Aug. 13, 1957 H. T. SEELEY 2,802,945

OSCILLATOR-TYPE CONTROL CIRCUIT

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Fig. 1.

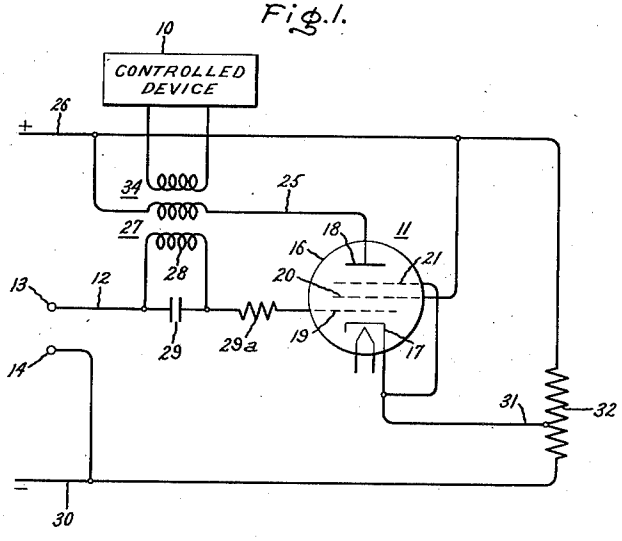


Fig. 2.

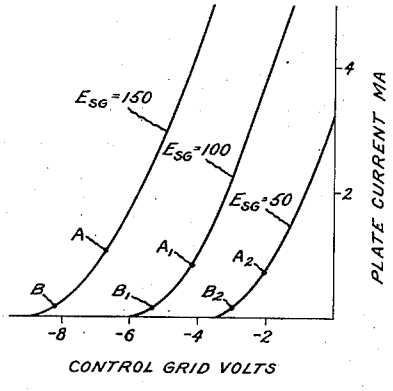
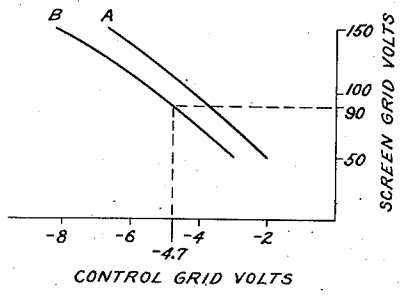


Fig. 3.



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OSCILLATOR-TYPE CONTROL CIRCUIT

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6 Claims. (Cl. 250—36)

This invention relates to an electronic control arrangement and, more particularly, a control arrangement which utilizes an oscillator to effect operation of an electroresponsive device.

Although various types of oscillators have been proposed heretofore for effecting operation of an electroresponsive device such as a relay, prior arrangements of which I am aware have not provided the high degree of reliability required for applications such as protective relaying. Minor variations in the control voltage supplied to the elements of the oscillator tube have caused the tube to respond inconsistently to predetermined input signals. In a protective relaying system, where extreme accuracy is usually required, such a characteristic seriously impairs the reliability of the system.

It is, therefore, an object of my invention to provide an oscillator which will consistently respond to input signals of a predetermined magnitude in spite of any variations in the control voltage supplied to the oscillator.

A further object is to operate an electroresponsive device such as a relay from an oscillator, the starting point of which is insensitive to variations in the control voltage supplied to the oscillator.

In accordance with one form of my invention, I provide an electron tube having a cathode, a plate, and a control grid, the control grid and the plate being coupled together in a manner to form an oscillator. Plate voltage is supplied by connecting the plate to one of the two terminals of a source of control voltage which is subject to variations. When a signal voltage varying beyond a predetermined starting value is applied between the control grid and the other terminal of the source, oscillations are initiated. This starting value is rendered insensitive to variations in the control voltage by means of a voltage divider connected across said terminals and having a cathode-connected tap which is set at a predetermined percentage of the variable control voltage. By correctly selecting the value of this predetermined percentage, the bias applied to the cathode is varied in response to control voltage variations by an amount sufficient to compensate for any tendency of the varying control voltage to change the oscillation starting point.

For a more complete understanding of my invention, reference may be had to the accompanying drawing in which Fig. 1 is a diagrammatic illustration of a control circuit embodying my invention, whereas Figs. 2 and 3 are graphical representations of certain characteristics of an electron tube of the type used in the circuit of Fig. 1.

Referring now to the drawing, the numeral **10** is used to designate a device such as a protective relay which it is desired to operate instantaneously when the magnitude of a signal voltage varies beyond a predetermined value. Additionally, it is desired that the response of this device be instantaneous even though the signal voltage varies only gradually. To obtain this desired response, I have provided an oscillator **11** having an input or grid circuit **12** to the terminals **13** and **14** of which the signal or input voltage is applied. The oscillator comprises an electron tube illustrated in the drawing as a pentode **16** having a cathode **17**, a plate or anode **18**, a control grid **19**, a screen grid **20** and a suppressor grid **21**. The plate **18** is connected through an output or plate circuit **25** to the positive terminal **26** of a suitable source of unidirectional control voltage. A suitable transformer **27** is provided for coupling the output circuit **25** to the input circuit **12** in such a manner that oscillations will be produced when the input voltage, which preferably is unidirectional, exceeds or varies beyond a predetermined value. The frequency of these oscillations is determined largely by a capacitor **29** connected across the output winding **28** of the transformer **27** to form a tuned oscillation circuit, as is well known in the art. The usual grid leak resistor is shown at **29***a* connected in series with the control grid **19**.

The screen grid **20** is shown connected directly to the positive terminal **26**, whereas the suppressor grid **21** is connected in a conventional manner to the cathode **17**. The cathode **17** is maintained at a voltage which is a predetermined fixed percentage of the total supply or control voltage between the positive terminal **26** and the negative terminal **30**. This is accomplished by connecting the cathode to a tap **31** of a voltage-dividing resistor **32** connected across the terminals **26** and **30**. In accordance with my invention, the setting of this tap **31** is selected in such a manner that the performance of the oscillator will be insensitive to variations in the control voltage existing between the terminals **26**, **30**. This latter feature will soon be explained in greater detail.

The circuit thus far described effects operation of the device **10** in the following manner: When the input or signal voltage applied to the terminals **13**, **14** varies beyond a predetermined value, the oscillator **11** instantly begins to oscillate and thereby causes an abrupt increase in the effective current flowing through the output circuit **25**. This abrupt increase in current acts through an inductive coupling **34** to effect instantaneous operation of the device **10** as desired. The increased effective current continues to flow in the output circuit **25** until the signal voltage returns to a normal range of values and thereby stops oscillations of the oscillator **11**.

A basic problem presented in operating an electroresponsive device from an oscillator of the type shown is that variations in the control voltage across the terminals **26**, **30** tend to vary the oscillation starting point. This is an especially critical problem where a battery is used as a source for the control voltage since the voltage of a battery rated at, say, 125 volts may vary between 100 and 140 volts. Variations of this magnitude can materially effect the oscillation starting point and thereby cause inconsistent operation of the device **10**. Because of the particular setting chosen for the tap of my cathode-connected voltage divider, I am able to render the oscillator starting point insensitive to such variations in the control voltage. The manner in which this insensitivity is obtained may be better understood by referring to Fig. 2 wherein I have shown a family of curves representing certain tube characteristics for a typical pentode such as the type 5693. Each of the curves illustrates the manner in which, for a constant screen grid voltage, the plate current will vary in response to variations in the control grid voltage. Plate voltage variations have been ignored because in a well designed pentode, for normal voltage conditions, the plate current varies only slightly with plate potential.

For a predetermined coefficient of coupling M between the input and output circuits, the starting point for oscillations will be determined by the slope of the curves shown in Fig. 2. Only when this slope equals a predetermined value, do oscillations begin. Thus, assuming that the control grid of the tube is initially biased

below the oscillation starting point, then to initiate oscillations, it is necessary to increase this control grid voltage in a positive direction until a point on the curve is reached at which the slope equals or exceeds the critical value. It has been found that this critical value of slope is the same irrespective of the screen grid voltage. Assuming then that the value of M is constant, the critical value of slope at which oscillations will begin is constant for each of the three curves of Fig. 2. Thus, by experimentally determining the oscillation starting point for one of these screen grid curves, it may be graphically determined for all of these curves of Fig. 2. For example, assume that with a fixed value of M and the screen grid at 150 volts, oscillations begin at the point designated A. After the slope of the curve at point A is determined, corresponding points of equal slope can be found on the other two curves. These are designated respectively A_1 and A_2. For different values of M, oscillations will start at different sets of equal slopes. I have designated another such set of these equal slope values as B, B_1, and B_2. After these points of equal slope have been determined, they may then be plotted in terms of control grid volts versus screen grid volts. Fig. 3 shows these oscillation starting points so plotted, the curve A containing the points A, A_1, and A_2 and the curve B containing the points B, B_1, and B_2. Thus, in Fig. 3 each curve represents, for a fixed value of M, the oscillation starting points in terms of screen grid volts versus control grid volts. With the curves of Fig. 3 established, the tap setting of the voltage-dividing resistor **32** may then be determined. First, assume that the setting is arranged to provide between the tap **31** and the negative terminal **30** a voltage drop of .10 times the total voltage between the terminals **26** and **30**. With the cathode taken as a reference point of zero voltage and with a total of 100 volts between the terminals **26** and **30**, the screen grid will have a voltage of 90 and the negative terminal a voltage of —10. If the coupling coefficient M is the same as that used for establishing the curve B of Fig. 3, it can then be determined from this curve that when the screen grid is at 90 volts, the control grid voltage required to begin oscillations is —4.7 volts. This step is illustrated by the dotted lines of Fig. 3. Since this value of control grid voltage is measured with respect to the cathode, this means that the input voltage between the control grid **19** and the negative terminal **30** must equal or exceed —4.7–(—10) or +5.3 volts before oscillations will begin. Now, if for an identical tap setting this same series of calculations is performed for a total voltage of 140 volts across the terminals **26**, **30**, it will be found that an input voltage of 7.5 volts between the control grid and terminal **30** is required to initiate oscillations. Thus, it may be seen that, with a tap setting of .10, when the supply voltage varies between the extremes of 100 and 140, the input voltage required to initiate oscillations may vary by about 40 percent. For protective relaying such a variation is obviously unacceptable. However, by repeating the above described calculations for a series of different tap settings, it is possible to determine the optimum tap setting required in order that this value of input voltage remain substantially constant as the control voltage varies between its extreme limits. For a curve such as B it has been found, by using the above calculations, that a tap setting of .052 will cause oscillations to start at an essentially constant input voltage (of 0.30 volts) even if the control voltage varies between 100 and 140 volts. Thus, with the tap **31** so adjusted, the device **10** will consistently operate in response to the same value of signal voltage in spite of appreciable variations in the control voltage supplied from terminals **26**, **30**.

Although I have demonstrated above the manner in which the tap setting may be determined by calculations, it is to be understood that the same results can be arrived at by experimentally varying the tap setting in the actual tube circuit.

I am aware that voltage dividers have been used heretofore for obtaining varying degrees of bias on the control elements of electron tubes, but I am not aware of their use in accordance with this invention, i. e., in controlling the cathode voltage of an oscillator in such a manner that the oscillation starting point is insensitive to appreciable variations in the control voltage.

It will now be evident to those skilled in the art that the foregoing preferred embodiment of my invention including a pentode oscillator provided with inductive feedback coupling is illustrative only, and that the invention is equally applicable to other well-known oscillators having one or more than one grid between plate and cathode. Thus, while I have shown and described a particular embodiment of my invention, it will be obvious to those skilled in the art that various changes and modifications may be made without departing from my invention in its broader aspects and I, therefore, intend in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of my invention.

What I claim as new and desire to secure by Letters Patent of the United States is:

1. In combination, an electron tube having a cathode, a plate, and a control grid, means for coupling said plate and said control grid together in a manner to form an oscillator, a pair of terminals for supplying an unidirectional control voltage which is subject to variations, means for connecting said plate to one of said terminals, means for applying between said control grid and the other of said terminals a signal voltage which upon varying beyond a predetermined starting value is operable to initiate and sustain oscillations and which upon returning to a normal range of values is operable to stop oscillations, and means for maintaining said cathode at a voltage which is a predetermined percentage of said variable control voltage, said percentage being selected to vary the cathode voltage in response to control voltage variations by an amount sufficient to maintain said predetermined starting value essentially constant in spite of said control voltage variations.

2. In combination, an electron tube having a cathode, a plate, and a control grid, means for coupling the control grid and the plate together in a manner to form an oscillator, a pair of terminals for supplying a control voltage which is subject to variations, means for connecting said plate to one of said terminals, means for applying between said control grid and the other of said terminals a signal voltage which upon varying beyond a predetermined starting value is operable to initiate oscillations, a voltage divider connected across said terminals and having a voltage tap set at a predetermined percentage of said supply voltage, means for connecting said tap to said cathode, the setting of said tap being selected to vary the cathode voltage in response to control voltage variations by an amount sufficient to maintain said predetermined starting value essentially constant in spite of said control voltage variations.

3. In combination, an electron tube having a cathode, a plate, and a control grid, a pair of terminals for supplying an unidirectional control voltage which is subject to variations, an output circuit connecting said plate to one of said terminals, means for coupling said output circuit to said control grid in a manner to form an oscillator, an electroresponsive device coupled to said output circuit and operable in response to the initiation of oscillations, means for applying between said control grid and the other of said terminals a signal voltage which upon varying beyond a predetermined starting value is operable to initiate and sustain oscillations, and means for rendering said starting value insensitive to control voltage variations comprising means for maintaining said cathode at a voltage which is a predetermined percentage of said

variable control voltage, said percentage being selected to vary the cathode voltage in response to control voltage variations by an amount sufficient to maintain said predetermined starting value essentially constant in spite of said control voltage variations.

4. In combination, an electron tube having a cathode, a plate, a screen grid and a control grid, means for coupling said plate and said control grid together in a manner to form an oscillator, a pair of terminals for supplying a control voltage which is subject to variations, means for connecting said plate and said screen grid to one of said terminals, means for applying between said control grid and the other of said terminals a signal voltage which upon varying beyond a predetermined starting value is operable to initiate oscillations and which upon returning to a normal range of values is operable to stop oscillations, means for maintaining said cathode at a voltage which is a predetermined percentage of said variable control voltage, the value of said percentage being selected to vary the cathode voltage in response to control voltage variations by an amount which compensates for variations in screen grid voltage, said compensation being effective to maintain said predetermined starting value essentially constant.

5. In combination, an electron tube having a cathode, a plate, a screen grid, and a control grid, means for coupling said plate and said control grid together in a manner to form an oscillator, a pair of terminals for supplying a control voltage which is subject to variations, means for connecting said plate and said screen grid to one of said terminals, means for applying to said control grid an input voltage measured with respect to the other of said terminals, which upon varying beyond a predetermined starting value is operable to initiate oscillations, and means for maintaining said cathode at a predetermined

fixed percentage of said variable control voltage, said percentage being selected to vary the cathode voltage in response to control voltage variations by an amount sufficient to maintain said predetermined starting value essentially constant in spite of said control voltage variations.

6. In combination, an electron tube having a cathode, a plate, a screen grid, and a control grid, a pair of terminals for supplying a unidirectional control voltage which is subject to variations, means including an ouput circuit connecting said plate and said screen grid to one of said terminals, means for coupling said output circuit to said control grid in a manner to form an osclator, an electroresponsive device coupled to said output circuit and operable in response to the initiation of oscillations, means for applying between said control grid and the other of said terminals a signal voltage which upon varying beyond a predetermined starting value is operable to initiate oscillations and which upon returning to a normal range of values is operable to stop oscillations, and means for maintaining said cathode at a voltage which is a predetermined percentage of said variable control voltage, said percentage being selected to vary the cathode voltage in response to control voltage variations by an amount which compensates for variations in screen grid voltage, said compensation being effective to maintain said predetermined starting value essentially constant.

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