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March 29, 1938. D. G. McCAA 2,112,705

RADIO CIRCUIT FOR STATIC LIMITATION

Filed Feb. 11, 1935 2 Sheets-Sheet 1

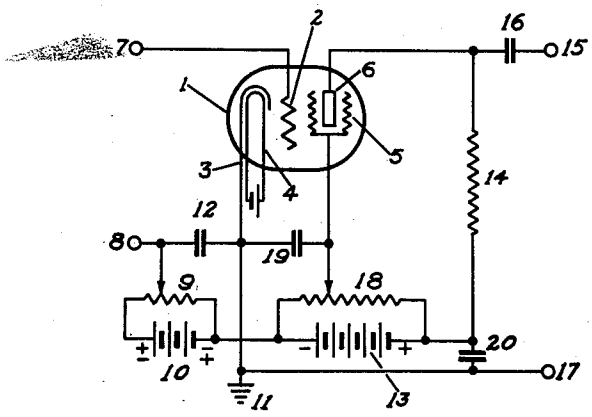


FIGURE I

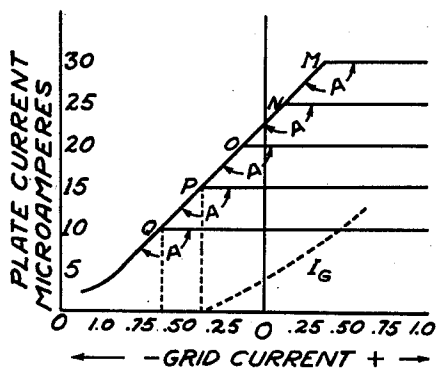


FIGURE II

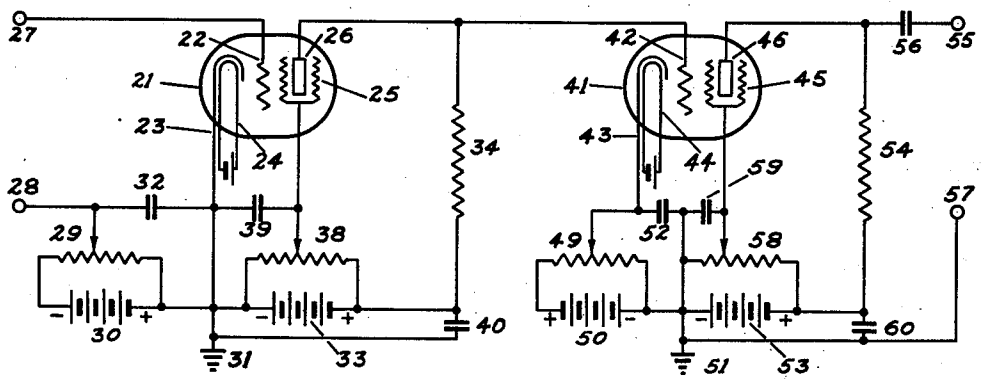
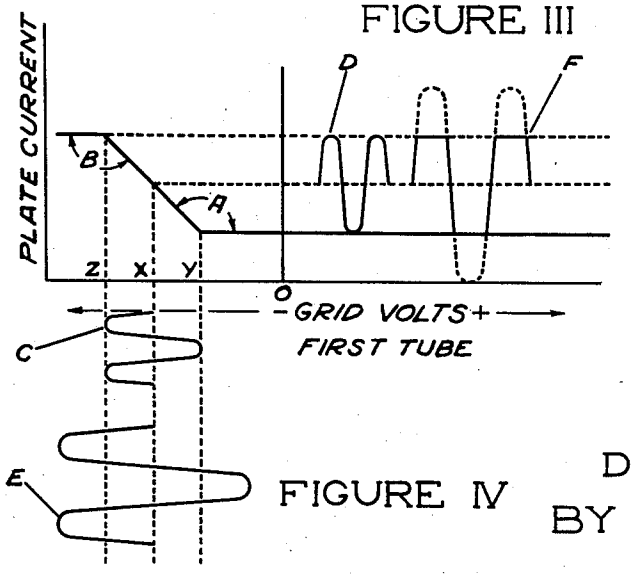


FIGURE III



OUTPUT CURRENT SECOND TUBE

FIGURE IV

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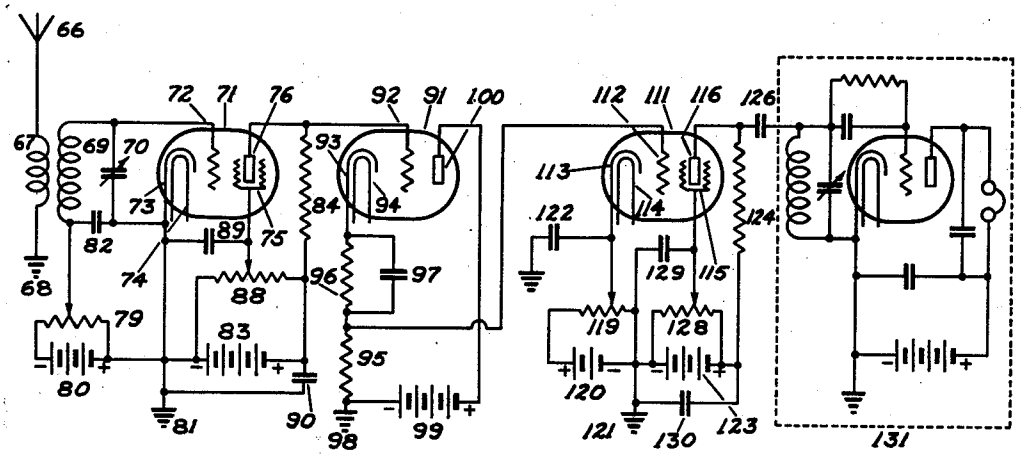


FIGURE V

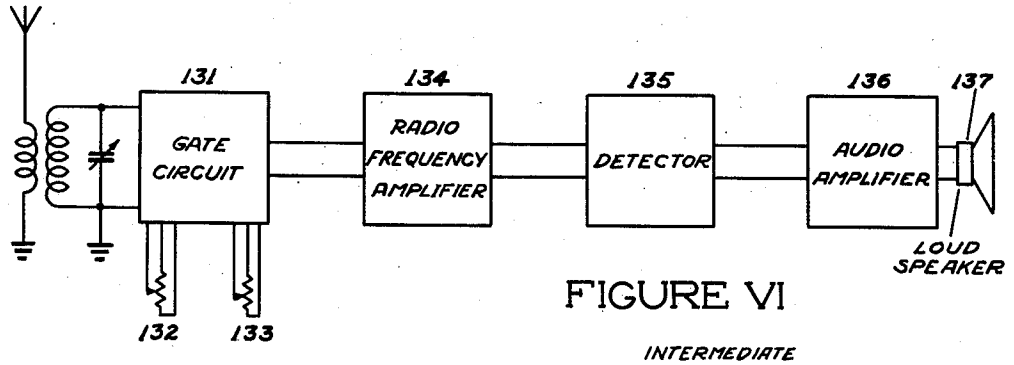


FIGURE VI

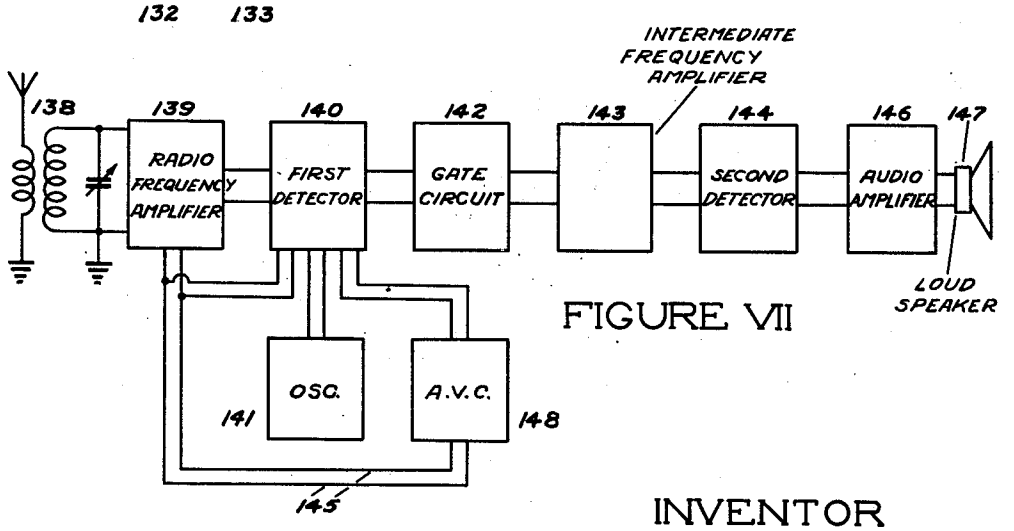


FIGURE VII

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UNITED STATES PATENT OFFICE

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RADIO CIRCUIT FOR STATIC LIMITATION

David G. McCaa, Lancaster, Pa., assignor to
Alan N. Mann, Scarsdale, N. Y., as trustee

Application February 11, 1935, Serial No. 6,015

9 Claims. (Cl. 250—20)

My invention relates to radio receiving circuits. More particularly it relates to a radio receiving circuit in which thermionic tubes are employed for limiting static impulses to predetermined values. In my co-pending application, Serial No. 6,014 filed February 11, 1935, entitled improvements in Thermionic tube circuits, I have disclosed specific circuits which may be employed as voltage limiting devices. In this application, I shall describe improvements in the aforesaid circuits and novel means in which said circuits may be employed in radio receiving circuits.

One of the objects of my invention lies in improvements in thermionic tube circuits for limiting and amplifying voltage impulses. Another object is to incorporate voltage limiting circuits in a radio receiving system. A further object is to automatically adjust the voltage gain of the receiving circuits with respect to the incoming carrier currents so that the gate or limiting action will be fully and automatically utilized. A further object is to provide a voltage limiting system capable of being extended to sharp, well defined, output limits by exceedingly small input voltages so that the system may be used in that part of the receiving system in which the input voltage is relatively small and the signal static voltage ratio is a maximum.

In the accompanying drawings: Figure I represents the basic circuit I employ.

Figure II shows a family of characteristic grid voltage-plate current curves obtained from the circuit of Figure I.

Figure III represents two stages of the arrangement of Figure I.

Figure IV shows the over-all grid voltage-plate current characteristic of the circuit of Figure III.

Figure V illustrates an alternative arrangement to Figure III applied to a radio receiver.

Figure VI is a schematic diagram of a radio receiving circuit embodying Figure III.

Figure VII is a schematic diagram of a superheterodyne receiver in which Figure III is employed at intermediate radio frequency and with automatic gain control.

In Figure I, 1 represents a screen grid tube in which 2 is the grid, 3 the cathode, 4 the heater, 5 the screen grid, and 6 the anode. The input terminals of the tube and circuit are 7 and 8. A suitable bias for the grid 2 may be obtained by adjusting the slider of potentiometer 9 which is shunted around battery 10. One terminal of the battery connects to cathode 3 which is grounded at 11. The slider of 9 is connected to 8 which is by-passed to 3 by condenser 12.

The negative terminal of B battery 13 is connected to ground 11. The positive terminal of 13 is connected to a non-inductive and relatively high resistance 14 which in turn connects to anode 6. The anode 6 is connected to an output terminal 15 by condenser 16. The remaining output terminal 17 is connected to ground 11. A potentiometer 18 is shunted across all or a suitable portion of B battery 13. The slider of potentiometer 18 is connected to screen grid 5. The screen grid may be by-passed to ground by condenser 19 and the B battery may also be bypassed by a condenser 20.

By employing suitable values, by the way of example, tube RCA 224, grid voltage —1.5, heater voltage 2.7, B battery 22 volts, screen grid voltage 6, and a megohm resistance in the external anode circuit, the unusual characteristic of grid voltage plotted against plate current illustrated in Figure II is obtained. The unusual abrupt change from the sloping character of the curve to the straight horizontal line, represented by angle A, is secured by a novel combination of means. The high external plate resistance and the low B voltage tend to straighten out the characteristic curve and to limit the anode voltages to values which normally insure anode current saturation. The adjustment of the screen grid voltage is a further insurance of anode saturation currents, and aid in positioning angle A, and means of determining the steepness of the slope of the grid voltage plate current characteristic curve. The grid voltage determines the normal position of the grid on the slope of the characteristic curve.

As the grid voltage is adjusted from positive toward negative (see Figure II) the anode current remains constant, until the angle A is reached. At this point the anode current changes very abruptly and as the grid is made more negative the curve is at first a straight line. Finally the curve begins to bend and approaches zero anode current, as the grid is made more and more negative. The theory and operation of Figure I is more fully described in my co-pending application mentioned above.

In Figure III two tubes and circuits, similar to the one illustrated in Figure I, are connected in series. A unipotential cathode tube such as an RCA 224 is represented at 21. In this tube 22 is the control grid, 23 the unipotential cathode, 24 the heater, 25 the screen grid, and 26 the anode. The control grid is connected to input terminal 27. The other input terminal is 28 which connects to the slider of potentiometer 29. The po-

tentiometer 29 is shunted around biasing battery 30. The positive terminal of 30 and the cathode 23 are both grounded at 31. A by-pass condenser 32 connects 28 to 23.

The negative terminal of B battery 33 is grounded at 31. The positive terminal of 33 connects to one terminal of resistance 34. The remaining terminal of 34 connects to the anode 26. A potentiometer 38 shunting all or part of battery 33 may be used to control the potential of screen grid 25 by means of the slider on 38. The screen grid 25 may be connected to ground 31 by condenser 39. The B battery may be by-passed by condenser 40.

The second stage employs screen grid tube 41, RCA type 224 by way of example. In this tube 42 is the control grid, 43 the unipotential cathode, 44 the heater, 45 the screen grid, and 46 the anode. A potentiometer 49 is connected across battery 50 to bias the cathode 43 positive with respect to the grid 42. The slider of 49 provides means to suitably adjust the biasing voltage. The negative terminal of 50 is grounded at 51. The slider of potentiometer 49 is connected to ground 51 by by-pass condenser 52.

The negative terminal of B battery 53 is grounded at 51. The positive terminal of this battery is connected to one end of resistance 54. The remaining terminal of 54 is connected to anode 46. The anode 46 is connected to output terminal 55 by condenser 56. The other output terminal 57 is grounded at 51. A potentiometer 58 shunts all or a suitable part of 53. The screen grid 45 is connected to the slider of the potentiometer 58. The screen grid may be by-passed to ground by condenser 59. A by-pass condenser 60 may be shunted across B battery 53.

The characteristic of each of these separate stages is similar to that illustrated in Figure II. The values given above for Figure I may be employed in the circuits of Figure III. When a varying input voltage is applied between 27 and 28, the plate or anode current varies in resistance 34 as shown in Figure II. As the anode current in 21 decreases, the anode 26 will become more positive with respect to ground because of less voltage drop in 34. Since 42 is directly connected to 26, as 26 becomes more positive, 42 will also become more positive with respect to ground, overcoming the bias voltage 49. The increasingly less negative, or even positive voltage on 42 with respect to cathode 43, causes the anode current in 41 to reach saturation represented by angle A as the anode current of 21 is falling.

On the other hand as the anode current of 21 approaches saturation, the maximum voltage drop is approached in resistance 34 and anode 26 becomes less positive or approaches its minimum positive charge. The minimum positive voltage on anode 26 also means minimum positive voltage on control grid 42 with respect to ground, because they are directly connected. Since the bias 49 makes the grid 42 negative with respect to cathode 43, the result is an increasing negative charge on 42 which results in decreasing anode current in 41.

The net result of the changes just described is illustrated by the grid voltage curve of the first tube plotted against the anode current of the second tube as shown in Figure IV. A and B represent the critical angles of tubes 21 and 41. The positions Y and Z at which angles A and B occur may be determined by the constants chosen. The actual values of voltage may be of the order given above for Figure I.

I do not intend to be limited to the precise values shown because I have found a wide range of tubes, resistances, and voltages may be used. By the way of preference, the unipotential cathode tube is especially suited to the circuits of my invention because of the sharp angle A which may be obtained by the use of this type of tube. Likewise the triode tubes may be used, but I prefer the screen grid tubes because the capacity between the grid and plate of the triode becomes effective at high radio frequencies and, unless neutralized, tends to upset the gate or limiting action. This may even be true, to a slight extent, in screen grid tubes, which may then require some neutralization.

If the second tube of Figure III happens to have a characteristic which causes it to draw grid current, (which is shown as I_G in Figure II) when operating near the angle B limit, a load is placed on resistance 34. This may disturb the characteristic illustrated in Figure IV. Although this is only true of certain tubes, and may be overcome by the choice of tubes, or the constants of the circuit, I have been able to entirely eliminate the trouble by the use of a coupling tube.

In Figure V, I have shown a complete radio receiver employing my gate or limiting circuits and in addition I have shown the use of a coupling tube. The coupling tube is inserted between the two stages of Figure III to avoid the deleterious effects of grid current in the second tube and make the first tube independent of the second.

In Figure V, 66 represents an antenna, 67 a primary inductance which is grounded at 68. The secondary inductance 69 is coupled to the primary 67. Variable tuning capacity 70 is connected in parallel to the inductance, through the large capacity of the by-pass condenser 82. The tuned circuit comprising 69, 70, 82 is connected to the screen grid type 224 tube 71 as follows: One terminal of condenser 70 connects to the control grid 72. The remaining terminal of 70 connects to the unipotential cathode 73. The heater 74 may be energized by batteries or alternating current. The screen grid 75 is suitably biased by an adjustable potentiometer connection.

The control grid 72 is biased negatively by adjusting potentiometer 79 which is shunted across battery 80. The positive terminal of 80 and the cathode 73 are both grounded at 81. The by-pass condenser 82 keeps the radio frequency currents from flowing in 79 and 80. The negative terminal of B battery 83 is grounded at 81. The positive terminal is connected to the resistance 84. The remaining terminal of the resistance 84 connects to the anode 76.

Potentiometer 88 shunts all or part of battery 83 to provide a suitable bias means for screen grid 75. The screen grid is by-passed to ground by condenser 89. The B battery 83 may be by-passed by condenser 90. Instead of directly connecting tube 71 with the succeeding tube, I interpose coupling tube 91 which may be unipotential cathode tube; such as, the RCA 227.

The grid 92 of tube 91 is connected to the anode 76 of the preceding tube 71. The unipotential cathode 93 is heated by 94 which may be energized by batteries or alternating current. The cathode is grounded through self-biasing resistances 95 and 96 which produce a normal voltage drop which biases 92 negatively with respect to 93, and

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112. This prevents the flow of grid current from grid 92 to cathode 93.

The self biasing resistance 96 may be by-passed by a suitable capacity 97. The resistance 95 is grounded at 98. The B battery 99 is grounded at 98 and its positive terminal is connected to the anode 100.

The coupling tube is connected to the limiter tube 111. This tube may be an RCA type 224 and is comprised of control grid 112, unipotential cathode 113, heater 114, screen grid 115, and anode 116. The control grid 112 is connected to the junction of resistances 95 and 96. The cathode 113 is connected to the slider of potentiometer 119 which shunts battery 120. The negative terminal of 120 is grounded at 121. A by-pass condenser 122 connects the cathode to ground.

The negative terminal of B battery 123 is grounded at 121. The positive terminal of 123 is connected to resistance 124. The resistance in turn is connected to the anode 116. The anode 116 is coupled to the detector circuit by capacity 126. A potentiometer 128 shunts all or part of battery 123. The slider of 128 is connected to the screen grid 115. A by-pass condenser 129 may be connected between the screen and ground. Likewise 130 may be connected across 123.

The detector circuit may be of any of the circuit arrangements well known to the art. Such circuit is represented by the device within the dotted lines 131. The circuit illustrated in Figure V, insofar as the gate or limiting action of tubes 71 and 111 is concerned, is the same as Figure III. The coupling tube connections are arranged so as not to affect the phase relations of tube 71 with respect to 111.

The bias of grid 111 is chosen to fix the gate width YZ when bias on grid 72 is zero, so that desired incoming modulated carrier currents will vary between Y and Z. The bias on grid 72 is then adjusted to the operating position corresponding with X of Figure IV. This is illustrated by the curve C. It is apparent that C will be faithfully and efficiently repeated as variations in the anode or plate current shown as D. Voltages, represented by static currents or otherwise, exceeding the limits YZ are shown as E. The effect of E on the anode current appears as F. The dotted line portion of F is cut off by the gate action.

In Figure V the incoming signal currents received by the antenna are induced in the first tuned circuit. Static currents are likewise set up in the first tuned circuit. The static charges are ordinarily of great amplitude but of short duration. The signal currents, on the other hand, usually are of long duration. When the signal currents are of low voltage, compared with the static voltage, the gate will cut off the excessive amplitude of the static impulses without affecting the signals. The detector circuit receiving the equalized desired and undesired voltages will integrate each of the two effects. Due to the marked difference in duration the energy involved in the reproduced desired signals will far outweigh the undesired static impulses. Although the voltage input at the detector is equal, the sound energy ratio of the signals to the static may be of the order of ten to one to a listener.

Thus my invention makes it possible to receive signals through atmospheric disturbances which may render an ordinary receiver practically useless. Although I have illustrated a relatively simple system operating from batteries, it should be understood that my circuits may be energized entirely from rectified and filtered currents. In Figure VI a tuned radio frequency system is shown in schematic outline. In this illustration 131 may be the circuit of Figure III or V. The potentiometers 132 and 133 are similar to 29 and 49 or 79 and 119. A conventional tuned or tunable radio frequency amplifier is shown as 134. The detector is 135, the audio amplifier 136, and the loud speaker 137.

I prefer operating the gate circuit in front of the radio frequency amplifier because the static signal ratio appears most favorable at this point. However, I have had excellent results when the gate follows the radio frequency amplifier. In the system of Figure VI, it should be understood that 132 and 133 are usually adjusted to the particular signal strength and gate action desired.

The gate action circuits may be applied to superheterodyne radio receivers. The circuit of Figure III may be applied in front of the intermediate frequency amplifier as shown in Figure VII. The manual operation of the gate controls may be simplified by employing automatic volume control. Such control may be employed to regulate receiver gain in front of the gate circuit so that all voltage applied to the gate will be subject to the A. V. C. (automatic volume control) action.

In Figure VII the antenna system 138 is coupled in the conventional manner to the radio frequency amplifier 139. The first detector or mixing tube 140 is coupled to the heterodyne oscillator 141 and an A. V. C. control circuit 148. The resultant currents, now at intermediate frequency, are fed to the gate circuit 142. This circuit may be that of Figure III. The currents in the output of the gate circuit are amplified by the intermediate frequency amplifier 143. The second detector is represented by 144.

The circuit 148 may include any of the forms of A. V. C. well known to those skilled in the art. The voltage derived from the rectifier for the A. V. C. is fed by means of conductors 145 to the radio frequency amplifier 139 and detector 140 to control the gain of the amplifier and first detector. The A. V. C. control tends to keep constant the voltages, representing desired signals, applied to the gate circuit 142. Thus the gate opening will be suitable for all desired signals and excessive voltage impulses will be limited as shown in Figure IV. The output signals may be amplified by audio amplifier 146 and reproduced by loudspeaker 147.

I have described several species of circuits which have a gate or limiting action. These circuits have been applied to different types of radio receivers. It will occur to those skilled in the art that the circuits of my invention may be varied and employed in different arrangements. By way of example, I have found that the A. V. C. action, instead of being applied to the radio frequency amplifier to control its gain, may be applied to effectively and variably operate the biases of the gate tubes. In this manner the gate is automatically adjusted to the signal instead of the signal to the gate. Similar modifications are within the scope of my invention.

I claim:

1. In a device of the character described, a pair of screen grid thermionic tubes, means including the screen grid in each of said tubes for limiting the maximum value of their anode currents, a single thermionic tube for coupling said pair of tubes and connections between said plu-

rality of tubes so arranged that the anode current in one of said screen grid tubes is rising when the anode current in the other is falling.

2. A device for receiving and limiting radio and atmospheric currents including a pair of thermionic tubes, anode circuit resistances for limiting the maximum value of the anode currents of such tubes so as to insure normally constant maximum currents in their anode circuits, a third single thermionic tube for coupling said pair of tubes and connections between said pair of tubes and said third tube so arranged that the anode currents of one of said pair of tubes are rising when the anode currents in the other of said pair of tubes are falling.

3. A device as described in claim 2, including biasing means for normally establishing the anode currents in the anode circuits of said tubes at values less than said constant currents.

4. A radio receiving device comprising a plurality of radio frequency responsive circuits, means for connecting one of said circuits to another of said circuits comprising a pair of thermionic tubes each having an anode and a cathode and a control electrode, operating connections for said tubes comprising an anode circuit for each of said tubes including a resistance, coupling means for coupling the output of the first of said tubes to the input of the second of the tubes, a source of anode potential for said tubes and biasing means for each of said control electrodes, the values of the operating connections for said tubes being such as to cause increasing currents to flow in one anode circuit concurrent with decreasing currents in the other anode circuit and being such as to cause said pair of tubes to have an operating graph in which the input voltage of the first of said tubes plotted against the output current of the second of said tubes is represented by a constant current portion, a changing current portion and a constant current portion, and being such as to cause the junctions of said portions to be affected by an input voltage of substantially less than one-tenth of a volt.

5. A structure as specified in claim 4, in which each of the said two tubes has a second control electrode and the operating connections for said tubes include means for applying potential to such second control electrodes.

6. A structure as specified in claim 4 which further includes means for preventing grid current in the input circuit of the second of said tubes from affecting the output circuit of the first of said tubes.

7. A structure as specified in claim 4, which further includes a third tube connecting the output of the first of said pair of tubes to the input of the other of said pair of tubes so that grid current in the second of said pair of tubes does not affect the first of said tubes.

8. A radio receiving device including several radio frequency responsive circuits, a pair of thermionic tubes, connections between one of said circuits and the input of the first of said thermionic tubes, connections between the output of the second of said tubes and the other of said circuits, and operating connections for said tubes comprising an anode circuit for each of said tubes including a resistance, means for limiting the maximum value of the anode currents in each of said tubes, connections between the first of said tubes and the second of said tubes adapted to limit the anode currents of said second tube to a maximum and minimum value, a source of anode potential for each of said tubes and means for establishing the normal anode current of the second of said tubes substantially midway between the maximum and minimum values, the values of the operating connections for said tubes being such as to cause said two tubes to have an operating graph in which the input voltage of said first tube plotted against the output current of said second tube is represented by a constant current portion, a changing current portion and a second current portion and being such as to cause the junctions of said portions to be affected by an input voltage of substantially less than one-tenth of a volt.

9. In a radio receiving system, a plurality of signal responsive circuits, means for coupling one of said circuits to another of said circuits, said coupling means comprising a pair of screen grid thermionic tubes, and operating connections for said tubes comprising means for adjusting the voltage applied to the screen grid of such tubes normally to limit the maximum value of the anode current of each of said tubes, anode circuits for said tubes including resistances, coupling means for coupling the output of one of said tubes to the input of the other of the tubes, a source of anode potential for said tubes and biasing means for the grids of said tubes, the values of said operating connections for said tubes being such that the output of the second of said tubes is limited to sharply defined maximum and minimum values represented by angular changes in the characteristic curve and being such that the angular change in such characteristic curve will be affected by changes of input voltage to the first of said tubes of substantially less than one-tenth of a volt.

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