means for actuating an alternating current motor in response to minute variations in a controlling signal, and means for adjusting the limit of such variation which may be tolerated and for realizing full torque in the motor immediately such limit is exceeded. Other objects include the provision of a sensitive detector of minute variations in a controlling signal which absorbs a negligible amount of power from the circuit in which it is included, and of a gas tube circuit for producing a full-wave, alternating current in response to a variation in the controlling signal. A specific object is the provision of improved means for maintaining a constant load on a radio communication transmitter notwithstanding variation in the frequency of the transmitted carrier signal.

According to the invention, a circuit is provided for obtaining a pair of alternating voltages which are equal to each other in magnitude and phase, but which vary in opposite senses upon any variation in the controlling signal. Means are provided for adjusting the degree of variation of the alternating voltages. These voltages are, in turn, applied to a gas tube network which is energized by alternating voltage of the same frequency and phase as the applied voltage and which produces a full-wave, alternating current of sufficient power to drive a motor, or for such other purpose as may be desired.

Reference may be made to our U. S. Patent 2,455,646, application for which was filed at the same time as this application was filed.

In the accompanying drawing, Figure 1 is a diagram illustrating an application of one embodiment of the invention,

Figure 2 is a circuit diagram of the embodiment, the application of which is illustrated in Figure 1, and

Figure 3 is a diagram of another embodiment of the invention.

Figure 1 illustrates an application of the invention designed for use in a multi-stage, radio communication transmitter. This transmitter is intended to operate over a wide range of carrier frequencies, say from two megacycles per

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second to twenty megacycles per second, and is completely automatically tuned; that is to say, operation of a single control varies the carrier frequency and also effects automatically a plurality of ancillary adjustments for operating the transmitter with efficiency at a number of different frequencies within the range. The wide variation in frequency is accompanied by a correspondingly wide variation in the resistance and reactance of the antenna, and the controls must be capable of compensating for these variations.

In Figure 1 the final stage of the transmitter is represented by a power amplifier 10 having a tank circuit 12 which includes an inductor 14 coupled to an inductor 16 in an antenna circuit 18. A motor 20, controlled by a relay and motor control 22, is mechanically connected to vary the coupling between the tank and antenna circuits. The power amplifier has a cathode circuit 24 which includes a resistor 26. When the transmitter is tuned to resonance at a particular frequency, current flowing in the anode circuit of the amplifier and, therefore, through the resistor 26 is at a minimum. When the frequency is changed this current increases and the voltage across resistor 26 increases correspondingly. The purpose of the relay and motor control 22 is to operate the motor 20 in consequence of a change in voltage across resistor 26, and thereby to vary the coupling between the tank and antenna circuits.

Conventional polarized balanced relays with mechanical contacts and magnetic actuation of a moving armature are not suitable for the purpose indicated, because those which operate at a differential of less than ten per cent from a mid value are expensive and extremely critical in adjustment and do not maintain their adjustment over any reasonable length of time. Prior art motor controls did not realize full torque in the motor immediately upon actuation and were not sufficiently positive and speedy for the application described.

Figure 2 is a circuit diagram of the relay and motor control 22 of Figure 1 which may be employed in the place of prior art devices. The relay consists basically of a tube 28, and the motor control of four gas tubes 30, 32, 34 and 36, respectively, each with its associated circuits. The relay tube comprises two identical sections numbered 1 and 2, respectively, section 1 having a cathode 42, an anode 44 and a control electrode or grid 46; section 2 has similar electrodes 48, 50 and 52, respectively. The two cathodes 42 and 48 are connected to each other and to ground

through a conductor 54, a resistor 56, a variable resistor 58 and a terminal 60, all as shown in Figure 2. The common cathode circuit is also connected to a terminal 78 between which and ground there is indicated a source of alternating current, which may conveniently be the commercial supply, having a frequency of sixty cycles per second.

The two sections of the relay tube 28 are shown as being contained in a single envelope and, in this form, may be of RCA Type 6SN7. Although such an arrangement is convenient, it is not essential for the purposes of the invention, it being desirable that the two sections have a common cathode circuit, as will appear subsequently in this description.

The grid 46 of section 1 is connected to a terminal 62 through a resistor 64 and a variable resistor 66. The anodes 44 and 50 of the two sections are connected through resistors 68 and 70, respectively, to a terminal 72 at which a regulated, positive potential is indicated as being applied. Potential from this source is also applied through a resistor 74 and variable resistor or potentiometer 76 to the grid 52 of section 2 of the relay tube.

The four gas tubes 30 to 36, inclusive, which may be of RCA Type 2D21, may conveniently be thought of as in two pairs, the pair constituted by tubes 30 and 32 being in one channel and the pair constituted by tubes 34 and 36 being in another channel. The two channels are identical in construction and arrangement, and the description of this part of the circuit will be confined, in the main, to the upper channel of Figure 2. Corresponding elements in the upper and lower channels have been given the same reference numerals, but are distinguished by the additional letters *a* and *b*, respectively.

The tube 30 has a cathode 80*a*, an anode 82*a*, a control grid 84*a*, and a fourth electrode 86*a* which serves as a shield around the anode to prevent ignition of the tube by stray electrostatic fields and is, therefore, connected to the heater 88*a* by a conductor 90*a* and thus to ground. The tube 32 has similar elements 92*a*, 94*a*, 96*a*, 98*a*, 100*a* and 102*a* in the order named.

The cathodes of tubes 30 and 32 are connected to ground by conductors 104*a*, 104*b*, and the anodes of tubes 32 and 36 are also connected to ground by conductors 106*a*, 106*b* and a common resistor 134. The anode of tube 30 is connected to a terminal 108*a* through a resistor 110*a* and conductor 112*a*, and the cathode of tube 32 is connected to the same terminal by a conductor 114*a*. Similarly, the anode of tube 34 is connected to a terminal 108*b* through a resistor 110*b* and conductor 112*b*, and the cathode of tube 36 is connected to the same terminal by a conductor 114*b*. The two terminals 108*a*, 108*b* are connected through the motor 20 to a source of alternating current, indicated at 116, of the same frequency and phase as the alternating current applied to the common cathode circuit of the relay tube 28.

The anode 44 of section 1 of the relay tube is connected to grid 84*a* of tube 30 through a coupling capacitor 118*a*, and the anode 50 of section 2 of the relay tube is connected to grid 84*b* through a coupling capacitor 118*b*. The grids 84*a*, 84*b* are also connected to a terminal 120 through identical resistors 122*a*, 122*b* and a variable resistor 124, common to both channels. At the terminal 120 a negative biasing potential is applied.

The anode of tube 30 is connected to the control

grid of tube 32 by a resistor 110*a* and a time delay network consisting of resistors 126*a*, 128*a* and capacitors 130*a* and 132*a*, connected as shown in Figure 2. Similarly, the anode of tube 34 is connected to the control grid of tube 36 by a resistor 110*b* and a time delay network 126*b*, 128*b*, 130*b*, 132*b*.

The operation of the circuit is as follows: The direct current voltage across the cathode resistor 25 of the power amplifier 10 in Figure 1 is a linear function of current flowing in the cathode circuit 24. This voltage is applied between the input terminals 62 and 60 of Figure 2 in a polarity which makes the grid 46 of section 1 of the relay tube 28 positive with respect to its cathode 42. The variable resistor 76 in the grid circuit of section 2 is adjusted to place an equal or balancing positive voltage (from the source connected to terminal 72) on the grid 52 of section 2. The potential difference between each grid and its respective cathode is, however, constantly varying by reason of the alternating voltage applied to the common cathode circuit of the two sections from the source indicated at terminal 78. This variation is, therefore, the equivalent of an alternating signal applied to the grid of each section and will be amplified equally by each section by reason of the positive potentials applied to the two grids and anodes.

The signals, therefore, which are applied to the grids 84*a* and 84*b* of the first two gas tubes 30 and 34 from the anodes 44 and 50 of the relay tube through the coupling capacitors 118*a* and 118*b* are equal to each other in magnitude and phase, and are each an amplified replica of the sixty cycle per second voltage applied at terminal 78. The variable resistor 124 is adjusted to place a bias on the grids 84*a* and 84*b* sufficient to prevent the tubes 30 and 34 from conducting when these signals from the relay tube (in its balanced condition) are applied to their grids.

When the power amplifier 10 of Figure 1 is no longer at resonance, current in its anode-cathode circuit increases and the voltage across resistor 26 increases also. This raises the potential of grid 46 with respect to cathode 42 and increases the amplification effected by section 1 of the relay tube, and hence its anode current. The signal applied to the control grid of gas tube 30 is, therefore, higher than previously. The increased anode current causes an increased potential drop across the common cathode resistor 56 and, therefore, reduces the amplification of section 2 of the relay tube. The signal, therefore, applied to grid 84*b* of the gas tube 34 from anode 50 is thus less than it was previously. A decrease in the applied direct current signal will cause an unbalance in the opposite direction with an increase in the voltage applied to grid 84*b* and a corresponding decrease in the voltage applied to grid 84*a*.

It may be here pointed out that while it will frequently be desirable to balance the direct current voltage applied to grid 46 with an equal direct current voltage on grid 52. This balancing is necessary only when the amplification of the two sections of the relay tube is equal; because what is desired is that the alternating signals applied to grids 84*a*, 84*b* shall be equal but shall vary in opposite senses when the direct current signal applied to grid 46 varies. It is within the scope of the invention to have the amplification of the two sections unequal and so to vary the direct current potential applied to grid 52 (by adjustment of resistor 76) as to have equal

currents flowing in the two anode circuits of the relay tube.

Similarly, while the operation of the two sections of the relay tube has been referred to as amplification, what is strictly desired is to produce two balanced replicas of the alternating signals applied at terminal 78. In some cases an unamplified, or even a reduced, replica may be desired. Conversely, if the amplification effected by each half of the relay tube is not sufficient for any particular application, a further stage or stages of amplification may be inserted between the anode 44 and grid 84a and between anode 50 and grid 84b.

The operation of the gas tube circuit will now be described. When the direct current voltage applied to grid 46 increases, the alternating signal applied to grid 84a increases and the signal applied to grid 84b decreases. Since this last grid was already biased (by adjustment of resistor 124) below ignition point, tube 34 will not conduct. In tube 30, however, the alternating voltage applied to grid 84a overcomes the biasing potential applied at terminal 120. This alternating voltage is in phase with the voltage applied to the anode of tube 30 through terminals 108a and 108b. The 2D21 tube is of a type which conducts when grid potential is above -3 volts with respect to cathode, and when anode potential is approximately 10 or 12 volts or greater with respect to the grid. The tube 30 will, therefore, conduct during substantially the whole of the positive half cycle of anode voltage and will continue to conduct during each ensuing positive half cycle of anode voltage. Current will flow in the anode circuit of tube 30 through the winding of motor 20, through conductor 112a and through resistor 110a. This causes the end of resistor 110a, which is more remote from the anode 82a, to be more positive than its end nearer that anode. The positive voltage thus created is applied to grid 96a of the second gas tube 32 through the delay network constituted by resistors 126a and 128a, and capacitors 130a and 132a. The circuit parameters of the time delay network are chosen to create a delay of approximately 50°.

The second gas tube 32 is connected to the alternating supply voltage source at 116 through conductors 114a and 112a and terminal 108a, and its anode is connected to ground through conductor 106a. The anode voltage of tube 32 is, therefore, completely out of phase with that of tube 30. Because of the delay network through which it passes, at the time when the positive voltage derived from tube 30 and resistor 110a is applied to the grid of tube 32, the anode of that tube is becoming more positive. The tube 32, therefore, conducts during the ensuing half cycle and during each half cycle when tube 30 is not conducting. Tubes 30 and 32 together, therefore, produce a full wave of substantial energy connected through terminal 108a and ground to drive motor 20 in one direction.

If the voltage across cathode resistor 26 decreases, then the signal applied to the grid of tube 34 rises and that applied to tube 30 falls. In this event, tubes 34 and 36 will conduct, the full wave of energy will appear across terminal 108b and ground, and the motor 20 will be driven in the opposite direction.

It was previously pointed out that the common cathode circuit of the relay tube includes a variable resistor 58. Adjustment of this resistor will determine the amount by which the grid-to-cathode potential of section 2 will diverge from

the grid-to-cathode potential of section 1 when current flowing through section 1 changes. It therefore determines the extent of the divergence between the alternating signals applied to the grid of tubes 30 and 34, respectively, and thus the sensitivity of the whole device. The variable resistor 66 in the grid circuit of section 1 serves to control the amount of positive potential derived from the cathode circuit of Figure 1 which is applied to the grid 46.

It will be apparent that the embodiment of the invention thus far described has wider application than in the particular transmitter referred to. A direct current signal, however derived, may be applied to the circuit and any variation in that signal will result in a full wave of alternating energy in the output circuit which may be used to drive a motor, or for such other purpose as may be desired. If an alternating signal is to be controlled, it may be rectified and integrated, if necessary, by methods known to the art, and the resulting direct current signal applied as here described. Any other condition which may be represented by a direct current signal (for example, light intercepted by a phototube) may be controlled in the manner described. It should also be noted that when either pair of gas tubes conducts, the current applied to terminals 108a, 108b is not proportional, or in any other way a function of the variation in the original input signal. The device may be made as sensitive as desired by adjustment of resistor 58 as before explained. Once the tolerance limit desired has been exceeded, and immediately that occurs, one pair or other of the gas tubes will conduct and the full torque of the motor will be realized.

If the embodiment of the invention which is illustrated in Figure 3, the necessity for the balancing voltage which is applied to grid 52 in the embodiment of Figure 2 is dispensed with. Corresponding elements in Figures 2 and 3 have been given the same reference numerals and letters. In Figure 3, four resistors R_1 , R_2 , R_3 and R_4 are connected in a Wheatstone bridge between anode and grid and between grid and cathode of the two sections of the relay tube 28, as shown in this figure. A voltage or other signal, distinguished by the letter E, is applied to the bridge and the condition for balance is that $R_1:R_2=R_3:R_4$. The applied signal E in this embodiment may be alternating instead of direct current and may, if desired, be of radio frequency. The circuit illustrated may be employed, for example, in the production testing of resistors in which three of the four resistors constituting the arm of the bridge are fixed, and, say, R_1 is the resistor under test. The tolerance limit would be set by adjustment of resistor 58, as in the previous embodiment. On a departure in the value of the resistor from the tolerance limit, the balance of the bridge will be disturbed, one of the two pairs of gas tubes will be actuated and the motor will operate to pass the resistor under test into one of two receptacles, depending on whether it is above or below a given value. In place of resistors, inductors or capacitors may be used for the arms of the bridge.

There has thus been described an electronic relay in which there is produced a pair of balanced, alternating currents which vary in opposite senses upon any variation in the controlled circuit. These voltages are, in turn, applied to a gas tube circuit so connected and energized as to produce a full wave of substantial energy in response to an increase in either of the voltages.

We claim as our invention:

1. An electronic relay operable on variation of a direct current signal from a given value to shift an alternating current from one channel to another, said relay comprising a pair of amplifiers having a common cathode circuit, each of said amplifiers having at least a control electrode in addition to a cathode and an anode, connections for applying said direct current signal to the control electrode of one of said amplifiers, connections for applying a balancing potential to the control electrode of the other of said amplifiers, connections including said common cathode circuit for applying an alternating voltage to each of said amplifiers, output means to be controlled having alternate alternating current channels, first and second gas tubes in each of said channels, each of said tubes having at least a cathode, an anode and a grid, a supply of alternating energy for said output means and said tubes of the same frequency as said alternating voltage and in phase therewith, means for applying the output of said amplifiers to the grids of said first tubes in said channels, respectively, and means for applying to the grids of said second gas tubes voltages delayed in time with respect to said alternating energy.

2. A relay according to claim 1, characterized in that said common cathode circuit includes a variable resistor.

3. A D.-C. voltage responsive device comprising a pair of signal tubes, means to apply the D.-C. voltage to which the circuit responds to at least one of said signal tubes to vary its gain with respect to the other signal tube, an A.-C. voltage source connected to have the voltage therefrom amplified respectively by each of said signal tubes, two pair of gas tubes each pair being connected respectively to one of said control tubes to receive the amplified A.-C. voltage therefrom, said A.-C. voltage source being connected to each pair of gas tubes, said gas tubes being interconnected in circuit to give no rectification for equal amplitudes of said amplified voltages and to give full wave rectification by the pair of gas tubes receiving the larger amplified voltage and not by the other pair of gas tubes.

4. A D.-C. voltage responsive circuit comprising

two channels, each channel comprising a signal tube and a pair of gas tubes connected thereto to receive the output thereof, each gas tube having a cathode-anode circuit, a connection from at least one of said signal tubes to said D.-C. voltage source to receive said D.-C. voltage and to vary the gain of one of said signal tubes with respect to the other in response to said D.-C. voltage, and an A.-C. voltage source connected to be amplified antiphasally by said signal tubes to provide a signal output from each signal tube, said A.-C. source being applied in the cathode-anode circuit of one gas tube in each channel and being applied antiphasally in the cathode-anode circuit of the other gas tube of each channel, said gas tubes being interconnected, whereby said A.-C. voltage is full-wave rectified by the pair of gas tubes receiving the larger amplified voltage of unequal amplified voltages.

5. The circuit claimed in claim 4, each said gas tube having a control element, the said gas tubes of each said channel having at least one control element connected to receive the amplified output of the signal tube of the same channel.

6. The circuit claimed in claim 4, one of one pair of gas tubes in one channel having a cathode resistor in common with one of the pair of gas tubes in the other channel, and the other of the pair of gas tubes in the other channel having a different cathode resistor in common with the other gas tube of the other pair.

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