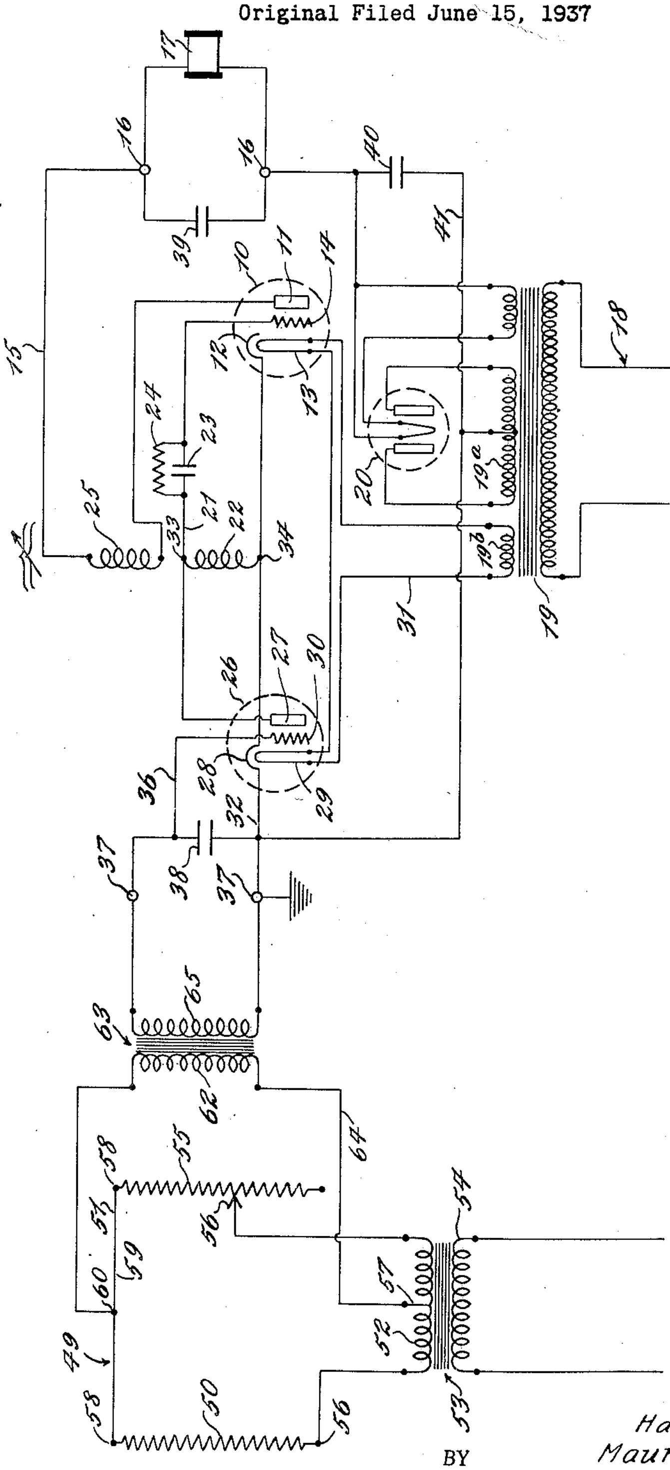
Feb. 6, 1940. H. P. DONLE ET AL 2,189,462

BRIDGE CIRCUIT

Original Filed June 15, 1937



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UNITED STATES PATENT OFFICE

2,189,462

BRIDGE CIRCUIT

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Application June 15, 1937, Serial No. 148,336
Renewed July 7, 1939

10 Claims. (Cl. 250—36)

Our invention relates to improvements in control means sensitive to variations in resistance resulting from various external energy excitations, and the same has for its object to provide a simple, reliable and efficient circuit arrangement which is energized by an alternating current source without impairing the sensitivity thereof as a device for translating the external energy excitations into their corresponding potential variations for the operation or control of various circuits, devices or forms of apparatus for measuring or indicating the energy excitations or for effecting a control or regulation in accordance therewith.

Further, said invention has for its object to provide a circuit arrangement of the character specified which is capable of maintaining a relatively high level of potential at the output thereof responsive to the variations or changes in resistance while minimizing heating effects in the circuit due to current therein.

Further, said invention has for its object to provide a circuit arrangement of the character specified, in which the relatively variable legs thereof are normally unbalanced so that a variation in resistance in one direction from a normal value may be readily distinguished from a variation in resistance in the opposite direction from normal value.

Further, said invention has for its object to provide a circuit arrangement of the character specified which includes means responsive to variations of potential in one direction only from a mean or normal value for controlling or regulating the operation of various devices or instruments.

Other objects will in part be obvious and in part be pointed out hereinafter.

To the attainment of the aforesaid objects and ends, our invention consists in the novel features of construction, and in the combination, connection and arrangement of parts hereinafter more fully described and then pointed out in the claims.

In the accompanying drawing, the figure shows a diagram of one form of circuit constructed according to and embodying our said invention, the arrangement including an electronic tube circuit particularly adapted to be activated by the potential variations.

The electronic tube circuit herein shown and described is claimed herein in combination with the bridge circuit constituting the subject matter of the present invention. Said electronic tube circuit per se constitutes the subject matter of a separate application for patent, Serial No. 148,335 filed on June 15, 1937, by the inventor thereof, Harold P. Donle.

Referring to the drawing, the electronic tube circuit includes the tube or valve 10 of the usual type having plate 11, cathode 12 heated by filament 13, and grid 14. The output or plate circuit 15 is provided with the terminals 16 to which the electro-mechanical device, relay, controller, regulator, indicator, or other means 17 to be controlled or operated is electrically connected. The plate circuit 15 includes the usual source of energy 18 capable of supplying the current and voltage required for operation of the system, including the device 17. As an example, the energy for operation may be supplied from the A. C. line through the step-down transformer 19, including the secondary 19ª in circuit with the usual full wave rectifying tube 20 in the output circuit 15, having the usual circuit connections for rectifying the current supplied to the output circuit 15 through the transformer 19.

The input circuit 21 of the tube 10 includes a coil or inductance 22 between the grid 14 and the cathode 12 and a grid condenser 23 bridged by a resistance or grid leak 24 disposed between the grid 14 and coil 22. The output circuit 15 of the tube 10 has a coil or inductance 25 included therein disposed in inductive relation with the coil 22 to form with the inherent capacity of the tube 10 a feed-back coupling capable of adjustment between the input and output circuits of the tube 10 for causing the tube to oscillate under certain conditions as hereinafter more fully described.

The system also includes a second electronic tube or device 26 including plate 27, cathode 28 heated by filament 29 and grid 30. The filaments 13 and 29 of both tubes 10 and 26 are preferably in the same circuit 31, including a portion 19ᵇ of the secondary of the transformer 19 for supplying heating current to the filaments. The cathodes 12 and 28 are in series with each other and are grounded through the conductor 32. The two tubes 10 and 26 may be enclosed within one and the same envelope or bulb, if so desired.

The plate 27 of the tube 26 is connected to one end 33 of the coupling coil 22, and the cathode 28 is connected to the opposite end 34 of said coil 22, the tube 26 is thus connected constituting, as hereinafter more fully described, a variable capacity across the coil 22. The electronic tube 26 constitutes means for causing a variation of capacity in the circuits of the tube 10 and therefore does not operate as the usual amplifier or relay, and does not require in the output circuit 27—22—28 thereof a local source of energy, Bbattery, or the like, for supplying energy required for amplification.

The potential variations imposed on the grid 30 located between the plate 27 and heated cathode 28 cause, apparently because of the electronic characteristics of the tube 26, an appreciable variation in capacity of said tube, which capacity variations are made to control the circuits of the tube 10 to throw the same into and out of oscillation.

The electrical energy or potential for exciting the grid 30 is supplied from the bridge circuit constituting the subject matter of the present invention and serving as a translating device to the input circuit 36 of the tube 26 through the terminals 37. A condenser 38 is inserted between the grid 30 and cathode 28 for by-passing any stray energy from the oscillating circuits around the translating means and also for preventing capacity variations in the translating circuits connected to the terminals 37 from affecting the operation of the system. A condenser 39 also bridges the terminals 16 of the output circuit of the tube 10 to provide a high frequency path by-passing the device 17. A condenser 40 is also inserted in the connection 41 by-passing the rectifier 20 to provide a path for the high frequency currents around the rectifier to ground and to block the flow of direct or rectified current through the connection 41.

In the system illustrated, the control tube 10 is connected in a feed back circuit including either an inductive or capacitive coupling, or both, for causing energy transfer between the input and output circuits of the tube for producing oscillation of any desired frequency, depending upon the period of the circuits. When the tube 10 is caused to oscillate, there will be a change in the direct current component in the output circuit 15 of the tube 10. The magnitude of this change in plate current available for doing work, and the character thereof, depends primarily upon the character of the potential variation imposed upon the grid 14 by the oscillations. For example, when the grid 14 is connected to the circuit through the small capacity 23 shunted by a relatively high resistance 24, say, of the order of three megohms, the grid will build up a negative potential charge thereon as the oscillation continues, causing the direct current component in the output circuit to be reduced to a low value, which is maintained so long as the system continues to oscillate. When the oscillations cease, the work current again rises to its maximum value for energizing the electro-mechanical device 17, the tube 10 under said conditions operating as a "trigger" or cut-out valve to cause an abrupt change in the flow of output or work current. By adjustment or change in the value of the resistance or leak 24, the rate at which the negative potential on the grid 14 is discharged may be varied to correspondingly vary or modulate the direct current component in the output circuit 15. The system, therefore, may be readily adapted for use as a repeater and amplifier of energy impulses having a definite period, such as occur in telephony, radio, phonograph pick-up work, and in other arts.

The coupling provided by the coils 22 and 25 is critically adjusted so that a very slight variation of capacity in either grid or plate circuit will throw said circuits into and out of resonance to start and stop oscillation thereof, the bias on the grid 30 of the tube 26 being such that the capacity variation is operative in one direction only from a normal value for controlling the oscillation. Preferably, the circuits are adjusted in capacity and inductance to oscillate at superaudible frequencies, particularly when the tube 10 is employed for modulating the output or work current in accordance with energy impulses having a definite frequency to be reproduced or repeated.

The potential variations or impulses imposed upon the grid 30 for producing a capacity variation, may be obtained by translating various forms of energy, such as sound, light, heat, and other radiations, into their corresponding electrical equivalent for controlling the tube 26. The bridge circuit or energy translating means 49 embodying the invention, operates by a variation in a resistance in response to excitation by energy impulses or variations, such as those of heat or light. In the diagram the energy responsive element comprises a resistance 50 exposed to the energy impulses, and capable of varying in resistance as a function of the temperature change thereof. The resistance 50 is disposed in a bridging circuit 51, including the secondary 52 of a step-down power transformer 53 having its primary 54 in the circuit with the A. C. line for supplying the requisite energy to the bridge. The resistance 50 is opposed by resistance 55 capable of adjustment. The resistances or legs 50 and 55 are bridged at the corresponding ends 56 by the transformer secondary 52 which is subdivided at its midpoint 57 to form the other two legs of the bridge circuit, and the same at the opposite ends 58 are bridged by the circuit connection 59. The midpoint 60 of the conductor 59 is connected by the lead 61 to one end of the primary 62 of the step-up transformer 63, and the midpoint 57 of the secondary coil 52 of the transformer 53 is connected by lead 64 with the opposite end of the transformer primary 62. The secondary 65 of the transformer 62 is connected to the input terminals 37 of the system above described.

Metals in general vary either directly or inversely in resistance with variations in temperature. The element 50, as an example, varies in resistance directly with the temperature. The transformer 53 steps down the voltage to a low value of the order of 4 or 5 volts, so that no appreciable heating up of the resistance 50, due to current flow, will occur. If the variable resistance 55 constituting the opposing leg of the bridge circuit is made at a given temperature equal in value with that of resistance 50, there will be no flow of current to the transformer 63. However, if the resistance 55 is made either less than or greater than the value of resistance 50 at a given temperature, there will be a continuous flow of current through the transformer 63 which is proportional to the difference in the values of the resistances of the legs 50 and 55. In the example illustrated, the resistance 50 is preferably made greater in value than the resistance 55. The difference in the resistances unbalances the bridge circuit to cause a flow of current through the transformer 63 which steps up the voltage by an appreciable amount for application to the grid 30. The two resistances are relatively adjusted so that the biasing voltage or potential on the grid 30 is sufficient to produce a capacity effect causing oscillation of the tube 10 and to stop oscillation of said tub 10 upon a slight decrease in the temperature and hence of the resistance of the element 50. Utilizing a heat responsive element 50 having a greater resistance than that of element 55 renders the system particularly adapted for controlling the temperature conditions within buildings, because the normal resistance values at a given temperature and the characteristics of the transformers in the bridge circuit are such that a drop in the normal potential applied to the grid 30 will throw the circuits of the tube 10 out of oscillation and energize the relay 17 in response to a call for heat, the relay 17 then operating to supply the compensating heat to the building. Should the resistance 50, however, be subjected to a temperature rise, although the potential applied to the grid 30 increases, the control tube 10 continues in oscillation to maintain the mechanical relay 17 in its inoperative position, the increase in the potential on the grid 30 not affecting the oscillation of the tube 10 because of the characteristics of the tube 26.

The translating system or bridge circuit 49, illustrated as one example thereof, is very efficient in supplying the voltage variations to the grid 30 of the tube 26 for controlling the output or work current supply to the mechanical relay or other instrument 17. By utilizing the ordinary A. C. line for affording the necessary electrical energy supply for operating the system, we are able to supply the energy through a step-down transformer to the bridge circuit and to the grid 30 of the tube 26 through a step-up transformer. Ample voltage therefore is available for application to the grid 30 and the currents flowing in the bridge circuit are minimized to reduce the heating effects thereof on the resistances 50 and 55.

By utilizing a bridge circuit 49 in which the legs 50 and 55 are unbalanced we are able to maintain or impose a normal positive potential or bias on the grid 30 to render the tube 26 critically sensitive or responsive to the energy impulses imposed thereon, the tube 26 then operating at a point on its characteristic curve which renders it critically responsive to the imposed energy impulses for causing the capacity variation. By operating from an unbalanced relation instead of from a balanced relation at a given or desired temperature, both a decrease and an increase in the temperature are made distinguishable, a decrease of the resistance 50 from normal value decreasing the voltage applied to the grid 30 and an increase from normal value increasing the voltage applied to the grid 30.

In operation, assume that the coupling provided by the coils 22 and 25 is adjusted so that the circuits of the tube 10 are thrown out of oscillation upon a variation in capacity accompanying a reduction of potential on the grid 30 of tube 26 from a normal value. It is also assumed that the bridge circuit embodying our invention employed as the translating means, has the constants thereof chosen or fixed in accordance with the character of the incoming energy impulses and the operation to be effected thereby. The coupling 22—25 and the circuit constants of the circuits of the tube 10, by suitable adjustment in accordance with the principles of the invention, may be readily coordinated with the translating means and tube 26 to be operatively responsive to the variations produced by the tube 26.

When the circuits of tube 10 are in oscillation, a high negative potential obtained by the feed of energy from the plate circuit is maintained on the grid 14 through the condenser 23 and the high resistance leak 24. This action reduces the flow of the direct current component in the output circuit 15 to a minimum causing the deenergization of the relay 17. Should the potential on the grid 30 of the capacity controlling tube 26 decrease slightly for any reason, as, for example, because of a reduction in the temperature of the resistance 50 of the bridge circuit 49, the resulting variation in the capacity of the tube 26 causes a change in coupling between the input and output circuits of tube 10, throwing said circuits out of oscillation and allowing a maximum flow of the direct or work current through the relay 17 to energize the same.

When the potential on the grid 30 again increases towards normal value, accompanying, for example, an increase of the temperature of resistance 50, and attains a predetermined value, the resulting change in capacity of the tube 26 causes the oscillation to be resumed for reducing the work current available for operation and rendering the relay 17 inoperative. It requires a greater voltage change on the grid 30 to cause oscillation than it does to stop oscillation of the control tube 10. This characteristic of the system renders the same very stable in operation, particularly when utilized for room or building temperature control, and effectively prevents fluttering in the system, such as of the relay 17. As an example of the operation, assuming that the resistance 50 of the bridge circuit has a value for maintaining a room temperature at 70° F. upon a small fractional drop in the temperature, the system will be thrown out of oscillation and the relay 17 will respond to the demand for heat. As heat is supplied to the room, the resistance 50 will have to heat up to some fractional value above 70° F. before the potential rise on the grid 30 becomes sufficient to throw the tube 10 into oscillation and actuate the relay. The temperature of the resistance 50 may then drop to its normal value of 70° without affecting the oscillation. This potential lag in one direction of operation is an inherent characteristic of the system and depends upon the value of the circuit constants such as the inductances, grid leak, etc. By adjustment of one or more of these constants the potential lag in one direction of control of the system may be varied. By suitable selection of the resistance element 50, the latter may be coordinated with the system activated to control the limits of temperature variation so that the system will be stabilized at the desired normal temperature in both the oscillating and nonoscillating states.

The bridge circuit embodying our invention is particularly adapted for the detection and translation of weak, minute, or infinitesimal energy impulses or variations capable of causing a variation of resistance in the bridge circuit to effect a potential variation. By utilizing as the resistance 50 various devices, the bridge circuit may be made responsive to various forms of energy, such as those of sound, light, heat, radio, etc., whereby to render the same useful in various fields or arts, such as heating, telephony, radio, television, and the like, and for operating or controlling various indicating and recording instruments or devices in response to various energy excitations.

In our invention, we subdivide the secondary 52 of the step-down transformer 63 and utilize the parts thereof as two legs of the bridge having equal values, the remaining legs 50 and 55 thereof having unequal values to constantly maintain a difference of potential between the points 57 and 60 for application to the step-up transformer 63. The unbalanced bridge renders a rise in temperature from a normal value distinguishable from a drop in temperature from said value. Were such resistances **50** and **55** normally balanced or equal, both a rise and drop of temperature of the resistance **50** would produce the same change of potential on the grid **30** and correspondingly control the oscillating system. The translation bridge **49** is therefore particularly adapted for activating the control system illustrated, inasmuch as the coupling **22—25** and tube **26** are so designed or adjusted that a rise in temperature of the resistance element **50** from normal value, resulting in an increase of the potential on the grid **30**, will not affect the oscillation.

The present invention is particularly adapted for controlling the temperature conditions within a building in response to variations in temperatures at two or more points, such as at the outdoors, in a room or rooms, at a radiator, or at the return from said radiator or radiators, the resistance **50** then being subdivided into two or more parts in series having values proportional to the temperature ranges of the environments to which the resistances are exposed and operating as multiple thermostats serving to balance each other.

What we claim and desire to secure by Letters Patent of the United States is:

1. A system of the character described, comprising an electronic tube, a circuit having certain of the constants thereof controlled by said tube, and a bridge circuit connected to the grid of said tube and having a source of energy supply, said bridge including resistance legs differing in resistance sufficiently to maintain a potential on the grid of said tube serving to prevent operation thereof upon variation of grid potential in one direction from normal value, and certain of said resistance legs being variable in response to external energy excitations to vary the potential imposed on said grid.

2. A system of the character described, comprising an electronic tube, a circuit having certain of the constants thereof controlled by said tube, a bridge circuit including an input transformer connected to an alternating current supply and an output transformer connected to the grid of said tube, said bridge circuit having unbalanced resistance legs for normally imposing a potential on the grid of said tube sufficient to prevent operation thereof upon variation of the grid potential in one direction from normal value, and certain of said legs being variable in response to external energy excitation for causing a variation in the potential on said grid.

3. A system of the character described, comprising a circuit capable of control by a capacity variation, an electronic tube including cathode, plate and grid, said cathode and said plate being connected in said circuit as a variable capacity, and an alternating current bridge having unbalanced resistance legs for the application of a normal potential to the grid of said tube sufficient to prevent operation thereof upon variation of grid potential in one direction from normal value, certain of the legs of said bridge being variable in response to external energy excitation for causing a variation in the potential on the grid.

4. A system of the character described, comprising an electronic tube having plate and grid circuits coupled together, an electronic tube having the plate and cathode thereof connected to said coupling to vary the capacity component thereof, and a bridge circuit connected to the grid of said last-named tube and having a source of energy supply, said bridge circuit including unbalanced resistance legs for imposing a normal potential on said grid sufficient to prevent operation of said last-named tube upon variation of the grid potential thereof in one direction from normal value, and certain of said resistance legs being variable in response to external energy excitation to vary the applied potential.

5. A system of the character described, comprising an electronic tube having plate and grid circuits coupled together for oscillation, an electronic tube connected to said coupling as a variable capacity for controlling the oscillation, a step-down transformer connected to an alternating current supply and having a secondary divided to form resistance legs of a bridge circuit, resistance legs completing the bridge circuit, said last-named legs being unbalanced in resistance to an extent serving to maintain sufficient potential on the grid of said second tube for preventing operation thereof upon variation of grid potential in one direction from normal value, and one of said last-named legs being variable in response to external energy excitation, and a step-up transformer connecting the bridge circuit with the grid of the second tube.

6. A system of the character described, comprising an electronic tube having plate and grid circuits coupled together for oscillation, said coupling being adjusted in value to throw said circuits out of oscillation upon a variation in capacity thereof in one direction from a normal value, an electronic tube connected to said coupling as a variable capacity for normally maintaining oscillation of said circuits, a bridge circuit connected to the grid of said last-named tube and having a source of energy supply, said bridge circuit including unbalanced resistance legs for imposing a normal potential on said grid sufficient to prevent capacity variation of the second tube upon change of the grid potential thereof in one direction from normal value, and certain of said legs being variable in response to external energy excitation, the said coupling, said second tube and said bridge circuit being coordinated so that change in the resistance of the variable leg in one direction from a normal value becomes effective to throw said first-named circuits out of oscillation.

7. A system of the character described, comprising a circuit having a current source therein, an electronic tube having the plate and cathode thereof connected in said circuit to vary certain of the constants thereof, and translating means having a source of current energy therein and including unbalanced resistances connected to the grid of said tube so as to impose a potential thereon corresponding to the unbalanced relation, said unbalanced relation being such as to maintain on said grid a normal potential sufficient to prevent operation of said tube upon variation of the grid potential in one direction from said normal value, and one of said resistances being variable in response to external energy excitations to vary the potential on the grid.

8. A system of the character described, comprising an electronic tube having plate and grid circuits coupled together, an electronic tube having the plate and cathode thereof connected in one of said circuits, said coupling and said last-named tube being coordinated to throw said circuits into and out of oscillation upon variation of

said last-named tube, and translating means having a current source therein and including unbalanced resistances connected to the grid of said last-named tube so as to impose a potential thereon corresponding to the unbalanced relation, said unbalanced relation being such as to maintain a normal potential on said last-named grid sufficient to prevent operation of the tube thereof upon variation of the grid potential in one direction from said normal value, and one of said resistances being variable in response to energy excitations to vary the potential on said grid.

9. A system of the character described, comprising an electronic tube having plate and grid circuits coupled together, an electronic tube having the plate and cathode thereof connected to said coupling, said coupling and said last-named tube being coordinated to throw said circuits into and out of oscillation upon variation of the last-named tube, a capacity connected between the grid and the cathode of said last-named tube, and translating means including a source of current and unbalanced resistances connected to the grid of said last-named tube so as to impose a potential thereon corresponding to the unbalanced relation, said unbalanced relation being such as to maintain a normal potential on the grid sufficient to prevent operation of said tube upon an increase of grid potential from normal value, and certain of said resistances being variable in response to energy excitations to vary the grid potential.

10. A system of the character described, comprising an electronic tube having plate and grid circuits coupled together, an electronic tube connected to the coupling in one of said circuits as a variable capacity, said coupling and said last-named tube being coordinated to throw said circuits into or out of oscillation upon variation of the tube capacity, and translating means including a source of energy and unbalanced resistances connected to the grid of said last-named tube so as to impose a potential thereon corresponding to the unbalanced relation, said unbalanced relation being such as to impose a normal potential on said grid preventing change in the capacity effect of the tube upon further increase in potential, and the greater of the resistances being variable in response to energy excitation to vary the applied potential on the grid of said last-named tube.

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