July 17, 1934. R. D. BROWN, JR 1,966,607

VACUUM TUBE SYSTEM

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Fig. 1.

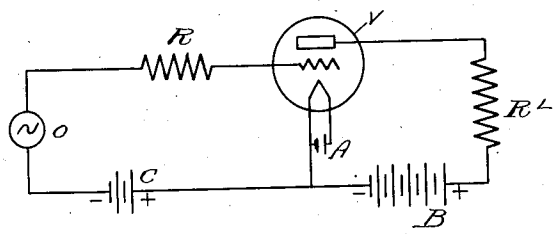


Fig. 2.

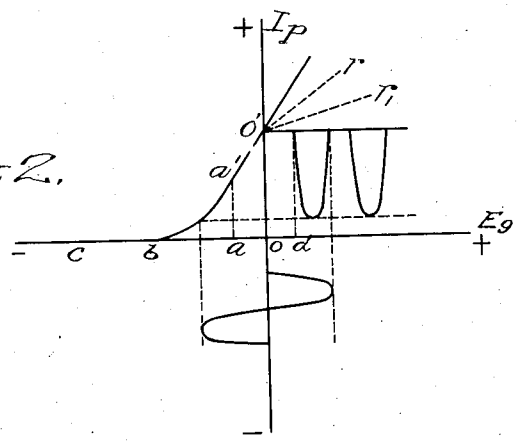


Fig. 3.

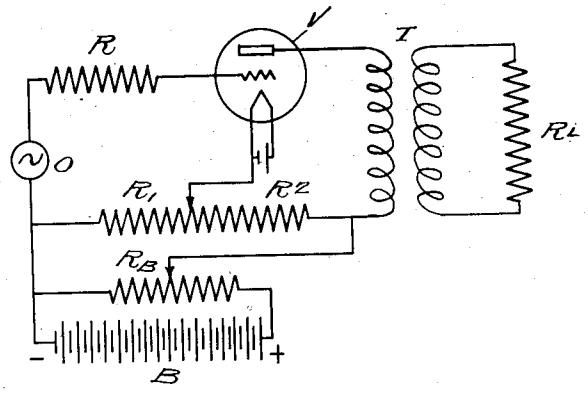
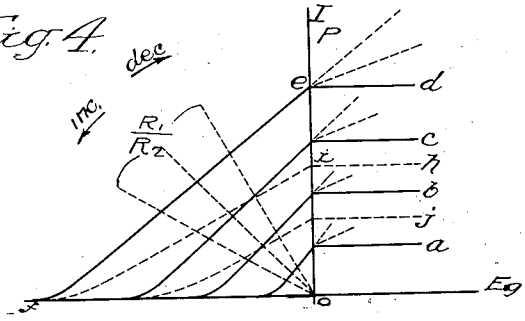


Fig. 4.



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Fig. 5.

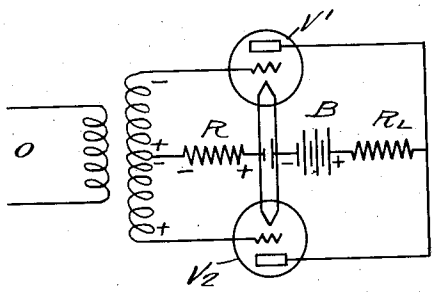


Fig. 6.

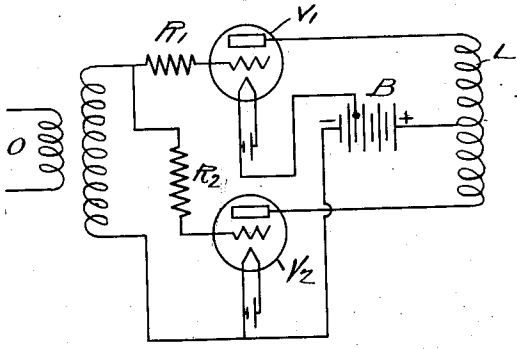


Fig. 7.

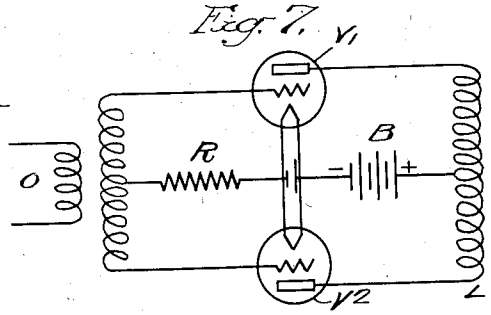


Fig. 8.

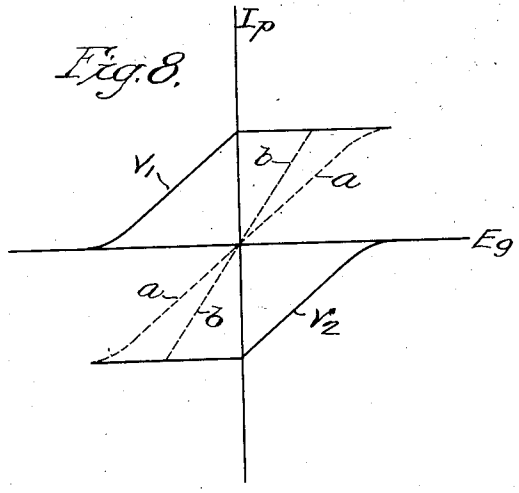
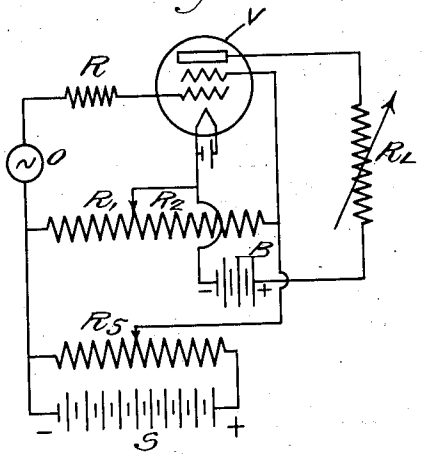


Fig. 9.



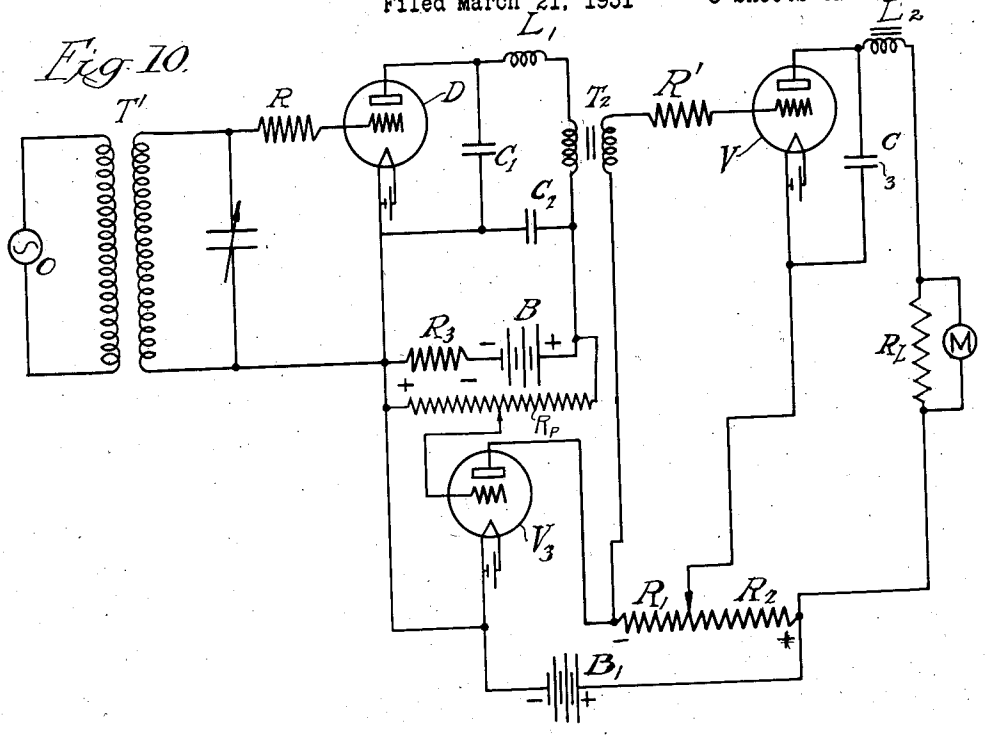
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Fig. 10.



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UNITED STATES PATENT OFFICE

1,966,607

VACUUM TUBE SYSTEM

Reynolds D. Brown, Jr., Philadelphia, Pa.

Application March 21, 1931, Serial No. 524,363

1 Claim. (Cl. 250—27)

This invention relates to signaling systems utilizing thermionic devices, and particularly to those systems wherein vacuum tubes are used.

An object of the invention is to provide a simple arrangement whereby the upper portion of a vacuum tube voltage input—current output characteristic may be modified in various predetermined manners without affecting the lower portion thereof.

A further object is to provide a simple method of and means for preventing the plate current of a vacuum tube from increasing beyond a value corresponding to zero grid potential, regardless of grid potential amplitudes.

Another object is to provide a novel method of and means for limiting the output current of a thermionic device to a certain predetermined value.

A still further object is to provide a new and novel method of and means for controlling the operation of a vacuum tube and its associated circuit.

Other objects of and various uses for my invention will be apparent from the following description.

In the drawings:

Fig. 1 shows a simple vacuum tube circuit to which my invention has been applied;

Fig. 2 illustrates graphically the operation of the system of Fig. 1;

Fig. 3 shows a system for controlling the operation of the vacuum tube by differentially varying the ratio of the grid bias to plate potential;

Fig. 4 illustrates graphically the operation of the system of Fig. 3;

Figs. 5 to 7 show the application of my invention to various push-pull arrangements;

Fig. 8 is a graphical illustration of the working of the tubes of Fig. 7 in push-pull relation;

Fig. 9 shows a modification of the system of Fig. 3; and

Fig. 10 shows a practical system embodying features of the other figures.

Referring to Fig. 1, there is shown a vacuum tube V having the usual sources of energization A, B and C. A source of oscillations O is connected in the grid-cathode circuit of the tube. This source may be any source of high or low frequency impulses. The anode-cathode circuit of the tube is represented as having included therein a resistance R_L which is intended to represent any load fed by the tube. A resistance R, which may for example have a value of 5 megohms is connected between the source O and the grid of tube V.

Referring to Fig. 2 for the operation of the fundamental circuit of Fig. 1, there is shown the characteristic curve of tube V, obtained by plotting plate current against grid voltage for a certain plate potential B. Let us assume that the grid of tube V is unbiased, that is, that the battery C has been removed, and that no oscillations are being delivered by source O. Then for all intents and purposes the grid will be at a low fixed potential with respect to the cathode, and a steady plate current I_B will flow. Now if oscillations be delivered by source O, the grid will alternately be charged positively and negatively. Upon becoming positively charged, the grid will draw current and a potential drop will take place across the resistor R. Since this drop is directly proportional to the current which in turn depends upon the voltage of source O, it will practically neutralize the potential of source O. For example, if the positive potential applied to the grid by source O be assumed as 5 volts, then if R equals 5 megohms and if internal resistance of the tube be neglected, since it is so small compared to R, the current will equal 1 microampere. The drop across R will then be 5 volts and the grid will be maintained at its original potential. In other words, as shown in Fig. 2, the plate current will never rise appreciably above its steady value. Negative grid charges will, of course, cause no grid current flow, and hence no voltage drop across R. As shown in Fig. 2, only the negative half of each incoming cycle will be repeated in the output circuit.

The obvious result of the above discussed action is that the entire upper half of the characteristic curve of tube V has been removed and a substantially straight horizontal line has been substituted therefor. In other words, a straight line cut-off has been given the plate current. However, the upper portion of the curve may be given any desired one of several various forms by varying the value of R. The broken lines r and r' in Fig. 2 indicate conditions for considerably smaller values of R. The grid may be biased in any desired manner, and four different bias points a, b, c and d have been indicated in Fig. 2. For bias c, the tube would be effectively blocked until the amplitude increases to a value greater than $c—b$. For bias b, impulses of plate current would be caused only by positive oscillations from the source o. Operating at either b or c, the plate current would be limited to the value at o. For bias a, the upper portion of the plate current impulses caused by positive oscillations would

be limited due to the action of resistance R. Impulses due to negative oscillations would be limited by the zero value of plate current. For bias *d*, impulses of plate current would not be caused by negative oscillations until the value *o—d* is exceeded, positive oscillations being totally ineffective due to resistance R.

Many practical applications of the system are possible. For example, operation of the tube V as a detector about the point *o'* gives straight line detection at 100% modulation for relatively small carrier waves. An added feature is that impulses of excessive value as for instance those exceeding *o—b*, will be limited by the zero value of plate current. The tube may, of course, be used as an amplifier operating about point *a'*, and is particularly adapted to amplifying code signals, since the tops of impulses of excessive value may be chopped off if desired to give a substantially square wave form while amplifying signals in the range *a—o*, *a—b* without undue distortion. Since the limiting action of the tube depends upon the value of resistance R, the value of bias source C may be adjusted to cause the tube to block oscillations of any predetermined amplitude as described above. For instance, adjustment of C to the values *o—b* will provide a detector with a definite maximum output limit. Many other applications are possible.

In Fig. 3, there is shown a system similar to that of Fig. 1 with an arrangement for varying the plate voltage and grid bias in a differential manner. A battery B and potentiometer R_B are provided to obtain varying supply voltages across the resistor R_1 R_2. By-pass condensers may be used across R_B, R_1 and R_2 if desired. One side of this resistor is connected to source O while the other side is connected to transformer T which in turn is connected to load R_L. The resistance of R_1 R_2 should be relatively low in order that the plate current may be low compared to the supply current in R_1 R_2. The cathode of the tube is connected to a movable contact which may vary the ratio of R_1 to R_2. It will be apparent that the voltage across R_1 is grid bias voltage while that across R_2 is plate voltage. In Fig. 4 the family of curves obtainable by varying the supply voltage of tube V is shown. These curves may be represented as substantially straight lines between the two axes, although in practice the lower portion of each is slightly curved. It will be apparent that the tube V can be made operative on any of the characteristic curves by varying the setting of potentiometer R_B, thereby varying the supply voltage. Varying the position of the cathode contact will vary the ratio of the grid bias voltage to the plate voltage. For any particular setting of the cathode contact, the points on the curves which represent the ratio R_1:R_2 for each value of supply voltage lie in a straight line, since the ratio R_1:R_2 remains constant. Three broken lines represent the loci for points representing different values of the ratio R_1:R_2. The effect then of changing the position of the cathode contact, is to cause the locus of a point representing a certain ratio R_1:R_2 to revolve about the origin O between the axes E_g and I_P, as indicated by the arrows.

In the above explanation, R_L was assumed to be coupled into the circuit in such manner that no substantial direct current potential drop occurred across it. When R_L is directly in the plate supply circuit, another condition occurs. With the load resistance R_L set at a very low value, potentiometer R_B may be adjusted to give a certain steady plate current for zero grid potential, such as *e*. This establishes point *e* on the curve, and if the adjustment of R_B is maintained constant, the tube will work along curve *d* and the zero plate current point will be established at point *f*. Now if the load resistance R_L is increased, the curve will take the form indicated by dotted curve *h*, since the increased resistance R_L decreases the plate current but, of course, has no effect at zero plate current. Thus, the point *f* is first established by adjusting potentiometer R_B, then point *i* is established by varying R_L. In other words, it might be said that curve *d* is revolved about point *f* as a center of rotation by varying R_L. This applies, of course, to any of the curves, although only two dotted curves *h* and *j* are shown in Fig. 4. Because no substantial change of grid bias occurs when the value of R_L is varied, the three broken lines above referred to as representing loci of points for different values of R_1:R_2 will take up new positions so that they cut curves *h* and *j* at the same values of grid bias at which the three corresponding lines cut *d* and *o*.

The above description of the device of Fig. 3 assumed, as above mentioned, that the supply current through R_1R_2 was large with respect to the plate current. However, the device will operate when the plate current constitutes the major part of the current through R_1 in which case the efficiency of the device will decrease for the following reason. An impulse from source O which adds to the effect of the potential across R_1 in determining the instantaneous value of plate current will be opposed by the potential set up by the resulting changed plate current in R_1. Consideration of this fact will show that in order to obtain the same effect in the output circuit under this condition, as compared with the condition where the supply current through R_1R_2 is high, an increased impulse from source O will be required. The extreme condition occurs when R_2 is infinite. Thus, I have provided three independent adjusting means, one for the supply voltage, R_B, which may be considered a linear adjustment, one for the plate current, R_L, and the other for the ratio of grid bias voltage to plate voltage, which latter two may be considered rotary adjustments. The practical advantage of such a system is obvious.

In Figs. 5 to 7, I have illustrated the application of my invention to various push-pull arrangements. In Fig. 5 the tubes V_1 and V_2 are connected with their input circuits in push-pull relation and their output circuits feeding a common load represented by R_L. The resistance R is connected as shown so as to be common to both grid circuits, and will alternately prevent each grid from going positive. The source O may be any source of high or low frequency oscillations. The action of this system is the same for each tube as described above in connection with Fig. 1, the resistance R in this instance acting on each half of every wave to maintain one or the other grid at zero potential. The resultant output of the system is, of course, the sum of the plate currents flowing through R_L at any moment.

While two resistors, one in each grid leg, may be used instead of a common resistor R, the use of a common resistor has a distinct advantage. When the grid of tube V_2, for example, tends to go positive, the resulting grid current flowing through the resistor R not only maintains the grid of tube V_2 at zero potential, but also causes a doubled voltage to be applied to grid of tube V_1. Since the polarity of the current flow through

resistor R will be as indicated, it is apparent that while the voltage drop across resistor R opposes the potential across the lower half of the input transformer secondary, it aids the potential across the upper half of the secondary, thus causing a voltage doubling action across the input of tube V_1. On the next half cycle the grid of tube V_1 will be maintained at zero potential while the voltage across V_2 will be doubled. The advantage of this voltage doubling action is obvious, since a signal amplitude of one-half the normal amplitude will give the same result as a signal of normal amplitude would give without this action. When used to detect signals, the system of Fig. 5 gives twice the efficiency of the ordinary single tube detector while providing full-wave linear detection of 100% modulated signals. Elimination of resistor R gives only about one and one-half times the efficiency of the ordinary detector even when a proper grid bias is used. Obviously, no bias or adjusting is necessary in the device of Fig. 5. This is a concrete illustration of the advantage of this system.

Fig. 6 shows the application of my invention to two tubes V_1 and V_2 having their input circuits in parallel relation to a common source of high or low frequency oscillations O and their output circuits in push-pull relation across output coil L. Two resistors R_1 and R_2 are shown in the respective grid circuits. The resultant output of the system is the differential output of the tubes. The system is capable of various practical applications. By varying the relative values of resistors R_1 and R_2 and the relative bias voltages of the tubes, the output can be governed at will.

In Fig. 7 my invention is shown applied to an ordinary push-pull arrangement, the input and output circuits of tubes V_1 and V_2 being in push-pull relation. The resistor R is shown as common to both grids, as in Fig. 5, but here also two resistors may be used. However, the same voltage doubling action as described in connection with Fig. 5 is obtained here also by using a common resistor. The resultant characteristic curve of the tubes is for the greater portion thereof a straight line, and the system functions much more efficiently as an amplifier than the ordinary push-pull circuit. This is illustrated in Fig. 8, which shows the characteristic grid voltage-plate current characteristic curves of the tubes V_1 and V_2 and the resultant curve *b*, the latter being illustrated by means of a broken line. Due to the voltage doubling action, however, the resultant curve is modified as indicated by curve *a*, which, as will be noted, is a straight line.

Fig. 9 shows a modification of the system of Fig. 3 utilizing a screen grid tube. In this system, the plate potential is maintained constant, while the control grid bias and screen grid potential are varied in a differential manner. The arrangement is such that the plate current does not disturb the voltage ratio of R_1 R_2. A constant source of plate potential B is connected between the cathode and plate in the output or load circuit. A source of potential S and potentiometer R_S are provided to obtain varying supply voltages across the resistor R_1 R_2. One side of this resistor is connected to source O, while the other side is connected to the screen grid. The cathode is connected to a movable contact which may vary the ratio of R_1 to R_2. The voltage across R_1 is control grid bias voltage, while that across R_2 is the voltage applied to the screen grid. The curves of Fig. 4 are applicable to this system also. However, in this case the tube is made to operate on different curves by varying the screen grid potential, and varying the position of the cathode contact varies the ratio of control grid bias to screen grid potential. Otherwise, the explanation of the operation of this system is the same as that given in connection with Fig. 3. Obviously, other modifications of this system are possible, the system being applicable to other types of tubes. It is only necessary that the control element bias voltage and the space discharge current be variable with respect to each other. For example, in the system of Fig. 9 the screen grid might be movable, in which case the space discharge current could be varied by moving the screen with respect to the cathode.

One feature of this invention which is of great advantage is that due to the presence of resistor R, the load on the input circuit cannot become greater than that of R itself, which may be made of as high a value as necessary. Obviously also, if R has a high value, small variations in its value will have no noticeable effect such as noise on the operation of the circuit with which it is associated. It is important to note that no plate or screen grid supply current should flow through resistor R. It is essential also that no capacity having an impedance so low as to be comparable to the impedance of R at the working frequency, exist between the grid and the external circuit.

The device of the invention provides a simple method of deriving a D. C. voltage which is a measure of the modulation of a given carrier at any given instant. A device such as that shown in Fig. 1 may be operated as a linear detector to provide a constant unidirectional voltage which is a measure of the unmodulated carrier. This voltage may be amplified if necessary and may be supplied across the terminals of R_1 and R_2 of a device similar to that of Fig. 9, while the audio frequency component is supplied in place of source *o* to the same device. Such a system is disclosed in Fig. 10, wherein O designates a source of modulated carrier waves. This source is coupled by means of radio transformer T' to a tuned detector stage which includes detector tube D and a resistor R connected in its grid lead. The plate circuit of the detector tube includes the usual source of anode potential supply B and also a large resistor R_3. A filter arrangement comprising condensers C_1 and C_2 and choke coil L_1 may be used to by-pass radio frequency currents. The detector is unbiased and, therefore, plate current of a steady value corresponding to zero grid potential normally flows when no incoming carrier is present.

The output circuit of the detector is coupled through audio frequency transformer T_2 to a device similar to that shown in Fig. 3. As in Fig. 3, a vacuum tube V has a resistor R' connected in its grid conductor and derives its grid bias and plate potentials from a potentiometer device comprising resistances R_1 and R_2. A by-pass condenser C_3 may be connected across the plate circuit of the tube and a choke coil L_2 may be provided. The tube has its output circuit connected to a load resistor R_L which may be shunted by a meter or other device M. A potentiometer resistance R_P is connected across resistance R_3 and source B. One terminal of R_P and a potentiometer movable contact are connected to the input electrodes of a vacuum tube amplifier V_3, whose plate circuit includes resistances R_1 and R_2 and also the usual plate voltage supply source B_1.

With no carrier present to excite the system,

a certain plate current flows in the output of the detector tube corresponding to zero grid potential, as will be clear by reference to Fig. 2. This current flows through resistance R_3 and sets up a potential thereacross which opposes that of source B. Since R_3 is large, a steady negative potential may be applied to the grid of amplifier V_3 by means of the potentiometer which biases this tube negatively to fix the steady value of plate current flowing through resistances R_1 and R_2 to a predetermined value. The potentiometer is as adjusted and source B_1 is of such value that substantially zero plate current flows in the output of tube V_3. Assuming now that an unmodulated carrier is sent out from source O, it will be obvious by reference to the illustration of Fig. 2 that only the negative half cycles of such carrier will affect the plate current of the detector if the value of R is suitable. Such half cycles will, however, cause a decrease in the average plate current flowing through resistor R_3 and a corresponding lessening of the negative bias on the grid of tube V_3. The plate current of this tube will then be increased to a predetermined value. In other words, the potential which is established across the terminals of R_1 and R_2 is proportional to the unmodulated carrier. If now a modulated carrier is sent out from source O, the potential established across resistance R_L is a measure of the modulation of such carrier. By properly proportioning the values of voltage and resistance, the unidirectional current in R_L may be made proportional to the percentage modulation. A very important feature is that due to the presence of R', the maximum current in R_L may be adjusted so that it will never exceed that corresponding to 100% modulation. This operates as a protection to meter M or other apparatus connected to R_L against the effects of electrical disturbances. The voltage across R_L could be used to provide a source of control voltage, which will vary with the envelope of the audio frequency and which will be substantially free from the effects of disturbances for any suitable purpose.

Obviously my invention is not limited to any particular type of vacuum tube or circuit. It is to be understood that the systems illustrated and described are for the purpose of disclosure only, and that my invention is not limited thereto. Many changes and adaptations of my invention will be apparent to those skilled in the art. Accordingly, my invention is to be limited only by the scope of the appended claim.

I claim:

In an electrical system, a pair of thermionic devices, each having a grid and a cathode and input and output circuits, a source of signal oscillations, said input circuits being connected in parallel relation with respect to said source and said output circuits being connected in push-pull relation, means biasing said grids to different extents, and a grid resistor for each of said devices to prevent electron current flowing from either of said cathodes to its corresponding grid regardless of the amplitude of any oscillations from said source.

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