Feb. 6, 1940. H. P. DONLE 2,189,461

ELECTRONIC TUBE CIRCUITS

Filed June 15, 1937 2 Sheets-Sheet 1

Fig. 1.

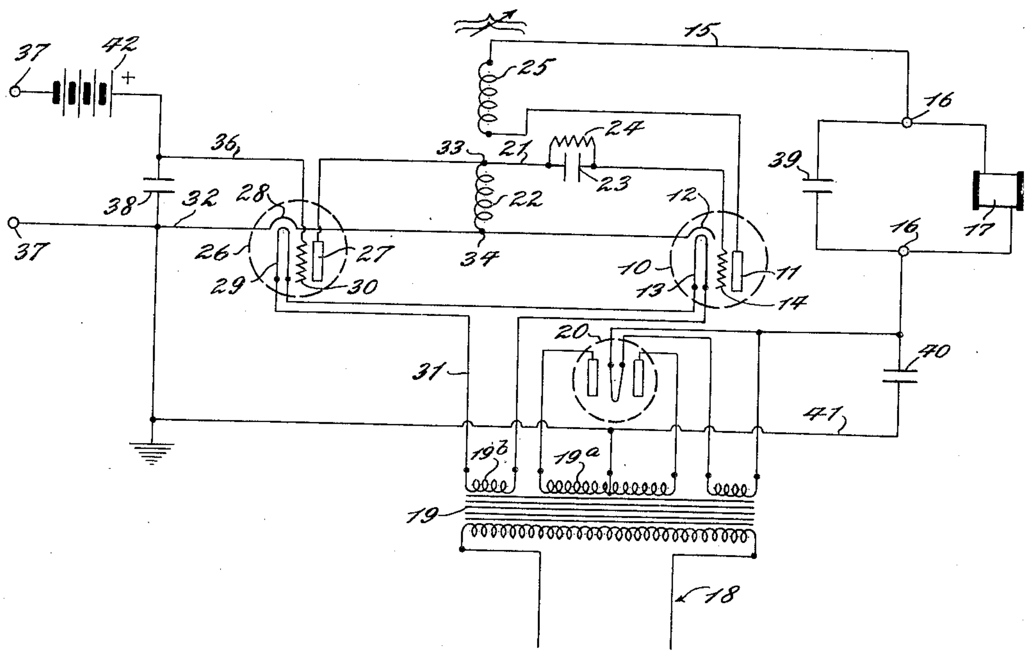


Fig. 3.

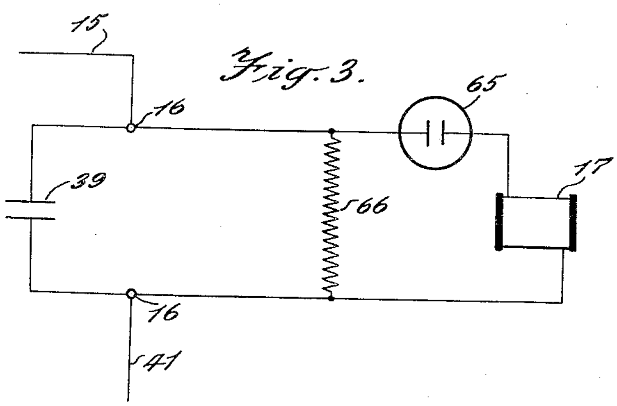
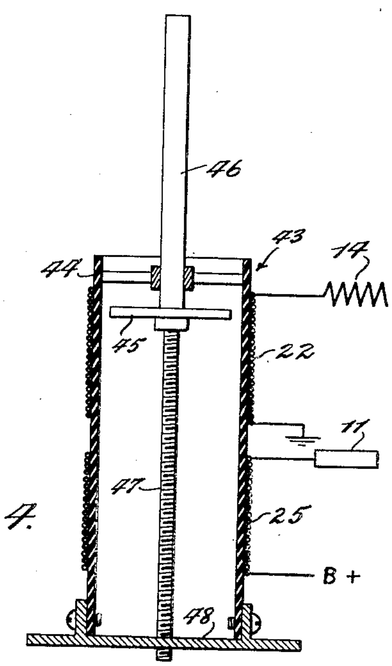


Fig. 4.



INVENTOR.
Harold P. Donle
BY
his ATTORNEY.

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2 Sheets-Sheet 2

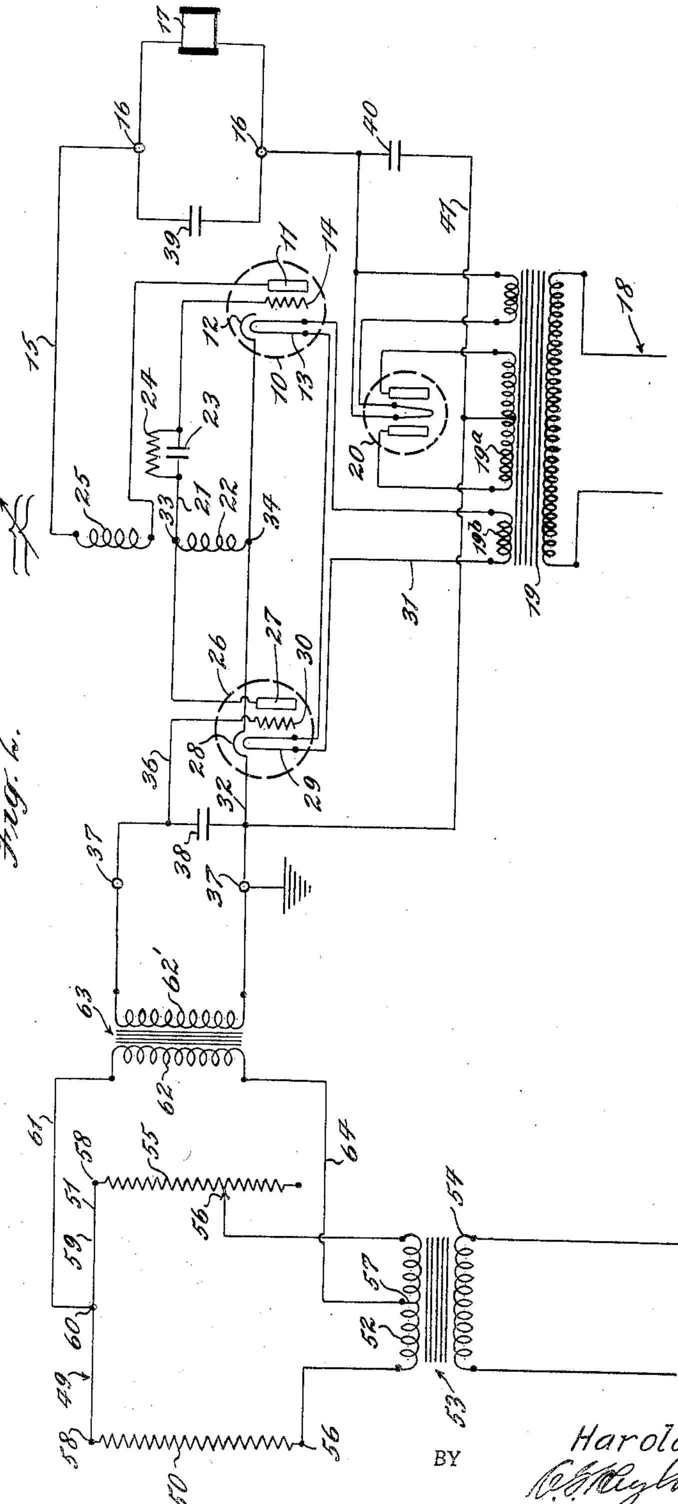

Fig. 2.

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UNITED STATES PATENT OFFICE

2,189,461

ELECTRONIC TUBE CIRCUITS

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Application June 15, 1937, Serial No. 148,335

6 Claims. (Cl. 250—36)

My invention relates to improvements in means for operating or controlling electro-mechanical devices or other instruments in response to weak, infinitesimal or minute energy impulses or variations, and the same has for its object to provide a simple, reliable and efficient system for controlling an electronic tube or valve in response to said impulses or variations for causing the desired variation in the output or working current of the tube for operation of the device or instrument.

Further, said invention has for its object to provide a method and system for carrying out said method, whereby to render said minute or weak energy impulses or variations available for activating the control tube or valve of the system with maximum efficiency or sensitivity without requiring the prior amplification of the electrical impulses resulting from or corresponding to said energy impulses or variations.

Further, said invention has for its object to provide a system of the character specified, in which the control tube thereof is operable to cause either abrupt changes in its plate or output current, or modulated variations thereof, according to the character of the energy impulses or variations applied to the system and the work to be done by said output current.

Further, said invention has for its object to provide a system of the character specified, in which the control tube or valve thereof is capable of operating with a trigger action for producing an abrupt rise or fall in the output or work current for controlling the operation of mechanical relays or other electro-mechanical devices requiring substantial energy to operate the same.

Further, said invention has for its object to provide a system of the character specified, in which means are included for translating the activating energy impulses or variations into corresponding capacity variations or changes effective in the circuits of the control tube or valve for controlling the operation thereof.

Further, said invention has for its object to provide a system of the character specified, in which the control valve or tube is capable of self-oscillation under control of the impressed capacity variations for varying the grid potential and hence the flow of working current or direct current component in the plate or output circuit of the tube or valve.

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

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

In the accompanying drawings,

Figure 1 is a circuit diagram of one form of system constructed according to and embodying my said invention;

Fig. 2 is a circuit diagram of the system including one form of translating means responsive to the activating energy impulses for converting the same into the corresponding potential variation for operating the system, said translating means being shown as a bridge circuit in operative relation with the input end of the system;

Fig. 3 is a circuit diagram of the output portion of my system showing a glow discharge tube in the circuit thereof, serving as a cut-out switch for the electro-mechanical device operated by the system, and

Fig. 4 is a view of one form of adjustable feed-back coupling which may be employed in the circuits of the control tube or valve.

Referring to the drawings, the electronic control tube or valve **10**, of the usual type required for the purpose, includes 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, instrument 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 **19**[a] 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 the 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 a 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 21 are preferably in the same circuit 31, including a portion 19^b 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 coupling coil 22, and the cathode 28 is connected to the opposite end 34 of said coil 22, the tube 26 as thus connected constituting, as hereinafter more fully described, a variable capacity across the coil 22. The electronic tube 26 in the present invention 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, B-battery, or the like, for supplying energy required for amplification.

I have discovered that potential variations imposed on the grid 30 located between the plate 27 and heated cathode 28 cause, because of the electronic characteristics of the tube 26, a corresponding change in the electron flow or emission resulting in a 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 a suitable translating device, such as that shown in Fig. 2, 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.

When the usual electronic device is employed as the tube 26, it is preferable to impose normally a positive potential or bias on the grid 30 thereof to render the tube 26 critically sensitive or responsive to the energy impulses imposed thereon. The imposed potential is preferably of an order preventing variation in capacity upon variation of the potential on the grid in one direction. Such biasing means is illustrated in Fig. 1 as comprising a low voltage battery 42 in series with the grid 30 for operating the tube 26 at a point on its characteristic curve which renders the tube critically sensitive in responding to the imposed energy impulses for causing the capacity variation.

In the system embodying my invention, the coupling capacity of the control tube 10 is supplemented by an inductive coupling which may include distributed capacity 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 variations 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 occurs in telephony, radio, phonograph, pick-up work, and in other arts.

In the present invention, 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 coupling and the tube 26 as biased being coordinated so that the capacity variation is operative in one direction only from a normal value for controlling the oscillations. 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.

In Fig. 4 is illustrated simple means 43 for critically adjusting the coupling between the coils 22 and 25. This means comprises a tubular support 44 about which the coils 22 and 25 are wound one above the other in spaced relation. The coupling or inductive relation between the coils 22 and 25 is adjusted by means of the disk-like metal core 45 carried by the adjustable handle or member 46 disposed within the tubular support 44. The member 46 has a threaded portion 47 of definite pitch operating in the base 48. Upon rotation of the member 46, the disk 45 is raised or lowered a definite amount per turn of the handle 46 to vary the inductive effect of one coil relative to the other, depending upon the position of the disk 45. By proper design of the coil values and their spacial relation, the coupling may be accurately adjusted by movement of the disk 45 so that the circuits of the tube 10 will be thrown into and out of oscillation upon the change in the capacity afforded by the tube 26.

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**. In Fig. 2 is illustrated, as one example, a form of energy translating means **49** operating 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 sub-divided 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** 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 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 tube **10** upon a slight decrease in the temperature and hence of the resistance of the element **50**. With this type of unbalanced bridge circuit the use of a separate bias on the grid **30**, such as provided by the battery **42** (Fig. 1), is not needed. 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 coupling **22**—**25** and the bias on grid **30**.

The translating system or bridge circuit **49** illustrated as one example of such device, 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**. Utilizing the ordinary A. C. line for the electrical energy supply, the energy is supplied 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 being available for application to the grid **30** while minimizing the currents flowing in the bridge circuit 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, the bridge distinguishably responds to changes of temperature in both directions from a predetermined mean value of temperature to vary the positive potential on the grid **30**. The tube **26** because of its rectifying action utilizes the positive voltage component of the alternating current.

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. If a bridge circuit of the character above described and shown in Fig. 2 is employed as the translating means, the constants thereof are 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 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 including the tube **26** to be operatively responsive to the variations produced by the tube **26**.

The tube **26** in the present invention constitutes a capacity in parallel with the coil **22** or coil **25**, and capable of variation in accordance with the potential applied to the grid **30**. I preferably impose an initial positive bias on the grid **30** for rendering the tube **26** critically responsive to a small change in one direction of potential upon the grid **30** from a normal value for producing the required change in the capacity of the tube **26** to throw the circuits of tube **10** into and out of oscillation. The tube **26** has no source of potential in its plate circuit other than that due to the electron emitting effect of the heated cathode **28** of the tube, and therefore does not function in the present invention as a relay or amplifier. The capacity of the tube **26** between cathode and anode is varied, as herein described, by variation of potential on the grid element **30** of the tube. It is this variable capacity which when connected to the oscillating circuits of the tube **10** controls the oscillation thereof.

Assuming then that 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.

By my invention I am able to control the flow of working current in the output of the tube **10** by a trigger action, so that the relay **17** may be adequately energized and deenergized in response to the activating energy impulses. In some cases it is advisable to provide means for switching off entirely the flow of energy through the relay **17** and prevent partial energizing thereof by the residue of direct current component flowing when the tube **10** is oscillating. For this purpose I place a gas discharge device **65** (Fig. 3), such as a neon tube, in series with the relay **17** beyond the output terminals **16**, and a resistance **66** in parallel with the relay **17** and the gas discharge device **65** across the output terminals **16** of the system above described. The resistance **66** has a value compensating for and taking the place of the load **17** when the latter is cut out of the circuit by operation of the tube **65**. When the working potential across the terminals **16** surges to maximum upon the cessation of the oscillations in the output circuit, glow discharge across the electrodes of the tube **65** occurs, and the relay circuit closes to cause the actuation thereof. When the working potential drops below the value required to maintain the glow discharge, the relay circuit opens.

When the potential on the grid **30** again increases, 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. With my system, however, 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 to control the limits of temperature variation so that the system will be stabilized at the desired normal temperature in both the oscillating and non-oscillating states. Further, the coupling **22—25** and biased tube **26** are coordinated so that a rise in temperature of the resistance element **50** from normal will not affect the oscillations.

My method and system for carrying out said method is particularly adapted for the detection and utilization of very weak energy impulses or variations, such as those of sound, light, heat, radio, electricity, and other radiations capable of being translated into potential variations or changes for exciting the system.

By suitable selection or adjustment of the circuit constants in accordance with the principles of the invention, the system becomes adapted for use in various fields or arts, such as heating, telephony, radio, television, and the like, and for operating and controlling various indicating and recording instruments or devices in response to various energy excitations. Further, the output or working current may be controlled according to the requirements of use, to produce an abrupt or trigger variation of the current in response to the energy impulses for operating various direct current devices, or to produce a varying current modulated in accordance with the incoming energy impulses for operating various audio frequency devices, recorders, indicators, or the like.

No claim is made in this application for the translating means or bridge circuit per se, or to the same in combination with the electronic tube circuit herein claimed, since the same constitutes the subject matter of a copending application, Serial No. 148,336, filed jointly by Maurice A. Michaels and myself on June 15, 1937.

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

1. 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 means for imposing a biasing potential on the grid of said last-named tube for preventing operation thereof upon variation of the grid potential thereon in one direction from its biasing value.

2. 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 in one of said circuits, said coupling and said last-named tube being coordinated to render said circuits responsive to variation of said last-named tube for throwing the circuits into and out of oscillation, a capacity between the grid and cathode of said last-named tube for preventing stray oscillations from affecting the grid thereof, and means for imposing a variable potential on the grid of said last-named tube for throwing said circuits into and out of oscillation, said potential serving to normally bias said grid for rendering said tube inoperative upon variation of the grid potential in one direction from its biasing value.

3. 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 in one of said circuits, said coupling and said last-named tube being coordinated to render said circuits responsive to change thereof to and from substantially resonant relation for throwing the circuits into and out of oscillation, means for building up a potential on the grid of said first-named tube in response to the oscillations for varying the plate current in accordance therewith, means for imposing upon the grid of said last-named tube a biasing potential for preventing operation thereof upon change of grid potential in one direction from its biasing value, and a capacity between the grid and cathode of said last-named tube for preventing stray oscillations from affecting the grid thereof.

4. A system of the character described, comprising an electronic tube having grid and plate circuits coupled together, an electronic tube having the plate and cathode thereof connected to said coupling to vary the capacity component thereof, 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 means for imposing a variable potential on the grid of the last-named tube and serving to prevent operation of said tube upon variation of grid potential in one direction from its normal value.

5. A system of the character described, comprising oscillation generating means including an electronic tube having coupled grid and plate circuits, oscillation controlling means including an electronic tube having the plate and cathode connected to said coupling to cause variation thereof, and means responsive to energy excitation for imposing a variable potential on the grid of the second tube, said oscillation generating means and said controlling means being coordinated to render said oscillation generating means responsive to the variation of grid potential of the second tube in one line of direction relative to a given potential for throwing said first-named means into and out of oscillation and to prevent such response upon variation of the grid potential in the opposite line of direction, and a capacity connected between the grid and cathode of the second tube.

6. A system of the character described, comprising oscillation generating means including an electronic tube having coupled grid and plate circuits, said coupling being adjusted to render said circuits critically responsive to variation of coupling for throwing said circuits into and out of resonance to correspondingly control the oscillations therein, means for building up a potential on the grid of said tube, controlling means including an electronic tube having the plate and cathode thereof connected in said coupling to cause the variation thereof and means responsive to energy excitation for imposing a variable potential on the grid of the second tube, said oscillation generating means and said controlling means being coordinated so that variation of the grid potential of the second tube in one line of direction relative to a given potential to the exclusion of the variation of the grid potential in the opposite line of direction is effective to throw said first-named means into and out of oscillation, and a capacity between the grid and cathode of the second tube.

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