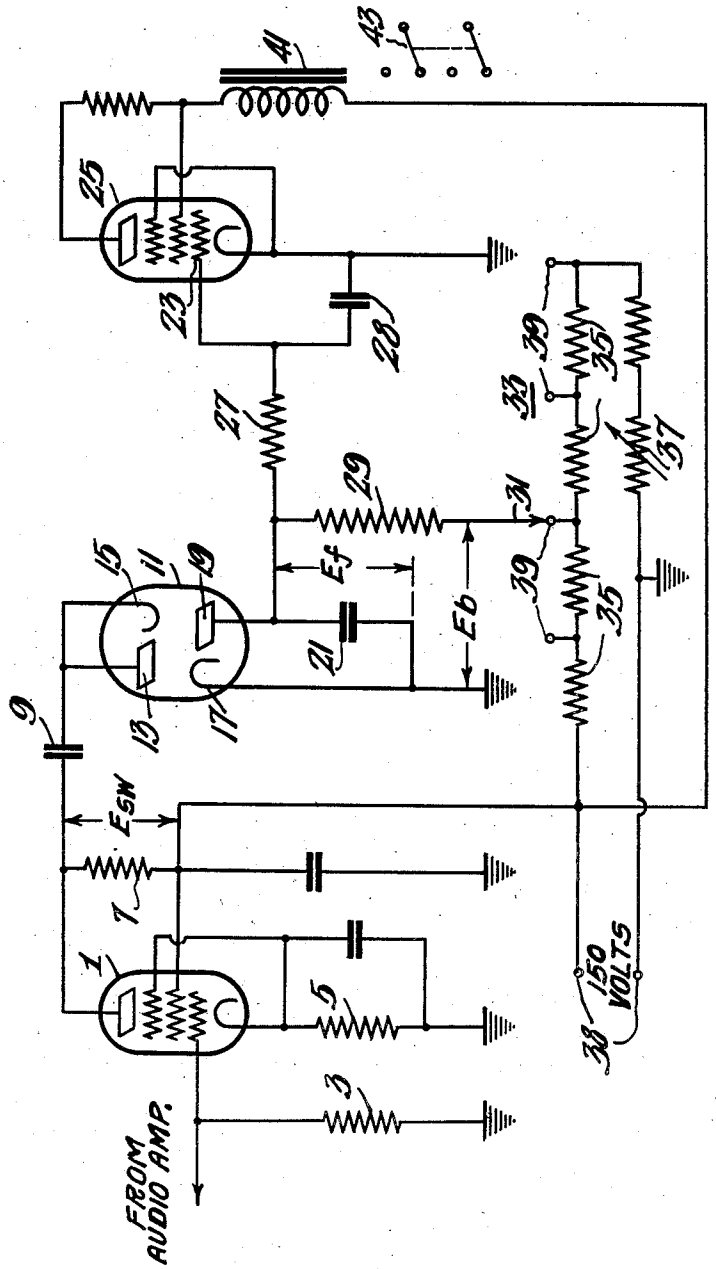
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FREQUENCY RESPONSIVE CIRCUIT

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FREQUENCY RESPONSIVE CIRCUIT

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This invention relates to frequency responsive circuits, and more particularly to a system for operating a relatively rugged relay in response to signals of predetermined or selected frequencies. When the input is above a preselected frequency, the relay is operated to one position; when the input is below this frequency the relay is operated to another position. Thus the device may be used to control motors or indicators in response to changes in the frequency of an alternating current source of relatively low power capability.

One application of this system is in the control of aircraft by means of a radio altimeter of the type described on pages 86–90 of Civil Aeronautics Bulletin No. 29, published by the Civil Aeronautics Administration. The radio altimeter provides an audio frequency output directly proportional in frequency to the height of the airplane above the ground. The airplane may be controlled to fly at some selected level by operating motors connected to the elevator surfaces in response to variations in the output frequency of the altimeter from the frequency corresponding to the selected level. A frequency responsive relay system for this purpose must withstand the vibration and acceleration forces occurring in flight without failure or false operation.

Accordingly, it is one object of this invention to provide an improved method of and means for controlling a relatively heavy and insensitive relay in response to variations from a predetermined value in the frequency of an alternating voltage.

Another object is to provide an improved device which is uniformly sensitive to frequency variations, independent of the selected frequency.

A further object is to provide an improved method of and means for controlling the damping of a relay or other electromagnetic device, to prevent erratic operation in response to sudden variations of the control voltage or received signal.

These and other objects will become apparent to those skilled in the art upon consideration of the following description, with reference to the accompanying drawing, which is a schematic circuit diagram of an embodiment of the invention.

A pentode amplifier tube 1 is provided, with a grid leak 3, a self bias resistor 5, and a load resistor 7. The plate of the tube 1 is coupled through a capacitor 9 to a double diode 11. The plate 13 of one diode section and the cathode 15 of the other diode section are connected to the capacitor 9. The cathode 17 of the first section

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is grounded, and the anode 19 of the other section is connected to ground through to a capacitor 21. The grid 23 of an amplifier tube 25 is connected to the diode plate 19 through a resistor 27. A load resistor 29 is connected from the anode 19 to the arm 31 of a tap switch 33. A plurality of resistors 35 are connected in series with an adjustable resistor 37 across a direct current source 38. The taps 39 of the switch 33 are connected between the resistors 35 so that an adjustable portion of the direct current voltage may be applied to the load resistor 29. A relay 41 is connected in the anode circuit of the tube 25.

The device operates as follows:

Audio frequency voltage applied across the resistor 3 is amplified in the tube 1. The amplitude of the input voltage is made high enough to cut off the tube on the negative peaks and cause saturation on the positive peaks. This clips the peaks of the amplified voltage, producing an output of rectangular wave form. The time constant of the condenser 9 and the resistor 7 is made so small that the condenser 9 will be almost 100% discharged or charged in one half cycle of the highest frequency at which this device is to operate.

The positive half cycle of the rectangular wave causes the condenser 9 to be charged through the diode section 13, 17. The negative half cycle of the rectangular wave discharges the condenser 9 through the diode section 15, 19 into the condenser 21 and hence stores its discharge current in the condenser 21. The condenser 21 discharges through the load resistor 29, potentiometer 33 and the direct current source 38. The condenser 9 charges and discharges through a voltage range Esw equal to the peak to peak amplitude of the rectangular wave voltage across the resistor 7 minus any average negative voltage Ef developed across the condenser 21. Hence every cycle, $(Esw+Ef)C$. Coulombs or $(Esw+Ef)(C)(F)$ amperes will be passed by the diode section 15, 19, where F is the frequency of the applied signal, and C is the capacitance of the capacitor 21. If Eb is the positive bias potential developed between point 31 and ground, and R is the resistance of the resistor 29, then

$$Ef=Eb-(Esw+Ef)(C)(F)(R)$$

when Ef is negative only. It is seen therefore that the voltage Ef is the resultant sum of the positive bias voltage Eb from point 31 to ground and the negative voltage developed across the resistor 29 due to the current $(Esw+Ef)(C)(F)$. When Ef is negative, the above relations hold exactly. However if the current $(Esw+Ef)(C)(F)$

is not sufficient to make E_f negative, then enough steady D.-C. current will flow thru the diodes 17, 18 and 15, 19 to maintain E_f at approximately zero volts. Thus E_f will not vary appreciably with frequency until the current

$$(E_{sw}+E_f)(C)(F)$$

is large enough to cause E_f to become negative. Above that point E_f will vary with frequency becoming more nonlinear as E_f becomes an appreciable part of E_{sw}. The rate of change of E_f with respect to frequency is:

$$\frac{dE_f}{df}=\frac{(E_{sw}+E_f)(C.R)}{1-C.FR}$$

The condenser 21 discharges through the load resistor 29, potentiometer 33 and the direct current source 38.

Thus the negative voltage E_f increases with frequency, becoming nonlinear with respect to frequency when E_f is an appreciable fraction of the square wave voltage E_{sw}. The voltage at the Eb tap 31 is adjusted to a value corresponding to the frequency at which the relay is to be operated. When the frequency is below the selected value, the grid 23 of the tube 25 is positive and the relay is energized, maintaining the contacts 43 in their upper positions. When the voltage E_f becomes slightly greater in magnitude than the voltage at the tap 31, the grid 23 becomes negative and the anode current of the tube 25 decreases, reducing the energization of the relay 41 and causing the movable contacts 43 to go to their lower positions.

In order to vary the frequency at which the relay 41 is operated the tap 31 may be moved to the corresponding contact 39. The system is then operated as described above, cutting off the tube 25 as the frequency increases about the selected value. Thus the same number of cycles per second deviation will actuate the relay at any selected frequency. The resistor 27 and the capacitor 28 are so proportioned as to have a time constant equal to or greater than that of the capacitor 21 and resistor 29. This causes the anode current of the tube 25 to change at the same rate with a decrease in frequency as it does with an increase in frequency, preventing erratic operation of the relay 41.

The invention has been described as a frequency responsive circuit for operating a relay in response to input of a predetermined frequency, a unidirectional voltage, related in magnitude to the frequency of the input, is derived. An adjustable unidirectional voltage is opposed to the frequency derived voltage, and the resulting difference voltage is used to control an amplifier tube connected to the relay.

I claim as my invention:

1. A frequency responsive relay system comprising a limiter, a rectifier coupled to the output of said limiter through a capacitor, a second capacitor in series with said rectifier, a discharge path for said second capacitor including a direct current source connected to oppose the voltage produced across said second capacitor by the current flowing through said rectifier, a second rectifier connected across said second capacitor and said first rectifier and poled oppositely thereto, an amplifier tube with its control grid coupled to said discharge circuit, a relay connected in the anode circuit of said amplifier tube, and means for adjusting the voltage of said direct current source which is applied to said discharge circuit, whereby said voltage overcomes the voltage produced across said second capacitor at a predetermined frequency of input to said limiter.

2. The method of operating a relay in response to variations in the frequency of an alternating voltage comprising the steps of deriving a unidirectional voltage related in magnitude to said frequency, opposing said voltage to a second unidirectional voltage of adjustable magnitude, controlling a power circuit in accordance with the amount by which said second voltage exceeds said first voltage, and energizing said relay with said power.

3. The method of operating a relay in response to variations in the frequency of an alternating voltage comprising the steps of deriving a unidirectional voltage related in magnitude to said frequency, opposing said voltage to a second unidirectional voltage of adjustable magnitude, controlling, a direct current in accordance with the amount by which said second voltage exceeds said first voltage, and energizing said relay with said current.

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