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ELECTRONIC CONTROL DEVICE RESPONSIVE TO RATE OF CHANGE OF A CONDITION

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Fig. 1.

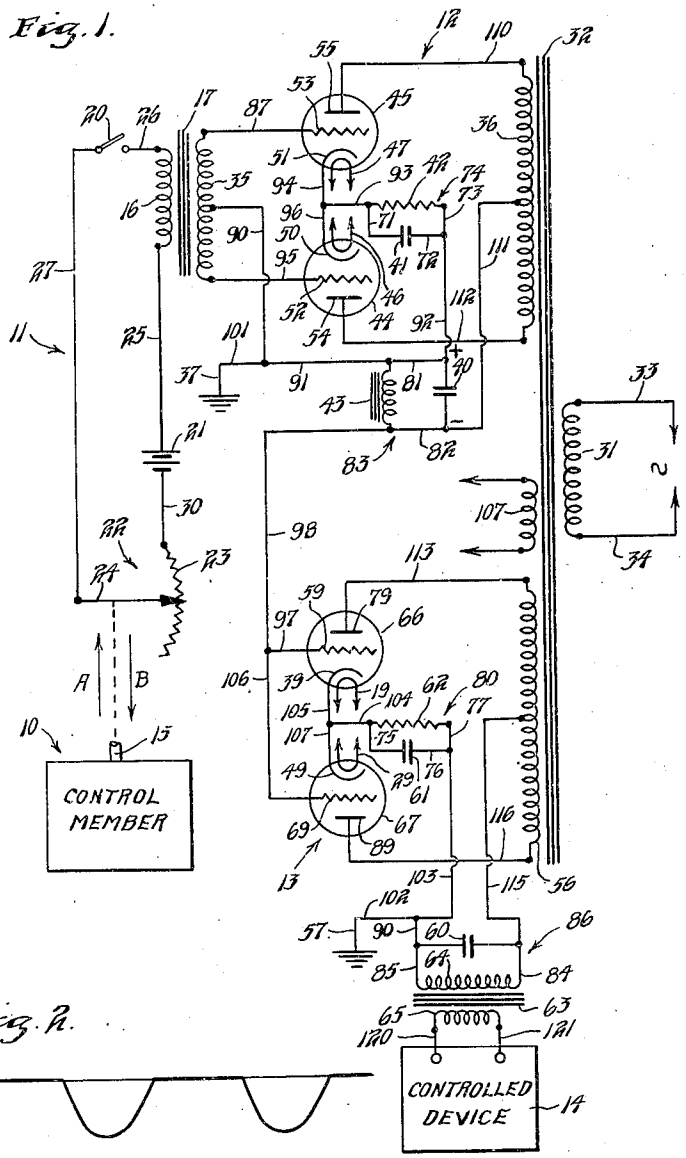
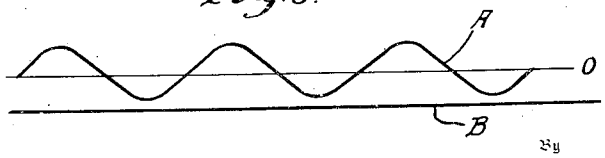


Fig. 2.

Fig. 3.



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ELECTRONIC CONTROL DEVICE RESPONSIVE TO RATE OF CHANGE OF A CONDITION

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7 Claims. (Cl. 250—27)

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This invention relates to control devices, and more particularly to devices adapted to be responsive to the rate of change in a condition.

Numerous control applications are well known in which utility is found in a device responsive to change in a given condition. This condition may be, for example, temperature or relative humidity as in the air conditioning art: it may be capacitance or frequency as encountered in the electrical art; hydrogen-ion concentration or constituent proportions as in the chemical art; or, more generally, time or space relation.

In the same way, numerous applications are found in which not only the change of a condition but the rate at which this change takes place is of significance, and it may be desirable to separate any effect, due to the change in the condition itself, from a concomitant effect due to the rate of change in the condition.

It is an object of this invention to provide a new and improved control device.

It is another object of this invention to provide in a control device, improved means responsive to the rate of change of a condition and free of response to the changing magnitudes of the condition itself.

A more specific object of this invention is to provide means responsive to changes in the velocity of a member moving along a given path.

A still further object of this invention is to provide means responsive to the rate of change of the effective resistance of a resistor due to movement of a movable contactor along the resistor.

Various other objects, advantages and features of novelty which characterize my invention are pointed out with particularity in the claims annexed to and forming a part of this specification. However, for a better understanding of the invention, its advantages and objects attained with its use, reference should be had to the subjoined drawing which forms a further part of this specification, and to the accompanying descriptive matter, in which I have illustrated and described a preferred embodiment of the invention.

In the drawing,

Figure 1 shows this preferred embodiment of my invention in an application of general utility, and

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Figures 2 and 3 are curves suggestive of certain voltage relations in my circuit.

Structure

The components of my invention as disclosed in the drawing comprise a control member 10, a rate responsive circuit 11, a first discriminator or amplifier circuit 12, a second discriminator or power control circuit 13 and a controlled device 14. Control member 10 may be any suitable device capable of interpreting changes in a condition by movement of a shaft 15 in opposite directions indicated by arrows A and B. By way of illustration only, control member 10 may conveniently comprise a bimetal responsive to temperature changes, the needle of a speedometer responsive to changes in velocity, the standard-weight arm of a balance, and so forth.

Rate responsive circuit 11 is inductively coupled with amplifier circuit 12 by a transformer 17 having a primary winding 16 and a secondary winding 35, and comprises a battery 21 connected in series with a switch 20, the primary winding 16 of transformer 17, and a variable resistor 22 comprising a resistance winding 23 over which there moves a contact arm 24. The circuit may be traced as follows: the positive pole of battery 21, conductor 25, primary winding 16, conductor 26, switch 20, conductor 27, movable arm 24 and a portion of resistance winding 23 of variable resistor 22, and conductor 30 back to the negative terminal of the battery.

It is obvious that a change in the resistance of resistor 22 causes a change in the current flowing in the rate responsive circuit, and that the more rapidly the resistance changes, the more rapidly the current flow in the circuit, and therefore the magnetic flux in the transformer, changes. As is well known, the induced voltage in the secondary winding 35 of transformer 17 is determined in magnitude by the rate of change of the current of the primary winding, and in polarity by the direction of the change.

Amplifier circuit 12 and power control circuit 13 are respectively energized from a pair of center tapped secondary windings 36 and 56 of a transformer 32, having primary winding 31 connected as by conductors 33 and 34 to a suitable source of alternating current at a selected frequency. Transformer 32 is provided with a third

secondary winding 107 for energizing the heaters of the various electron discharge devices comprised in the amplifier and power control circuits.

Amplifier circuit 12 includes a pair of triodes 45 and 44, having cathodes 51 and 50, control grids 53 and 52, and plates 55 and 54, respectively. The amplifier circuit also includes a ground connection 37, a parallel circuit 74 comprising a capacitor 41 and a resistor 42 connected by conductors 71 and 73, an antiresonant load circuit 83 comprising a capacitor 40 and an inductor 43 connected by conductors 81 and 82, the secondary winding of transformer 17 and the first secondary winding 36 of transformer 32.

The end terminals of secondary winding 36 are connected as by conductors 110 and 112 to the plates 55 and 54 of triodes 45 and 44, and the center tap of this winding is connected to the cathodes of the triodes, which are joined as by conductors 94 and 96, by conductor 111, antiresonant load circuit 83, conductor 92, parallel circuit 74, and conductor 93. A ground connection is made between parallel circuit 74 and load circuit 83, as by conductors 91 and 101, and the center tap of secondary winding 35 is connected thereto as by conductor 90.

Thus, it will be seen that during a first half cycle of the alternating current plate 55 of triode 45 is positive, while plate 54 of triode 46 is negative, and that during the next half cycle these polarities are reversed. Therefore, in the absence of inhibiting negative potentials on the control grids of these tubes, they are conductive during alternate half cycles of the source.

It will be seen that regardless of the actual magnitude of the current flowing in rate responsive circuit 11, so long as this magnitude is unvarying no potential appears at the terminals of secondary winding 35 or transformer 17 and that if the current in circuit 11 changes a potential appears at the terminals of winding 35 which is determined in magnitude by the rate of the change and in polarity by the direction of the change. For example, if the current in circuit 11 increases, the secondary potential may be such that grid 53 is positive with respect to grid 52: should the current decrease, the secondary potential must then be such that grid 53 is negative with respect to grid 52. Since the potential at center tap is midway between those of the end terminals, and since the tap is connected to the cathodes of the two triodes, through the common ground connection, it follows that on an increase in the current in circuit 11, grid 53 becomes positive with respect to cathode 51 and grid 52 becomes negative with respect to cathode 50, while on a decrease in the current in circuit 11, grid 53 becomes negative with respect to cathode 51 and grid 52 becomes positive with respect to cathode 50. Thus, when the current in circuit 11 is increasing, triode 45 conducts during a first half cycle of the source, while when the current in circuit 11 is decreasing triode 46 conducts during a second half cycle of the source.

Regardless of which triode is conducting, a potential drop appears across load circuit 83 which is of such a polarity that conductor 82 is negative with respect to grounded conductor 81, and which has the wave form of the output of a half-wave rectifier, as illustrated in Figure 2. The amplitude of this potential depends on the amplitude of the pulsating current through the load circuit, which in turn is determined by the magnitude of the positive potential on the grid of the conductive triode. It will be understood that the magnitude of this wave remains constant only so long as the current in rate responsive circuit 11 changes at a constant rate.

A wave form of the type illustrated in Figure 2 can be analyzed by the use of Fourier series, and it is found to be a compound of many sine curves of many frequencies, together with a basic D. C. component. Figure 3 is illustrative of the two principal components of the wave form of Figure 2: although it must be understood that there are a large number of components of higher frequencies, these two are those of principal interest. In Figure 3 curve A is the fundamental sine wave, and it is found to have the frequency of the source and to have its negative maxima at the same time as the negative maxima of curve 2: it may therefore be considered as an alternating current signal in phase with the output of amplifier circuit 12.

The constants of inductor 43 and capacitor 40 are so chosen that load circuit 83 is antiresonant at the frequency of curve A in Figure 3. The circuit therefore presents an extremely high impedance to this component of the output of the amplifier circuit, while it may present a very low impedance to the D. C. component represented by curve B in Figure 3, and to the components of higher frequency not shown in that figure. Accordingly, the potential drop across the load circuit, which is impressed on the power control circuit as later set forth, is substantially of the wave form of curve A in Figure 3.

Power control circuit 13 includes a pair of triodes 66 and 67 having cathodes 39 and 49, control grids 59 and 69, and plates 79 and 89, respectively. The power control circuit also includes a ground connection 57, a second parallel circuit 80 comprising a capacitor 61 and a resistor 62 connected by conductors 75 and 77, a second antiresonant load circuit 86 including a capacitor 60 and an inductor 64 connected by conductors 84 and 85, and the second secondary winding of transformer 32.

The end terminals of secondary winding 56 are connected as by conductors 113 and 116 to the plates 79 and 89 of triodes 66 and 67, respectively, and the center tap of this winding is connected to the cathodes of the triodes, which are joined by conductors 105 and 107, as by conductor 115, anti-resonant load circuit 86, conductor 103, parallel circuit 80, and conductor 104. A ground connection is made between parallel circuit 80 and load circuit 86, as by conductor 102, and grids 59 and 69, joined by conductor 106, are connected to load circuit 83 by conductor 98.

Thus it will be seen that the potential impressed between grids 59 and 69 and cathodes 39 and 49 respectively is the potential across load circuit 83 which has been shown to be essentially an alternating current of the frequency of the source and in phase with the output of the amplifier circuit 12. Plate 79 of triode 66 and plate 55 of triode 45 are both positive during a first half cycle of the source, while plate 89 of triode 67 and plate 54 of triode 44 are both positive during a second half cycle of the source. If the change in current in circuit 11 is such that grid 53 of triode 45 is positive, grid 59 of triode 66 is given a positive potential at the same time that plate 79 of triode 66 is positive, and current flows through antiresonant circuit 86 during first half cycles of the source. If, on the other hand, the change in current in circuit 11 is such that the

grid 52 of triode 44 is positive, grid 69 of triode 67 is given a positive potential at the same time that plate 89 of triode 67 is positive, and current flows through antiresonant circuit 86 during second half cycles of the source.

Antiresonant circuits 83 and 86 have been shown to act as means for providing, from the outputs of amplifier unit 12 and power control unit 13, respectively, alternating current of fixed frequencies, of phase which reverses with change in the response of rate responsive circuit 11, and of magnitude which depends on the magnitude of said response.

The output of the secondary winding 65 of transformer 63 is connected as by conductors 120 and 121 to any desired device which is selectively responsive to phase reversal and magnitude variation of an alternating current.

Operation

The operation of my device will now be described. Switch 20 is assumed to be closed, permitting the flow of current through the circuit including winding 16 of transformer 17 and resistor 23, under the influence of battery 21. As long as no change takes place in the position of arm 24 or resistance winding 23 a constant current flows in this circuit causing a constant magnetic flux in transformer 17, and no voltage appears across the secondary terminals of the transformer This is true regardless of the position of arm 24 along resistor 23. For all practical purposes in this network, the impedance of winding 16 is constant, and the current flowing in the circuit therefore is a function of the in-circuit resistance of resistor 23; that is, of the position of arm 24 on resistor 23.

However, if arm 24 is in motion along resistor 23, the current in this circuit and therefore the magnetic flux in the transformer is constantly changing, and this results in the appearance of an electromotive force across the terminals of secondary winding 35. The faster arm 24 moves along resistor 23, the more rapidly the current in the circuit, and hence the magnetic flux in the transformer, changes; and the more rapid the change in magnetic flux, the larger the E. M. F. induced in secondary winding 35. Further, movement of the arm along the resistor in a direction to increase the current, or an increase in the speed of movement of the arm in this direction, induces an E. M. F. of one polarity, while a movement of the slider in the opposite direction, or a decrease in the velocity of the arm in the first direction, causes the induced E. M. F. to be of the opposite polarity.

Assume that control member 10 moves upward at a certain rate. Then arm 24 moves across winding 23 in such a direction that the in-circuit resistance is decreased. The current increases in the circuit at a rate determined by the rate of movement of arm 24, inducing a voltage in the secondary winding 35 of transformer 17 such that grid 53 of triode 45 goes sufficiently positive to allow the triode to conduct. A current then flows in the antiresonant load of amplifier circuit 12, and a voltage determined by the IZ drop across the load, as shown in Figure 3, is impressed upon grids 59 and 69 of triodes 66 and 67. This potential is negative when plate 89 of triode 67 is positive and the triode conducts no current: it is positive when plate 79 is positive so that a current flows through antiresonant load 86 in a first time-phase relationship. The IZ drop due to this current induces a voltage in the secondary winding 65 of transformer 63 which is impressed on the load device; the potential comprises an alternating current which is determined in phase by the direction of motion of control member 10 and in magnitude by the rate of motion of control member 10.

Now assume that control member 10 moves downward at a certain rate. The arm 24 moves across winding 23 in such a direction that the in-circuit resistance is increased. The current decreases in the circuit at a rate determined by the rate of movement of arm 24, inducing a voltage in the secondary winding 35 of transformer 17 such that grid 52 of triode 44 goes sufficiently positive to allow the triode to conduct. A current then flows in the antiresonant load of amplifier circuit 12, and a voltage determined by the IZ drop across the load, as shown in Figure 3, is impressed upon grids 59 and 69 of triodes 66 and 67. This potential is negative when plate 79 of triode 66 is positive and the triode conducts no current: it is positive when plate 89 of triode 67 is positive, so a current flows through antiresonant load 86 in a second time-phase relationship. The IZ drop due to this current induces a voltage in the secondary winding 65 of transformer 63 which is impressed on the load device; this potential comprises an alternating current which is determined in phase by the direction of motion of control member 10 and in magnitude by the rate of motion of control member 10.

I previously pointed out that controlled device 14 may be any structure adapted to give a response in a first sense when energized in a first time-phase relation, and in a second sense when energized in a second time-phase relation, and one in which the magnitude of the response is dependent on the magnitude of the energization. Thus, the device when connected in a circuit such as I have described gives a response in a first sense when arm 24 moves in one direction across winding 23, and in the opposite sense when arm 24 moves in the opposite direction. It must be remembered that a decrease in the velocity of arm 24 in one direction is the equivalent, in electrical response, of an increase in the velocity of arm 24 in the opposite direction.

In the foregoing specification I have completely disclosed a device for giving a signal which is proportional in amplitude to the speed of an arm of the resistor, and whose phase reverses with a reversed direction of movement of this arm across the resistor. Minor changes and equivalent circuits may occur to those skilled in the art, and I therefore wish this disclosure to be considered illustrative only, and to be limited only by the following claims.

I claim as my invention:

1. Means for responding to the velocity of a member along a path, comprising in combination, first means adapted to regulate a flow of electric energy in accordance with the position of said member along said path, second means providing differential electrical potentials in response only to the rate of change in said flow of electrical energy, a source of alternating voltage, a load circuit to be energized, and electronic means for energizing said circuit from said source in accordance with the polarity and magnitude of said potentials, whereby movement of said member in opposite directions results in the energization of said load circuit with alternating currents of opposite phases, and whereby further the amplitude of the alternating current is a function

only of the velocity of said member, said electronic means comprising a pair of circuits energized in opposite phase relation from a source of alternating current of fixed phase, said second means comprising a transformer having a primary winding cooperating with said first means and a secondary winding having portions cooperating respectively with the circuits of said pair.

2. In combination, a first pair of electron discharge devices each having a cathode, an anode, and a control element, means impressing a unidirectional signal voltage of variable magnitude and reversible polarity between the control elements of said discharge devices, a first center tapped inductor, means maintaining an alternating potential of a selected frequency and time-phase relation across said first inductor, the anodes of said electron discharge devices being connected to the ends of said first inductor, a first load circuit having a high impedance to alternating current of said selected frequency, and having a low impedance to unidirectional current and to alternating currents of other than said frequency, said first load circuit being connected between said center tap of said first inductor and the cathodes of said discharge devices, a second pair of electron discharge devices each having a cathode, an anode, and a control element, said control elements and said cathodes of said second pair of discharge devices respectively being connected together, the voltage drop across said first load circuit being applied between said cathodes and said control elements, a second center tapped inducter, means maintaining an alternating potential of said selected frequency and time-phase relation across said second inductor, the anodes of said second pair of electron discharge devices being connected to the ends of said second inductor, a second load circuit having a high impedance to alternating current of said selected frequency, and having a low impedance to unidirectional current and to alternating currents of other than said selected frequency, said second load circuit being connected between said center tap of said second inductor and the cathodes of said second pair of discharge devices, and an output circuit, said output circuit delivering a potential which is determined by the voltage drop across said second load circuit.

3. A device of the class described comprising, in combination: a source of alternating voltage of a selected frequency; first and second full wave grid controlled rectifiers, including respectively first and second load impedances; an electric circuit including a source of direct current and means for varying said current; a transformer coupling said circuit to one of said rectifiers to provide a pair of grid control voltages therefor which vary in opposite senses solely with change in said current, whereby to produce across said first load impedance an alternating voltage drop, of said selected frequency, which reverses in phase and varies in amplitude with reversal in the direction of change and variation in the rate of change of said current; and means controlling the discharge of said second rectifier in accordance with said alternating voltage drop across said first load impedance.

4. A device of the class described comprising, in combination: a source of alternating voltage of a selected frequency; first and second full wave grid controlled rectifiers, including respectively first and second load impedances; an electric circuit including a source of direct current and condition responsive means for varying said current; a transformer coupling said circuit to one of said rectifiers to provide a pair of grid control voltages therefor which vary in opposite senses solely with change in said current, whereby to produce across said first load impedance an alternating voltage drop, of said selected frequency, which reverses in phase and varies in amplitude with reversal in the direction of change and variation in the rate of change of said current; means controlling the discharge of said second rectifier in accordance with said alternating voltage drop across said first load impedance; a controlled device; and means actuating said controlled device in accordance with the voltage drop across said second load impedance, whereby actuation of said controlled device is determined solely by the rate and direction of the change of said condition.

5. A device of the class described comprising, in combination: a member movable in opposite directions at a variable rate; a variable resistor; means connecting said member to said resistor to vary the resistance thereof upon movement of said member; a source of direct current, a transformer having a primary winding and a plurality of secondary windings; means connecting said source, said resistor and said primary winding in a single series circuit so that the current in said primary winding varies with movement of said member; a plurality of electron discharge devices each having a cathode, an anode, and a control electrode; anode circuits for said discharge devices including separate sources of alternating plate voltage and a common load impedance; grid circuits for said discharge devices including a common bias portion and separate control voltage sources, said last named sources comprising said secondary windings of said transformer so connected as to influence said control electrodes in opposite senses.

6. A device of the class described, comprising, in combination: a source of direct current; a transformer having a primary winding and a centertapped secondary winding; a variable resistor; means electrically connecting said source, said transformer primary winding and said variable resistor in series such that the current in said primary winding varies with change in resistance of said resistor; means operable to reversibly vary the resistance of said resistor at variable rates; two electron discharge devices each having an anode, a cathode and a control electrode; a source of alternating voltage; means impressing said alternating voltage on said anodes such that the voltage on one of said anodes is opposite in phase to the voltage on the other of said anodes; anode circuits for each of said discharge devices; a load impedance common to said anode circuits; means connecting the centertap on said transformer secondary winding to both of said cathodes; and direct electrical connections between the terminals of said transformer secondary winding and said control electrodes such as to influence said control electrodes in opposite senses.

7. A device of the class described, comprising, in combination: a polarity sensitive discriminator circuit comprising two electron discharge devices, each having an anode, a cathode and a control electrode; a source of alternating voltage; means impressing voltages from said source on said anodes such that the phasing of the voltages on said anodes are in opposition; an output circuit connected to each anode; a load impedance com-

mon to said output circuits; a controlling condition; a control circuit comprising a transformer primary winding, a source of direct current and a resistor, the resistance of which is reversibly varied at varying rates by said controlling condition, in series; a transformer secondary winding cooperating with said transformer primary winding to produce a direct voltage output the polarity of which is dependent upon the direction of change of current in said control circuit and the magnitude of which is dependent upon the rate of change of current in said control circuit; and direct electrical connections from said transformer secondary winding to said grids such that the polarities of the voltages on said grids are in opposition to control the output of said discriminator circuit.

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