

Oct. 12, 1937.

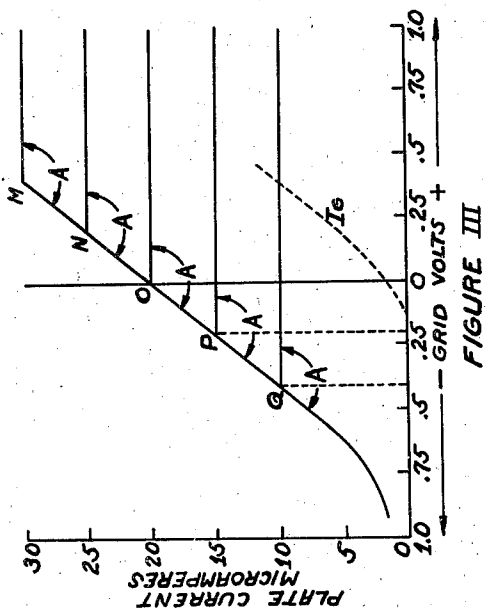
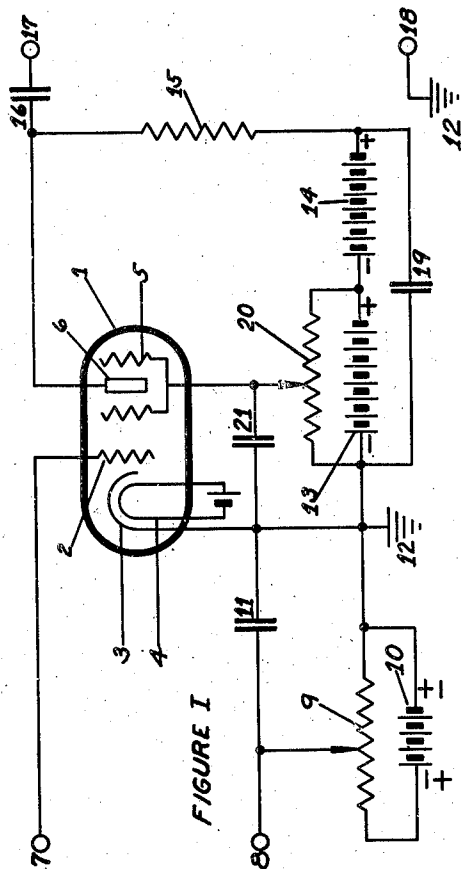
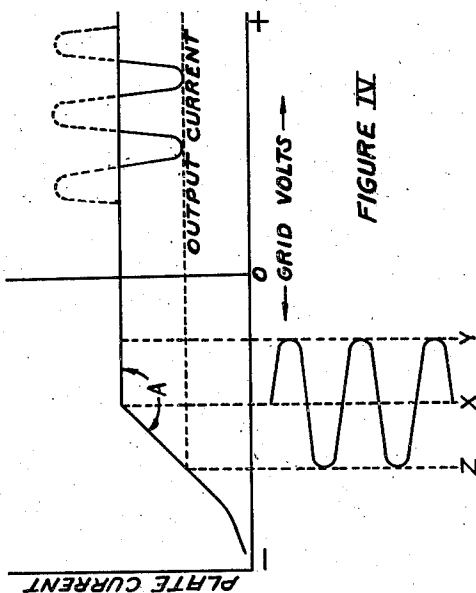
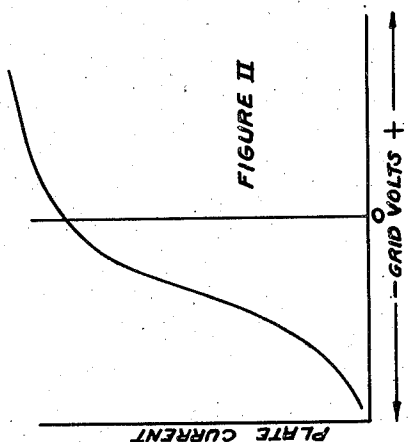
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2,095,261

THERMIONIC TUBE CIRCUIT

Filed Feb. 11, 1935

2 Sheets-Sheet 1



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THERMIONIC TUBE CIRCUIT

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2 Sheets-Sheet 2

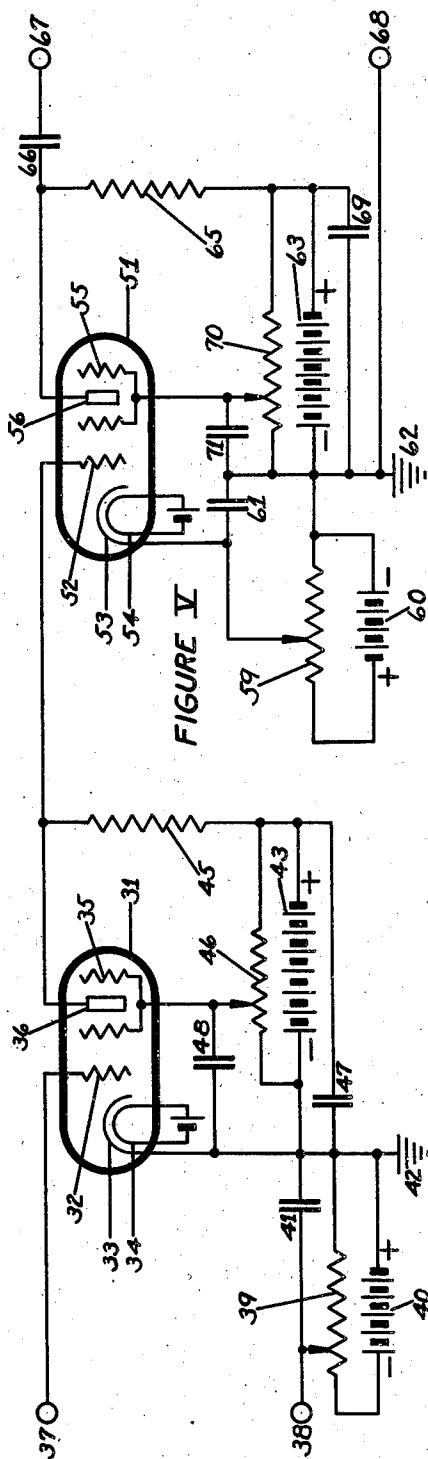


FIGURE V

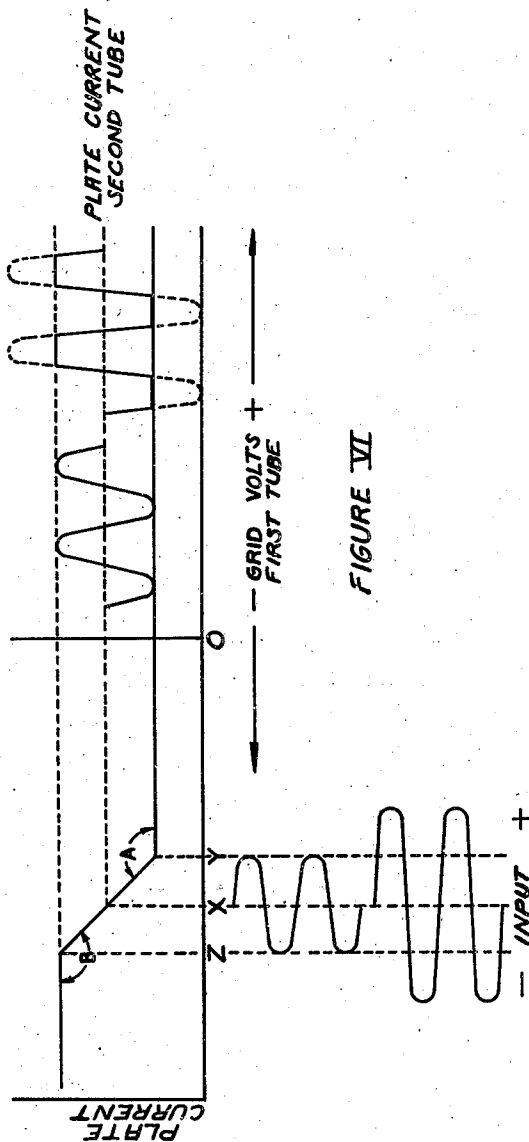


FIGURE VI

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UNITED STATES PATENT OFFICE

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THERMIONIC TUBE CIRCUIT

David G. McCaa, Lancaster, Pa., assignor to
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Application February 11, 1935, Serial No. 6,014

18 Claims. (Cl. 250-27)

My invention relates generally to thermionic tube circuits. More specifically I have devised improvements in thermionic tube circuits in which characteristic grid voltage-plate current curves may be obtained which have a sloping portion which abruptly changes to horizontal.

One of the objects of my invention is to provide a vacuum tube circuit arrangement in which the grid voltage-plate current characteristic changes abruptly from a slope to a horizontal line as the grid electrode is made less negative or more positive. Another object is the arrangement of a detector or rectifier circuit in which the positive cycles of alternating currents, impressed on the input circuit, will be completely eliminated in the output circuit, while the negative potentials of the signal currents will be faithfully reproduced without distortion.

A further object of my improvement is found in the sharp cut-off characteristic which may be had by practicing my invention. Another object lies in a vacuum tube circuit in which the output anode current is sharply limited for an increasing negative input grid voltage as well as an increasing positive input grid voltage. Further objects will be more apparent from the accompanying drawings and specification.

Figure I is a circuit embodying my invention in a single screen grid tube.

Figure II is the grid voltage-plate current characteristic curve of the conventional type.

Figure III illustrates a family of grid voltage-plate current characteristic curves of the circuit of Figure I.

Figure IV is a graphic illustration of a characteristic detection action of the circuit shown in Figure I.

Figure V shows my invention applied to two tubes for effecting a double cut-off or gate characteristic.

Figure VI is a graphic illustration of an operating characteristic of the circuit of Figure V.

In Figure I, 1 represents a screen grid thermionic tube, in which 2 is the control grid, 3 is the cathode, 4 the heater, 5 the screen, and 6 the anode. The input voltage is applied between 7 and 8. A suitable bias, either positive or negative, may be applied by means of potentiometer 9 which is connected across battery 10. Terminal 8 is connected by by-pass condenser 11 to the cathode 3 which is grounded at 12. B batteries 13 and 14 are connected in series. The negative terminal of 13 is connected to the cathode 3 and ground 12. The positive terminal of 13 connects to the negative terminal of 14. The positive ter-

minal of 14 is connected to the resistance 15 which is, by preference, non-inductive. The remaining terminal of the resistance 15 is joined to plate 6 and also connected to output condenser 16. The output terminals are 17 and 18.

A suitable by-pass condenser 19 is connected from the positive terminal of 14 to the ground connection 12. A potentiometer 20 is connected across 13 and the movable terminal of the potentiometer 20 is connected to screen grid 5. A by-pass condenser 21 is connected from screen grid to cathode. It will be seen that the screen grid may be given a suitable potential with respect to the cathode from zero to positive by means of the potentiometer 20.

It should be observed that the normal characteristic curve of grid voltage plotted against plate current is a smooth uniform curve. The curve shown in Figure II represents a normal tube characteristic. Although the curve of Figure II may be straightened somewhat by the use of an external plate resistance, the upper and lower portions will gradually curve.

By examining the following table those skilled in the art will recognize that I employ voltages, and currents which are many times lower than are recommended by the tube manufacturers. By means of these unusually low voltages, suitable biasing, and relatively high external resistance, I have arrived at operating characteristics entirely different from those previously employed.

By way of example, the following table shows operating constants for two types of tubes under given conditions:

Type tube	Heater volts	External anode resistance in meg-ohms	B-battery volts	Screen grid volts	Anode current in micro-amperes	Grid voltage at which angle A appears
22A	2.7	1.0	22	0	22	-0.9
22A	2.7	1.0	22	6	22	-1.5
22A	2.7	0.50	22	0	50	-0.8
22A	2.7	0.50	22	9	50	-1.5
227	2.7	1.0	45	—	45	-0.5
227	2.7	1.0	6	—	6	-0.9
227	2.7	0.25	6	—	24	-0.6

Figure III illustrates a family of curves which may be obtained from the circuit of Figure I, and the operating constants shown in the above table. It will be apparent that the plate current is substantially unchanged as the grid potential is varied from the extreme positive voltage to lower values until a critical angle is reached. I have called this angle A. It will also appear that angle

A may be made to occur at positive, zero or negative grid voltages. The dotted line Ig shows the grid current which may occur with the various curves of the family. The most preferable condition is represented by the curves marked P or Q because at these angles the grid current is zero. The condition of zero grid current is desired because no load is placed on the circuit to which my device may be connected. I also prefer to use a characteristic curve which has a slope with straight line portion.

The angle A may be positioned or located on any part of the characteristic curve by adjusting the B battery voltage, the value of the external anode resistance, and the screen grid voltage for any given tube. The higher the external resistance, the lower the B battery voltage, and the higher the screen grid voltage the more the angle A is shifted from positive to negative grid voltages; i. e., from M toward Q of Figure III. Likewise for increasingly high positive screen grid potentials, with a given B battery voltage and external anode resistance, the more negative or less positive the grid voltage at which angle A occurs.

In Figure III for each of the curves, a horizontal portion is met by an angular portion which finally bends and approaches zero. The characteristic may be changed from a steep to a gradual slope by making the screen grid increasingly positive with respect to the cathode. Since the useful portion of the characteristic curve is the slope, it should be understood that the less the slope the greater may be the applied grid voltage variations and vice versa.

I prefer the screen grid type of tube. However, the invention may be applied to other types of tubes. While the RCA 227 tube will give results similar to the characteristic illustrated in Figure III, it will be found that at radio frequencies the interelectrode tube capacities will interfere with complete realization of my invention. This objection may be overcome by neutralizing the grid plate capacity by any of the well known methods. Even in the case of a screen grid tube, it may be desirable to neutralize the small interelectrode capacities present.

Tubes with uni-potential cathodes have characteristics which are especially suited to my circuits owing to the sharp angle obtainable, but it should be understood that I am not limiting my invention to any particular type of tube. I have found a wide range of tubes, potentials and resistances will accomplish the sharp angular cut-off shown in Figure III.

I do not wish to limit my disclosure to any particular theory of operation in setting forth the following: The cathode is heated in the normal manner. Electrons are emitted from the heated cathode. The number of emitted electrons reaching the anode is relatively low because the potential of the anode with respect to cathode is in the order of zero or slightly positive. The electrons passing from the filament form a space charge which further restricts or limits the number of electrons which can reach the plate. Since the number of electrons which can reach the plate is limited by the space charge, the grid electrode has no effect upon the plate current, until the grid reaches a very critical potential at angle A. In actual practice the location of angle A is so precise and sharp, that it is difficult to determine the exact grid voltage at which it occurs. For increasingly less negative or more

positive grid voltages beginning at angle A, the plate current remains absolutely constant.

I shall now describe one application of my invention. In Figure IV, I show how the characteristics of the circuit of Figure I may be applied to the detection of radio frequency currents. The terminals 7 and 8 are connected to a source of radio frequency current. The connection may include a tuned circuit in which capacity and inductance are used. A signal reproducing instrument may be connected to the output terminals 17 and 18. The potentiometer 9 is adjusted until the grid is slightly negative as shown in Figure IV as represented by the dotted line X. It will be observed that X coincides with the critical angle A. The radio frequency currents are represented by the solid lines between Y and Z. Since the impulses between X and Y are equivalent to a relatively less negative grid, it will be seen that they do not alter the plate current. On the other hand the XZ impulses make the grid more negative and appear, without distortion, as changes in plate current. The above arrangement is a substantially perfect detector and avoids the distortion effects which take place in the conventional triode and pentode detector circuits.

While the arrangement thus far described is useful as a detector and limiter tube, it has limitations which interfere with its use in what I have termed "a gate". There have been numerous proposals in the art to employ thermionic tubes as limiters. One conventional use has depended upon producing saturation effects in the anode current by reducing the cathode emission. Another use depended upon loading the tube by excessive grid currents. These limiters have been characterized by the relatively high voltages required before the limiting action became effective and the distortion due to the bending of the characteristic curves. Although these devices may have had a useful limiting action for telegraphic signals, they were relatively useless where telephonic currents were involved. This failure is due to the requirement of excessive input voltages and distortion. Many of the prior art limiters were extremely inefficient because they were loss devices.

In contrast to these limiters, I propose a gate which will cut off at relatively low voltages and pass radio frequency currents, up to the cut off value, without distortion and without loss, or loading of the associated circuits. By connecting two of the devices of Figure I in series as shown in Figure V, I can not only obtain the characteristic angle A of Figure II but I can also obtain a second or complementary angle B (see Figure VI). Furthermore, by suitable adjustments I can determine the size of the gate, or the limits of voltage impulses it will pass.

In Figure V, 31 represents a screen grid thermionic tube, in which 32 is the control grid, 33 is the cathode, 34 the heater, 35 the screen, and 36 the anode. The input voltage is applied between 37 and 38. A suitable grid bias, preferably negative, may be applied by means of potentiometer 39 which is connected across battery 40 whose positive terminal joins 33. Terminal 38 is connected by by-pass condenser 41 to the cathode 33. The cathode is grounded at 42. A B battery 43 is connected between cathode and a non-inductive resistance 45. The remaining terminal of 45 is connected to the anode 36.

The screen grid 35 is connected to the slider of potentiometer 46 which may be connected across all or a suitable portion of B battery 43.

A by-pass condenser 47 is connected between the positive terminal of 43 and ground 42. Another by-pass condenser 48 may be used between 33 and 35.

Thus far the description of Figure V is substantially the same as Figure I. A second screen grid tube 51, with circuits similar to those already described is arranged as follows: In tube 51 the control grid is 52, the cathode 53, the heater 54, the screen grid 55 and the anode 56. The control grid 52 is connected to the anode 36 of tube 31. The cathode 53 connects to the slider of potentiometer 59 which is connected across battery 60 whose negative terminal is grounded at 62. A by-pass condenser 61 may be used between cathode 53 and ground 62.

The negative terminal of B battery 63 is grounded at 62 and its positive terminal is connected to non-inductive resistance 65. Resistance 65 in turn connects to anode 56 and also to coupling condenser 66. The output terminals are represented by 67 and 68. A by-pass condenser 69 shunts the B battery 63. A potentiometer 70 is connected across all or a suitable portion of battery 63. The slider of potentiometer 70 is connected to screen grid 55 from which by-pass condenser 71 is connected to ground 62. Again it will be noted that the second tube and circuit of Figure V is not unlike the arrangement of Figure I.

The operation of each of the tubes 31 and 51, and their associated circuits corresponds substantially with the operation and theory of Figure I. Substantially the same voltages, resistances, and adjustments may be employed for Figure V as already described for Figure I. Since the voltage relation of tube 31 is substantially 180 degrees out of phase with tube 51, it follows that as grid of tube 31 is made less negative and is approaching its critical angle A, the grid of tube 51 is going further from its critical angle B. Likewise when the plate current of tube 31 starts to vary, the plate current of tube 51 varies in the opposite direction or may become fixed.

In the practical operation of Figure V, I set the bias voltage on the grid 32 to zero. Next the bias voltage on grid 52 is adjusted by means of 59 until the grid is on a desired portion of the slope. Then for a given variable voltage applied between 37 and 38, I find experimentally the optimum value of grid voltage on 32 by means of 39.

If the various potentials of Figure V are carefully chosen, a condition is reached when the input voltage across 37—38 may be varied between wide limits and the output currents across 67—68 will be constant. Departing slightly from this condition by suitably biasing grids 32 and 52, I can arrange the gate action described above. The bias of the grid of the second tube determines the size of the gate, and the operating position on the characteristic curve of the gate is determined by the bias on the grid of the first tube. This same adjustment may be made by fixing the biases on the grids 32 and 52 and shifting the location of the angles A and B by varying the potentials on screen grids 35 and 55.

The characteristic curve of the gate combination of my invention can be observed in Figure VI. In the case of an applied alternating current, as the grid 32 is made increasingly negative from Y to Z the angle B is approached and less negative or positive voltages (from Z to Y) determines the approach to angle A. Between the input voltage limits represented by the angles

A and B, the plate current of the output tube varies uniformly. Beyond the voltage limits of angles A and B, no change is observed in the plate current of the output tube. In Figure VI for the sake of simplicity I have shown angle A as occurring in the second tube but it should be understood that angle A actually occurs in the first tube and is reflected in the anode current of the second tube.

If the grid of the input tube is biased to point X, all impressed voltages on the grid, up to the limits of Y and Z, will be faithfully reproduced by corresponding anode current changes in the second tube. All voltages on the first grid in excess of Y and Z will be cut-off by the sharp limits of the critical angles A and B. The gate may be made extremely small so that the potentials beyond a very small fraction of a volt are cut off. Likewise suitable grid bias voltages may be employed to pass considerably higher voltages.

In practice the circuit of Figure V may be used in radio frequency reception of telephonic or telegraphic signals without distortion, and excessive voltages, representing undesirable signals, will be cut off or limited by the gate action described.

In the case of telephonic radio signals the gate is made sufficiently large so that the modulations of the carrier frequency are not cut off but all impulses in excess of the gate size are cut off as shown in Figure VI. The arrangement may also be employed in the elimination of one or both sidebands in modulated continuous wave transmission or reception. Further applications of the arrangement will be found in my co-pending application, Serial No. 6,015, filed February 11th, 1935, entitled Radio circuits for static limitation.

I claim:

1. A thermionic tube circuit comprising, a thermionic tube having cathode, anode and control electrodes, an external anode circuit comprising an impedance, means for limiting the flow of current in said anode circuit, and other means for decreasing the flow of current in said anode circuit, so that an abrupt change is effected in the anode current, said abrupt change being characterized by the junction of two angularly disposed lines within a radius represented by less than one-tenth volt on the characteristic input voltage-output current curve of said tube and circuit.

2. A thermionic tube circuit comprising, a thermionic tube having cathode, anode and control electrodes, an external anode circuit comprising a resistance, means for limiting the flow of current in said anode circuit, and other means for decreasing the flow of current in said anode circuit so that an abrupt angular change is effected in the anode current by a voltage change between said cathode and said control electrode of less than one-tenth of a volt.

3. A thermionic tube circuit comprising, a thermionic tube having cathode, anode and control electrodes, an external anode circuit comprising a resistance, means for determining the normal slope of the grid voltage anode current characteristic of said tube, and means for abruptly altering said slope to effect a characteristic of constant current in said anode circuit, the change from said slope to said constant current being represented by a radius occupying not more than one-tenth volt on the grid voltage-anode current characteristic of said tube and circuit.

4. A thermionic tube circuit comprising, a vacuum tube having cathode, anode, and control

electrodes; an anode circuit comprising said cathode, said anode, a non-inductive resistance, and a source of potential; a control electrode for limiting the maximum flow of current in said anode circuit; and a second control electrode for varying said anode current below but not above said maximum current flow, the junction of the characteristic curve of said varying and said maximum current characteristics being effected by not more than one-tenth volt change of input voltage.

5. A thermionic tube circuit comprising, a thermionic tube having cathode, anode, and grid electrodes; a source of anode potential; means for limiting said anode potential to a value insuring constant current in the anode circuit; and means for impressing a constant potential on said grid electrode so that varying potentials applied to said grid electrode will decrease but not increase said constant current, the junction of the characteristic curve representing said decreasing and said constant anode current being represented by a change of less than one-tenth volt grid potential.

6. A thermionic tube circuit comprising, a screen grid thermionic tube having cathode, anode, screen, and control electrodes; a source of anode and screen potentials; means for establishing said screen potential at a value insuring current saturation in the anode circuit; means for applying a constant potential to said grid electrode so that varying potentials applied to said grid electrode will decrease but not increase said saturation current, and establish a sharp angular junction between said decreasing currents and said saturation currents represented by a grid potential change of less than one-tenth volt.

7. A thermionic tube circuit comprising, a thermionic tube having a uni-potential cathode, anode, and grid electrodes; a source of anode potential; means for limiting said anode potential to a value insuring constant current in the anode circuit; and means for impressing a constant potential on said grid electrode so that varying potentials applied to said grid electrode will decrease but not increase said constant current, the junction of the characteristic curve representing said decreasing and said constant anode current being represented by a change of less than one-tenth volt grid potential.

8. A thermionic tube circuit comprising, a screen grid thermionic tube having a uni-potential cathode, anode, screen, and control electrodes; a source of anode and screen potentials; means for establishing said screen potential at a value insuring constant current in the anode circuit; means for applying a constant potential to said grid electrode, whereby varying potentials applied to said grid electrode will decrease but not increase said constant current, and having a characteristic input voltage-output current graph in which the junction of said constant current and said decreasing current is represented by a radius equivalent to less than one-tenth volt input voltage change.

9. A thermionic tube circuit for detecting radio frequency currents comprising, a thermionic tube having cathode, anode, and grid electrodes; a high resistance external to said tube connected to said anode for limiting the anode potential to a value normally insuring constant current in the anode circuit; means for normally biasing said grid electrode to a potential not effecting said constant current; means for coupling a signal indicating instrument to said

anode circuit, and having a characteristic input voltage-output current graph in which the junction of said constant current is represented by a radius equivalent to less than one-tenth volt input voltage change.

10. A thermionic tube circuit for detecting radio frequency currents comprising, a thermionic tube having cathode, anode, screen, and grid electrodes; a high resistance external to said tube connected between said anode and cathode; means for impressing a constant potential on said screen electrode to normally insure constant current in the anode circuit; means for normally biasing said grid electrode to a potential not effecting said constant current; means for coupling a signal indicating instrument to said anode circuit, and having a characteristic input voltage-output current graph in which the junction of said constant current and the portion approaching said constant current is represented by a radius equivalent to substantially less than one-tenth volt input voltage change.

11. A thermionic tube circuit comprising, two thermionic tubes connected in series each having cathode, anode, and control electrodes; means for limiting the anode potential of each of said tubes to values normally insuring constant current in the anode circuit; means for impressing a constant potential on each of said control electrodes, means for connecting the output of the first tube to the input of the second, and represented by an operating graph in which the constant anode currents are represented by two substantially parallel lines, each terminating in a common sloping connecting line in which said straight parallel lines and said sloping line have junctions which are equivalent to a radius of less than one-tenth volt of input potential.

12. A thermionic tube circuit comprising, serially connected thermionic tubes each having cathode, anode and control electrodes; a connection from the anode of the first tube to the control electrode of the second tube; means normally determining constant currents in the anode circuits of each tube; means for applying constant potentials between cathode and control electrodes of each of said tubes, and having an operating characteristic represented by a graph having substantially parallel lines for the constant anode currents, each terminating in a common sloping line, said terminations being equivalent to a radius of substantially less than one-tenth volt input potential.

13. A thermionic tube circuit comprising, serially connected thermionic tubes each having uni-potential cathode, anode, and control electrodes; a connection from the anode of the first tube to the control electrode of the second tube; means determining the saturation of the currents in the anode circuit of each tube; means for applying constant potentials between cathode and control electrodes of each of said tubes, and represented by an input voltage-output current operating graph having substantially parallel lines representing said saturation currents and terminating in a common sloping line, each termination being equivalent to an input voltage change of less than one-tenth volt.

14. A thermionic tube circuit comprising, a pair of serially connected vacuum tubes each having cathode, grid, screen, and anode electrodes; a connection from the anode of the first tube to the grid of the second tube; connections for applying a constant potential on the screen grid of each tube, for determining constant currents in

the anode circuits in said pair of tubes, biasing voltages for the grids of each of said tubes, and further characterized by an input voltage output current curve which has a constant current portion, a variable current portion and a second constant current portion, the junctions of said portions being effected by an input potential change of less than one-tenth volt.

15. A thermionic tube circuit comprising, a pair of serially connected vacuum tubes each having a uni-potential cathode, grid, screen, and anode electrodes; a connection from the anode of the first tube to the grid of the second tube; connection for applying a constant potential on the screen grid of each tube, for determining the saturation of the currents in the anode circuits in said pair of tubes; biasing voltages for the grids of each of said tubes so that variable voltages applied to the grid of the first tube produce changes in the anode current of the second tube not exceeding sharply defined limits and characterized by an input voltage-output current graph having a sloping portion terminating in two non-sloping flat portions, said terminations having a radius of substantially less than one-tenth volt of input potential.

16. A thermionic tube circuit comprising, two serially connected thermionic tubes each having cathode, anode, and control electrodes; a high resistance connected to the anode of the first tube; a second high resistance connected to the anode of the second tube; a connection from the anode of the first tube to the control electrode of the second tube; sources of anode potentials for each of said tubes normally insuring currents in each anode circuit; biasing voltages for the control grids so that varying voltages impressed on the control electrode of the first tube produce changes in anode current of the second tube within the

limits determined by said anode constant currents, and characterized by an input voltage-output current graph having a variable voltage variable current portion terminating in two constant current variable voltage portions, said terminations having a radius of substantially less than one-tenth volt of input potential.

17. A device of the character described, including serially connected thermionic tubes, a connection from the anode of the first tube to the grid of the second tube, means for limiting the maximum anode currents in each of said tubes to predetermined constant currents and means which limit the output currents of the second tube to sharply defined minimum and maximum values so that the input voltage output current characteristic may be represented by a graph having a sloping portion terminating in non-sloping portions equivalent to said minimum and maximum values, the angular intersection of said portions having radii equal to less than one-tenth volt of input potential change.

18. A device of the character described, including serially connected thermionic tubes, means for limiting the maximum anode currents in each of said tubes to predetermined constant values, means which limit the output currents of the second tube to sharply defined minimum and maximum values, and means which determine the difference in said minimum and maximum anode currents so that the input voltage output current characteristic may be represented by a graph having a sloping portion terminating in non-sloping portions equivalent to said minimum and maximum values, the angular intersection of said portions having radii equal to less than one-tenth volt of input potential change.

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