May 12, 1936. J. M. SCHMIERER 2,040,341

ELECTRONIC TUBE SYSTEM

Original Filed Oct. 3, 1930

Fig. 1

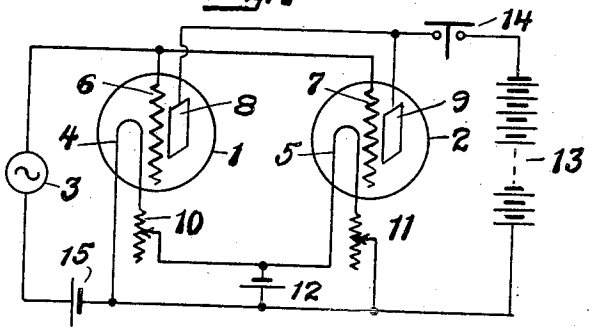


Fig. 2

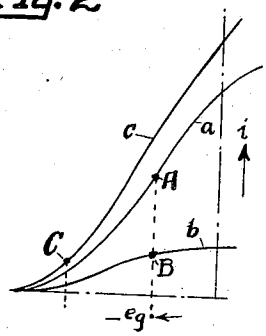


Fig. 7

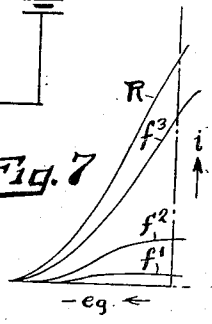


Fig. 3

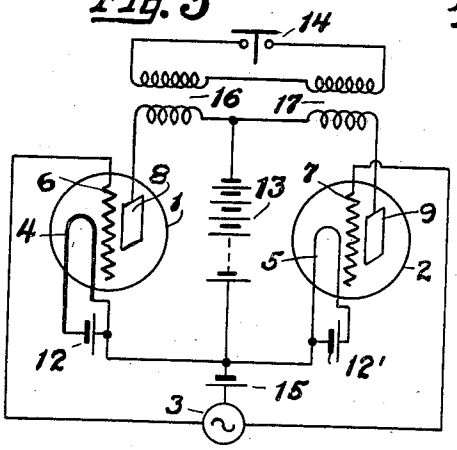


Fig. 5

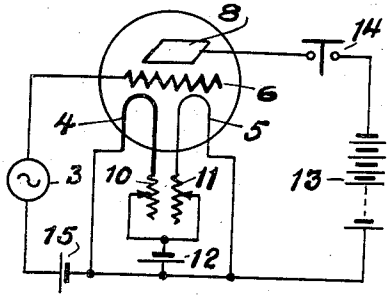


Fig. 4

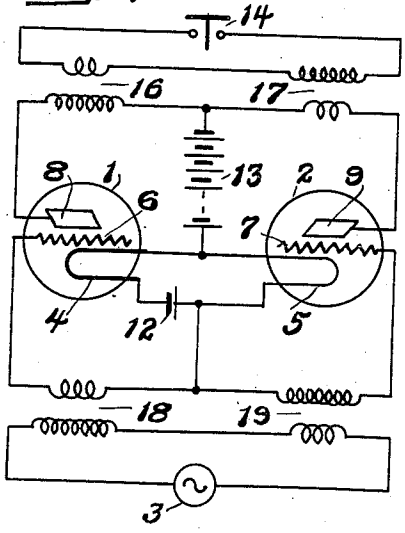
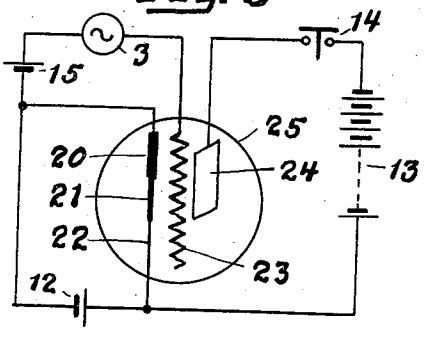


Fig. 6



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ELECTRONIC TUBE SYSTEM

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21 Claims. (Cl. 250—27)

My invention relates to thermionic tubes and methods of operation thereof and more particularly to vacuum electron tubes and methods of operation thereof, as used in the radio art for amplifying, detecting and generating high frequency and audio frequency electrical oscillations.

As is well known, the characteristic operating curve of such vacuum tubes, comprising essentially a thermionic cathode, anode and control electrode arranged in an evacuated vessel, starts out with a very slow rise when the negative grid voltage is decreased and with gradual increase of steepness, until it reaches a point, known as the lower bent, from which point on the steepness remains practically constant, or, in other words, the curve becomes a straight line. At this value of the grid voltage a predetermined uni-directional thermionic current flows through the tube and over the output circuit connected to the anode and cathode electrodes. When incoming current or potential variations are applied to the grid, these are then reproduced in the anode or output circuit by corresponding variations of the aforementioned uni-directional, or, as it will be referred to hereinafter, zero anode current.

This zero anode current, which in the ordinary tube as available on the market, has an intensity of several milliamperes, constitutes a loss in that it is necessary to operate an amplifying tube within the steep or straight line portion of the characteristic curve, in order to insure faithful reproduction of the anode current variations, in accordance with the input current or potential variations to be amplified and applied to the grid electrode.

This zero anode current is objectionable, as it increases operating expense by the continuous draw and consequent rapid exhaustion of the anode battery. Furthermore, in the case of radio sets operating directly from alternating current supply mains ordinarily available in private homes, it is necessary, because the zero anode current is high, to use larger rectifying tubes and smoothing devices for suppressing the alternating current ripples occurring in the rectified current.

The high position of the lower bent on the characteristic curves entails the further disadvantage that it is necessary to use dangerously high anode voltages. The necessary high voltage also makes it impractical to employ a power amplifier in portable sets, since the size and weight of necessary batteries would be too great.

An object of my invention is, accordingly, to provide a new and improved tube and a novel method of operation thereof.

A further object of my invention is to provide novel means for using a vacuum tube to its fullest capacity and to improve its operating efficiency.

Another object of my invention is to provide novel means in connection with a thermionic vacuum tube, whereby the straight line portion of the grid voltage-anode current operating characteristic is extended and the amplification factor of the tube increased.

A further object of my invention is to provide novel means in thermionic vacuum tubes for shifting the lower bent of the characteristic operating curve towards the region of increasing negative grid voltage.

Still a further object of my invention is to provide novel means whereby a thermionic vacuum tube may be operated with a lower anode voltage, as compared to voltages required for operation of the customary tubes without incurring distortion of the anode current variations.

Another object of my invention is to provide a thermionic tube, by which, with lower anode voltage and anode current, as compared to the ordinary tubes known in the art, the same effect as to operating efficiency and faithfulness of reproduction of input variations is obtained.

A more specific object of my invention is to design a vacuum tube system, in which a number of individual complementary grid voltage anode current characteristic curves are superimposed, in such a manner that the upper bent of some of these curves coincides with the lower bent of one or more of other curves, to obtain an extended straight line portion of the resultant characteristic by superimposition of the individual characteristics.

These and further objects of my invention will become more apparent as the following detailed description proceeds, taken in reference to the accompanying drawing, in which I have shown circuit arrangements and tubes, in which the novel feature of my invention may be embodied. I wish it to be understood that the exemplifications of the invention, as represented by the views of the drawing and the description herein, are to be regarded as illustrative only of the general principle underlying my invention, which, as will become obvious, is subject to many modifications coming within its broad and most comprehensive scope, as expressed in the appended claims.

Figure 1 shows a simple circuit arrangement, by which my invention may be practiced, utilizing two vacuum tubes connected in parallel and having differently heated cathode electrodes and, accordingly, different forms of operating char-

acteristics for producing an improved resultant characteristic in the common output circuit.

Figure 2 shows some curves explanatory of the novel effect obtained by an arrangement in accordance with Figure 1.

Figure 3 is a similar circuit to Figure 1, whereby an inductive connection of the output circuits of the tubes is employed in place of a direct connection, as in accordance with Figure 1 and in which different characteristics for both tubes are obtained by providing filaments of different structure or composition.

Figure 4 shows a further modification of a circuit according to Figure 3, in which also the grid circuits of both vacuum tubes are connected by inductive means.

Figure 5 illustrates another embodiment of my invention, showing a single tube in which two filaments of different structure or composition cooperate with a common anode and grid electrode, to produce the novel effect, according to the invention.

Figure 6 illustrates a further example by which the desired effect, in accordance with my invention, may be obtained in a single tube, by providing a filament divided into different portions, each of which exhibits different characteristics.

Figure 7 illustrates curves explanatory of the theoretical operation of a tube, in accordance with Figure 6.

Similar reference numerals refer to similar elements throughout the different views of the drawing.

In order to improve the operating characteristic of a vacuum tube, as pointed out in accordance with my invention, I may, for instance, couple the anode circuit of an amplifying tube to the anode circuit of a further amplifying tube of less power controlled by the same input current and whose anode current reaches its condition of saturation on or about the point at which the steepness of the characteristic curve of the first tube becomes constant, or, in such a manner that the upper bent of the second tube approximately coincides with the lower bent of the first tube, whereby on account of the opposite curvatures of both curves, a compensation of the curvature takes place by superimposition and a practically straight line resultant characteristic is obtained.

The coupling of both anode circuits may be either inductive, capacitative, or direct. In place of a direct coupling of the anodes, the cathodes and the grid electrodes may also either be coupled inductively, or capacitatively, or vice versa, the primary object of the invention being to superimpose both anode currents so as to compensate each other as to their curvature and to obtain a resultant straight, or nearly straight line characteristic. By proper choice of the second tube and, eventually, also of the associated elements, this aim may be approached to such a degree that the deviations from a purely straight line will be practically negligible.

The simplest arrangement consists in a parallel connection of two or more tubes, such as is illustrated in Figure 1 of the drawing. Referring to this figure, I have shown two vacuum tubes **1**, **2**, having cathodes **4** and **5** and grid electrodes **6** and **7** and anodes **8** and **9**, respectively. Both tubes are directly connected in parallel and are controlled by a common source of input currents shown at **3**, which may, for instance, be the incoming oscillations of a radio receiver, or the voice currents originating from a microphone, or the signal currents derived from a detector circuit, or the like. I have shown at **15** a grid biasing battery for adjusting the proper negative grid potential for operating the tube at the steep portion of its operating characteristic. I have, furthermore, shown a common output circuit for both tubes, including an anode or B battery **13** for supplying the thermionic discharge current and a translating device for utilizing the amplified current variations, such as a telephone or a loud speaker **14**, in case the amplifier is to be used in connection with a radiophone receiver, public address system, etc.

In accordance with the present invention, I provide means whereby both tubes exhibit different operating characteristics and, in the case of Figure 1, I accomplish this aim by adjusting the heating currents of both tubes differently, by means of separate variable assistances **10** and **11**, provided for each of the tubes, respectively. A common heating current supply source **12** serves to provide the necessary heating energy.

Referring to Figure 2, I have shown at *b* a characteristic curve-thermionic discharge current *i*, flowing from cathode to anode as a function of the potential e_g applied to the grid electrode, the anode potential **13** being kept constant—as may be obtained with tube **1** according to Figure 1, heated to very low cathode temperature. As is seen, the thermionic current *i* gradually increases until it reaches its saturation value at a point B. By operating tube **2**, according to Figure 1, with a high emitting temperature, I may obtain a curve as shown in *a* in Figure 2, which has the lower bent A approximately coinciding with the upper bent or saturation point B of the curve *b*. By superimposition of both curves *a* and *b*, a resultant curve *c* is obtained for the common output circuit, which, as is seen, has an increased range covering its straight line portion and a lower bent C shifted towards the region of decreasing negative grid voltage e_g.

It is readily seen that by this compensation the aforementioned drawbacks inherent in the common vacuum tubes have been overcome. The compensation has the further effect, as is seen, of extending the steep portion of the characteristic in a direction which permits an increasing negative grid voltage, which enables an increase of the negative grid bias **15**, according to Figure 1 and, accordingly, results in a decrease of unidirectional or zero anode loss current.

Referring to Figure 3, I have shown an alternative arrangement for obtaining the object in accordance with the invention. This arrangement is similar to Figure 1 and differs only from the latter in that the anode circuits of the tubes **1** and **2** are coupled inductively by means of transformer **16** and **17** in place of a direct coupling, according to Figure 1. I have also shown an alternative manner in this figure for obtaining different characteristics of the tubes, in that tube **1** is shown with a filament of different composition (indicated by heavy lines as compared to filament **5** of tube **2**). Thus, for instance, filament **4** of tube **1**, which may be an ordinary tungsten filament of the old type, which will have a curve similar to curve *b* according to Figure 2, whereas filament **5** of tube **2** is of the oxide or thoriated type, as at present used extensively in vacuum tubes and which will provide an operating curve similar to curve *a* in accordance with Figure 2, in such a manner that, by

superimposition, a similar effect is obtained in the comon output circuit, as by the arrangement of Figure 1. I have shown, for the sake of clearer illustration, two separate heating batteries 12 and 12' for the tubes 1 and 2 respectively.

In Figure 4 I have shown a circuit in which the grid circuits are also coupled inductively by means of transformers 18 and 19. It is advisable to use different ratios of the primary to secondary windings of the transformers 16, 17, 18, and 19, as shown by different number of winding turns in the drawing, in view of the fact that the currents carried by the tubes are largely different from each other. By properly choosing the transformer ratio of transformers 16 to 19, a proper and proportionate superimposition in the output circuit, also as to amplitude of the currents, is obtained.

The filament of both tubes may be connected either in parallel, as shown in Figures 1, 3, 5, or they may also be connected in series, as in Figure 4. The parallel connection of the filaments presents the advantage that the heating currents for both tubes may be adjusted independent of each other. The series connection of the filaments, on the other hand, has the advantage that the mean cathode voltages, in respect to the grid, are different from each other, which enables a better adaptation of the tubes to the most favorable operating conditions. In case of a parallel connection, this latter aim could only be accomplished by using additional resistances.

Referring to Figure 5, this illustrates an example of how a single tube may be used in place of different tubes. This tube includes two filaments of different construction, similar to filaments 4 and 5 of the tubes, in accordance with Figure 3. Both filaments cooperate with a common anode and grid electrode and are heated by the same battery 12 and provided with separate filament heating resistances 10 and 11 respectively. It is obvious that the operation of this tube is similar to the operation of the arrangements according to Figures 1 and 2, the only difference being the inclusion of the tube electrodes in a common vessel, in place of using two different vessels.

In place of using filaments of different material, as referred to in the above example, filaments of the same material may be used, heated to different temperatures, such as by properly adjusting heating resistors 10 and 11, or by using filaments of different cross section heated by the same current as shown in Figure 4.

The invention may, furthermore, be practiced in an easy manner, by using a single tube with a single filament, which is comprised of different portions having different electron emissivity. This I have illustrated in Figure 6, wherein a tube 25 comprises a filament having three portions 20, 21, and 22, which may, for instance, be of different cross section, such as indicated schematically, thus being heated to different temperatures and, accordingly, having different electron emissivity. The cathode cooperates with a single anode 24 and grid electrode 23.

Referring to Figure 7, which shows curves explanatory of the operation of the tube according to Figure 6, similar to curves of Figure 2, f_1 represents the characteristic corresponding to the portion 20, which has the largest diameter and, accordingly lowest emitting temperature. Curve f_2 in the same manner corresponds to the portion 21 of the filament of less diameter and, accordingly, of higher emitting temperature and increased emission, whereas curve f_3 corresponds to the portion 22 having the highest emissivity. The resultant thermionic discharge current has a characteristic, as illustrated at R, which is obtained by superimposition of the curves f_1, f_2, and f_3 and which, as is seen, possesses the same advantageous characteristics as outlined in connection with the previous figures. Instead of using a filament of like material and portions of different cross sections, as shown in Figure 6, the same effect may be obtained, as will be obvious, by using a filament with portions of different composition, such as, for instance, by using a tungsten filament, a portion of which, such as portion 21, according to Figure 6, is covered with a thorium layer, or another portion, such as portion 22, according to Figure 6, of which carries an oxide layer, all these different materials, as is well known, possessing different emitting characteristics, thus producing a number of individual characteristics of the same relative configuration as according to Figure 7.

I wish it to be understood that I do not desire to be limited to the exact detail of construction as shown and described, for obvious modifications will occur to a person skilled in the art.

What I claim is:—

1. In an electron tube, comprising an evacuated vessel, at least two thermionic cathodes having different electron emitting characteristics within said vessel, a common control electrode and an anode electrode cooperating with said cathodes, to produce two discharge components of different emission characteristics, means for separately heating said cathodes a common output circuit connected to said cathodes and said anodes and a common input circuit connected to said cathodes and said control electrode, the output current component supplied from one of said cathodes being modified at a predetermined portion of its operating characteristic by the output current supplied from said other cathode at a different predetermined portion of its operating characteristic.

2. In an electron tube system, comprising an evacuated vessel, at least two thermionic cathodes having different electron emitting characteristics within said vessel, a common grid electrode and a common anode cooperating with said cathodes, means for separately heating said cathodes whereby the electric discharge components from each of said cathodes to said anode have different operating characteristic curves, a common input circuit connected to said cathodes and to said grid and a common output circuit connected to said cathodes and said anode, the curvature of the bent at the end of the straight portion of the operating characteristic of one of said components being compensated by a curvature of opposite sign of the characteristic of said other component.

3. In an electron tube, comprising an evacuated vessel, at least two thermionic cathode electrodes within said vessel, a common grid electrode and a common anode cooperating with said cathodes, design and operating conditions of said cathodes being chosen in such a manner that the thermionic discharge components from each of said cathodes to said anode has a different grid voltage anode current characteristic extending the straight line portion of the resultant characteristic by compensating the curvature of one of said component characteristics by the curvature of said other component characteristic, a common input circuit connected to said cathodes

and said grid and a common output circuit connected to said cathodes and said anode.

4. In a thermionic discharge tube, comprising an evacuated vessel, at least two thermionic cathodes within said vessel, means for separately heating said cathodes, a common grid electrode and a common anode cooperating with said cathodes, design and operating conditions of said cathodes being chosen in such a manner that the lower bent of the grid voltage anode current characteristic of the thermionic discharge component from one of said cathodes to said anode coincides with the upper bent of the grid voltage anode current characteristic of said other thermionic discharge component from said other cathode to said anode for extending the straight line operating portion of the resultant discharge characteristic.

5. In an electron tube comprising an evacuated vessel, at least two cathode electrodes within said vessel, means for separately heating said cathodes, common control and anode electrodes cooperating with said cathodes to produce discharge current components of different characteristics, the design and operating conditions of said tube being chosen in such a manner that the output current component supplied from one of said cathodes is modified at a predetermined point of its operating characteristic by the output current component supplied from the other cathode at a different predetermined point of its operating characteristic.

6. In an electron tube system comprising an evacuated vessel, at least two cathode electrodes within said vessel, a common grid and anode electrode cooperating with said cathodes, the design of said tube electrodes and the operating conditions being chosen in such a manner that the electric discharge current components from said cathodes to said anode have different operating characteristics and with the positive curvature of the characteristic of one component compensating the negative curvature of the characteristic of the other component for extending the downward straight line portion of the resultant characteristic, a common input circuit connected to said cathodes and to said grid and a common output circuit connected to said cathodes and to said anode.

7. In an electron tube system as described in claim 6, a common heating battery for said tubes and separate heating resistors for each of the tubes for adjusting different emitting temperatures.

8. In an electron tube system as described in claim 6 in which the cathode of said tubes are of different cross section and a common heating source for said cathodes.

9. In an electron tube system as described in claim 6 in which the cathodes of said tubes have different electron emissivity and a common heating battery for said cathodes.

10. A discharge device comprising an envelope, a plurality of cathodes, a common anode and a common control electrode therein, said cathodes producing a plurality of discharge components of different current-voltage characteristics, an output circuit connected between said cathodes and said anode, an input circuit connected between said cathodes and said control electrode, the discharge component from one of said cathodes being modified at a predetermined portion of its operating characteristics by another of said discharge components at a different portion of its operating characteristics.

11. A discharge device comprising an envelope, a plurality of cathodes, a common anode and a common control electrode therein, said cathodes producing a plurality of discrete discharge components of different current-voltage characteristics, the curvature at the end of the sloping portion of the discharge characteristic of one of said components being compensated by a curvature of opposite sign of the characteristic of another of said discharge components for extending the sloping portion of the resultant characteristic curve of all of said discharge components from said cathode to said anode.

12. A discharge device having a plurality of cathodes and a common anode and a common control electrode, said cathodes having different current-voltage characteristics, whereby the curvature of the bent at the end of the sloping portion of one characteristic produced by the discharge component of one of said cathodes is compensated by a curvature of opposite sign in the characteristic of another of said cathodes for extending the straight line portion of the combined characteristic resulting from the discharge currents from all of said cathodes to said anode.

13. In combination with an electronic amplifier, means for producing a plurality of individual electron discharge streams each having a separate cathode, means for simultaneously controlling said streams in accordance with input signals, means for superimposing said streams in a common output circuit, further means for varying the electron emitting properties of each of said cathodes for modifying the current-voltage characteristic of each of said streams for compensating in the resultant superimposed current the effect of the curvature of the bent at the end of the sloping portion of the characteristic individual to one of said streams by a curvature of opposite sign to said first curvature of the characteristic individual to another of said streams for extending the sloping portion of the resultant characteristic of all said superimposed electron streams.

14. In combination with a discharge amplifier, means for setting up a plurality of discharge streams each having a separate cathode, means for simultaneously controlling said streams in accordance with input signals, further means for superimposing said streams in a common output circuit, and means for varying the emission characteristic of said cathodes for modifying the current-voltage characteristic of each of said streams for compensating the curvature at the end of the sloping portion of one characteristic individual to one of said streams by a curvature of opposite sign to said first curvature of the characteristic individual to another of said streams.

15. In combination with an electronic amplifier, means for producing a plurality of electron discharge currents each having a separate cathode, means for simultaneously controlling said electron currents in accordance with input signals, a common output circuit for superimposing all of said electron currents, and means for varying the electron emission characteristic of each of said cathodes for modifying the current voltage characteristics of said electron currents for compensating the curvature at the end of the sloping portion of one characteristic individual to one of said currents by a curvature of opposite sign of another characteristic individual to another of said electron currents.

16. In a discharge device having a plurality of

thermionic cathodes with means for separately heating the same and a common anode and a common control electrode, said cathodes having different discharge characteristics whereby the upper bent of the characteristic of one component discharge from one cathode coincides with the lower bent of the characteristic of another discharge component from another cathode for extending the straight line portion of the resultant characteristic of the resultant discharge from all of said cathodes.

17. A discharge system comprising means for producing a plurality of discharge streams each having a separate incandescent cathode; a common controlling and a common anode electrode for said discharge streams, said cathodes having different electron emitting characteristics whereby the upper bent of the current-voltage characteristic of the discharge stream from one of said cathodes coincides with the lower bent of the current-voltage characteristic of the discharge stream from another of said cathodes for extending the straight line portion of the resultant characteristic obtained from superimposing said discharge stream in the common anode circuit.

18. A discharge system comprising means for producing a plurality of electron discharge streams each having a separate incandescent cathode, said cathodes being separately and differently heated to secure different current-voltage characteristics of the respective discharge streams emitted from said cathodes whereby the upper bent of one of said characteristics coincides with the lower bent of another of said characteristics and common means for controlling and collecting said discharge streams into a single output current.

19. A space discharge device comprising means for producing a plurality of electric discharge streams each stream having a separate cathode, a current source for heating said cathodes, each of said cathodes having an individual emitting characteristic for a temperature corresponding to a predetermined current density different from the emitting characteristic for the same current density of any of the other of said cathodes, and means for commonly controlling and combining said discharge streams into a composite output current.

20. A space discharge system comprising means for producing a plurality of electron discharge streams each of said streams having a separate incandescent cathode, means for simultaneously heating said cathodes to constant but different emitting temperatures to secure current-voltage characteristic curves of different shape for each of said electron discharge streams, and means for controlling and combining said discharge streams into a common output current.

21. A space discharge arrangement comprising means for producing a plurality of electron discharge streams, a separate cathode for each of said electron streams, means for controlling and combining said electron streams into a composite output current, each of said cathodes having an individual electron emitting characteristic to secure a current-voltage operating characteristic curve for each of said electron discharge streams of different shape from the current-voltage characteristic curves for all of said other electron discharge streams.

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