April 27, 1948. M. M. LEVY 2,440,284

THERMIONIC VALVE CIRCUITS

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FIG 1.

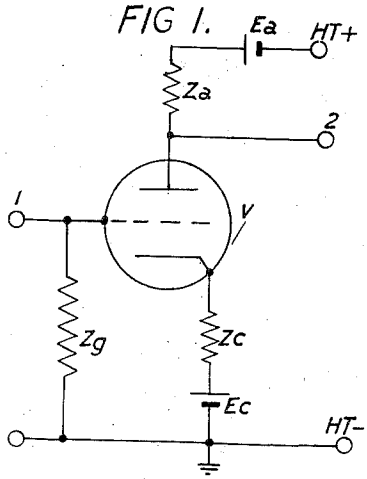


FIG.2.

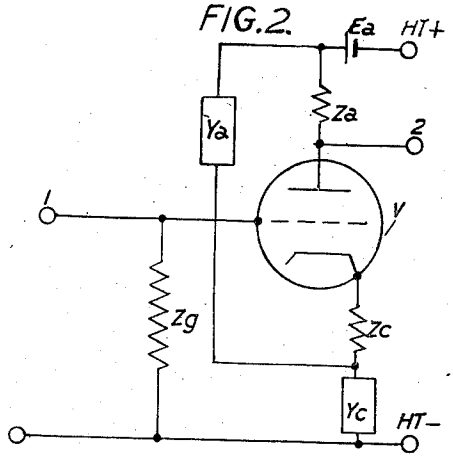


FIG.3.

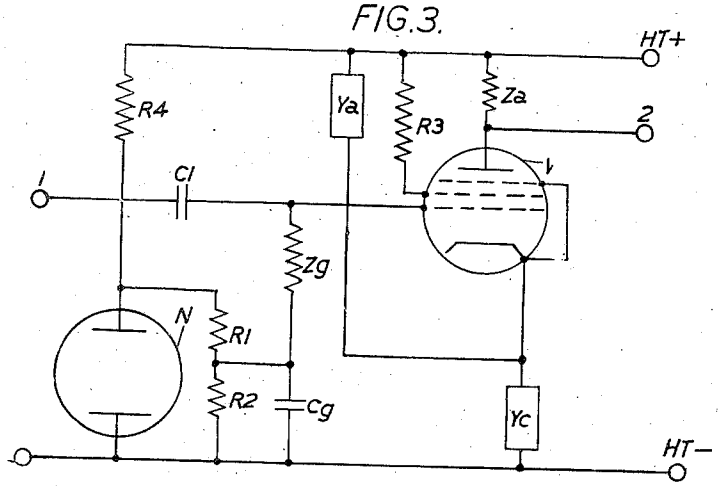
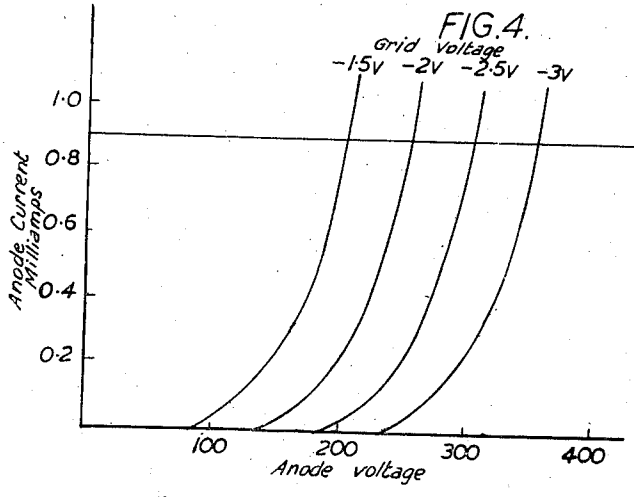


FIG.4.



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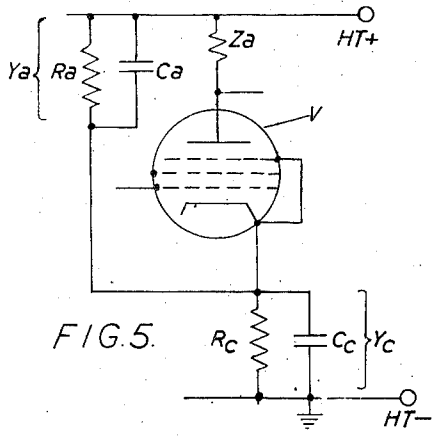


FIG. 5.

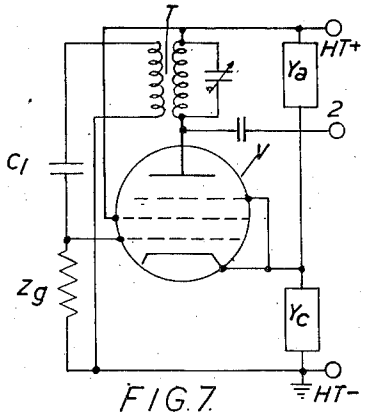


FIG. 7.

FIG. 6.

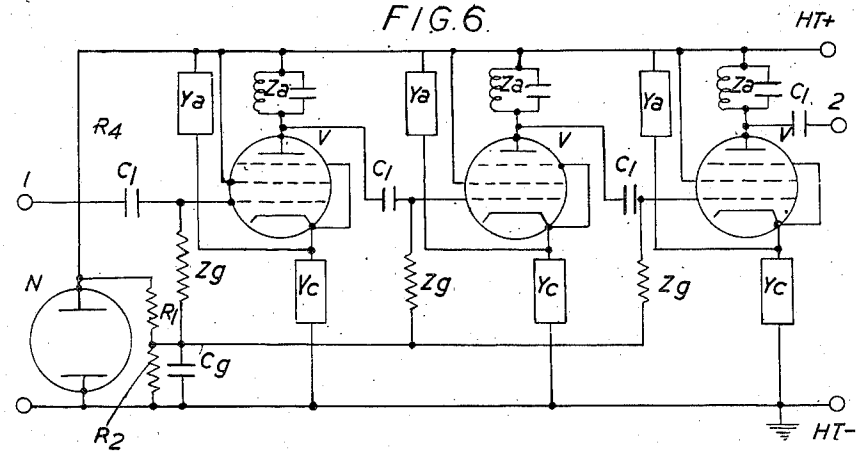
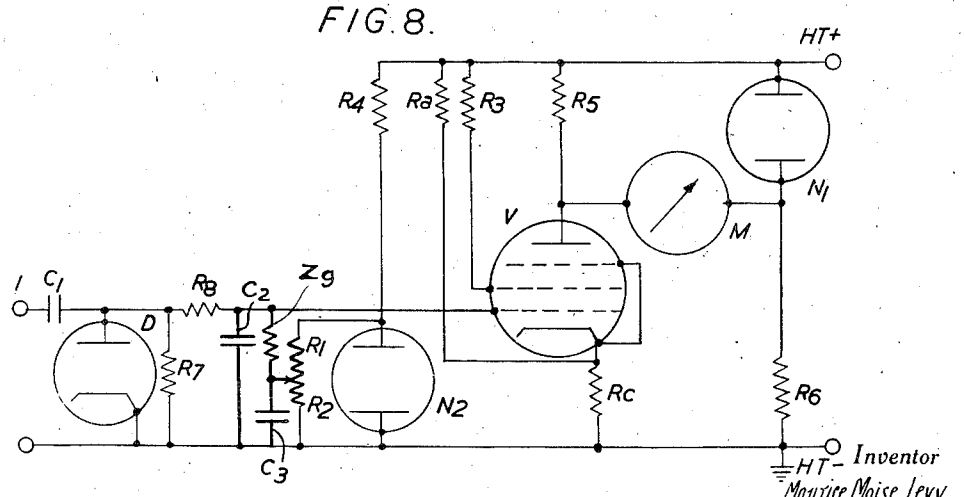


FIG. 8.



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Patented Apr. 27, 1948

2,440,284

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2,440,284

THERMIONIC VALVE CIRCUITS

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Application March 2, 1944, Serial No. 524,761
In Great Britain March 19, 1943

13 Claims. (Cl. 250—27)

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The present invention relates to thermionic valve circuits and is particularly concerned with means for eliminating or reducing the effects of variations in the voltage of the anode supply source.

It is well known that the performance of electrical circuits such as amplifiers, detectors, oscillators, and the like, which employ thermionic valves, is liable to be appreciably affected by variations in the voltage of the anode supply source. Such variations may be divided into three classes, namely, those of an irregular and discontinuous nature such as occur when the anode supply source has a constantly varying load; those in which the anode voltage varies more or less continuously and slowly, such as when a battery runs down or is charged up; and those due to a superposed alternating voltage, for example, a hum due to some periodic device operated from the anode supply source.

Various arrangements have been hitherto used for stabilizing the voltage derived from such a variable anode supply source, but these arrangements are often bulky and expensive, and moreover frequently consume a considerable amount of power. It is therefore the principal object of the present invention to provide a very simple arrangement for stabilizing the performance of thermionic valve circuits of any kind in which the anode current supply source is subject to voltage variations of any or all of the types described. It also enables the decoupling arrangements of such circuits to be simplified.

According to the invention, there is provided an electrical circuit arrangement comprising a thermionic valve having its anode-cathode circuit connected to a source of variable voltage, and having between one terminal of the said source and the cathode means for applying to the cathode such a fraction of the variable component of the said voltage that the performance of the valve circuit is unaffected by the variation of the said voltage.

According to another aspect, the invention provides an electrical circuit arrangement comprising a thermionic valve having its anode-cathode circuit connected to a source of variable voltage, two impedances connected in series to the terminals of the source and means for connecting the cathode of the valve to the junction point of the said impedances, the ratio of the impedances being so chosen that the performance of the valve circuit is independent of the variation of the said voltage.

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The invention will be explained with reference to the accompanying drawings in which—

Fig. 1 shows a schematic circuit diagram of a thermionic valve and associated elements to explain the principles of the invention;

Fig. 2 shows in general form the preferred method of applying the principles of the invention;

Fig. 3 shows a schematic circuit diagram of a valve stage according to the invention including auxiliary biassing means for the control grid of the valve;

Fig. 4 shows valve characteristic curves;

Fig. 5 shows details of the circuits of Figs. 2 and 3; and

Fig. 6 shows a multi-stage amplifier, Fig. 7 an oscillator, and Fig. 8 a valve voltmeter all equipped according to the invention.

In Fig. 1 is shown in its simplest form a single valve stage of some electrical circuit device such as an amplifier. The anode of the valve V (which may be of any type) is supplied from the positive terminal HT+ of the anode supply source through an impedance Z_a which may, for example, be a parallel tuned circuit. The cathode is connected to the negative terminal HT— of the source (which is usually earthed as shown) through an impedance Z_c, which may, for example, be a simple resistance used for biasing the cathode and/or providing negative feedback. The control grid is connected to earth through a grid impedance Z_g (very commonly a high resistance), signals are applied to the control grid at terminal 1, and the amplified or otherwise treated signals are obtained from the anode at terminal 2.

The voltage of the anode supply source is supposed to be variable and this is indicated in Fig. 1 by the electromotive force E_a shown as a battery in series with the HT+ terminal, and intended to represent a voltage variation. If μ is the amplification factor of the valve, then it is well known that the electromotive force E_a in the anode circuit is equivalent to an electromotive force E_a/μ applied in the control grid circuit. If therefore an electromotive force $-E_a/\mu$ is effectively applied to the control grid for all values of E_a, the change in anode current produced by the variation E_a will be exactly counterbalanced by the change caused by the voltage applied to the grid, so that the anode current will be rendered independent of the variations of the anode supply source, and the performance of the valve will be substantially unaffected.

Fig. 2 shows how this requirement may be carried out according to the invention. An imped-

ance Y_c is connected in series with the cathode impedance Z_c as shown, and the junction point of Y_c and Z_c is connected through another impedance Y_a to the terminal HT+. The impedances Y_a and Y_c are then chosen so that

$$\frac{Y_a+Y_c}{Y_c}=\mu$$

or $Y_a/Y_c=\mu-1$. Under these conditions a varying electromotive force of $+E_a/\mu$ will be effectively applied to the cathode, and this is equivalent to applying $-E_a/\mu$ to the control grid, which is the condition desired to neutralize the effect of E_a in the anode circuit.

Although in Figs. 1 and 2 E_a has been represented as a battery, it is evident that it can have any value and either sign.

The impedances Y_a and Y_c can take any desired form, depending on the conditions which have to be met. In the simplest case they will both be pure resistances.

It will be understood that the total voltage applied to the cathode by the impedance Y_c will be $+E/\mu$, where E is the voltage of the anode supply source. This will in many cases effectively apply a negative bias to the control grid which is much too great; accordingly any suitable means may be provided to apply an independent counteracting positive bias of appropriate constant value to the control grid. One preferred way in which this may be done will be explained in connection with Fig. 3.

The method of suppressing the effect of the variations of the anode supply voltage which has been described requires that the amplification factor μ should remain substantially constant. This is generally the case over a considerable range for thermionic valves operated on the straight part of the characteristic curve. Fig. 4 shows, for example, characteristic curves for a typical valve, giving the relation between the anode voltage and anode current for several equally spaced values of the grid voltage. If such a valve is operated with an anode current of 0.9 milliamp, for example, all the characteristic curves are nearly straight at this level and the tangents are all parallel. The curves are also substantially equally spaced and it will be seen therefore that anywhere in the range, for example, of 200 to 300 volts a reduction of anode current produced by a given change in anode voltage can be made up by a proportional change in the grid voltage.

Fig. 3 shows a practical example of an amplifying stage neutralized for variations of the anode voltage according to the invention. The valve V is shown as a pentode, the screen grid of which is polarized from the anode source through a resistance R_3. An arrangement for supplying positive bias for the control grid is provided by a neon tube N (or other type of gas discharge tube) connected in series with a resistance R_4 across the anode supply source. A potential divider comprising resistances R_1 and R_2 is shunted across the neon tube N and the grid resistance Z_g is connected to the junction point of R_1 and R_2. A blocking condenser C_1 is included between the input terminal i and the control grid. The remaining elements are as shown in Fig. 2. The neon tube N provides a substantially constant voltage across the potential divider, which voltage is practically independent of the variations of the voltage of the source. The resistances R_1 and R_2 are chosen so that the grid is biassed appropriately with respect to the cathode of the valve. Since neon tubes are sometimes subject to slight fluctuations, which are superposed on the previously mentioned constant voltage, it is preferable to shunt the resistance R_2 with a large condenser C_g for suppressing these fluctuations.

In Fig. 3 the impedance Z_c has been omitted as its function of biassing the cathode is carried out by Y_c. As already stated Y_c and Y_a can be pure resistances; but in that case considerable negative feedback may be produced by Y_c. If this feedback is not required, Y_c may consist of a resistance R_c shunted by a by-pass condenser C_c, in which case, Y_a will consist of a resistance $R_a=(\mu-1)R_c$ shunted by a condenser

$$C_a=C_c/(\mu-1)$$

as indicated in Fig. 5. This arangement will completely neutralize the HT voltage variations. If, however, the supply voltage is sufficiently constant, but has an alternating hum voltage superposed, the resistance R_a may be omitted. By choosing the condenser C_c sufficiently large, the impedance Y_c at the hum frequency may be made substantially that of the condenser, so that the resistance R_c can be neglected. This enables R_c to be chosen to provide an appropriate bias for the cathode (making unnecessary any additional counteracting bias for the grid) and the hum is suppressed by the action of the condensers C_c and C_a.

Furthermore, if the anode supply source has no hum but if its variations are rather slow, then the condenser C_a in Fig. 5 can be omitted. The resistances R_a and R_c will neutralize the variations, and the condenser C_c can be used as a by-pass condenser to prevent the introduction of feedback and provided its capacity is not too large, it will not affect appreciably the action of R_a and R_c in suppressing the slow variations.

When the valve V is a pentode operated in the usual way, the anode current will be practically independent of the anode voltage variations, but will depend instead chiefly on the variations of the screen voltage which is commonly derived from the anode current source. The invention is still applicable, however, provided that the value of μ employed is that which applies to the cathode, control grid and screen grid considered as a triode.

In a particular example of Fig. 3, the elements employed were as follows:

Valve V.—Pentode μ=about 68, total cathode current about 13 milliamps with anode voltage=250 volts.

Neon tube N.—Small tube stabilizing at 70 volts and taking a current of about ¼ milliamp.

R_1=90,000 ohms	R_4=250,000 ohms
R_2=50.000 ohms	R_c=2,000 ohms
R_3=5,000 ohms	R_a=135,000 ohms
C_c=2 microfarads	C_a=0.03 microfarad

The normal anode voltage is 250 volts. The current drawn by the resistance R_a is about 1.8 m. a., or about 14% of the load taken by the valve, and the current drawn by the resistance R_4 is about 0.7 m. a. or about 5% of the load. Thus the total load current drawn by the stabilizing arrangement is less than 20% of the normal load current.

In circuits involving several valve stages supplied from the same anode current source, it is usually necessary to provide decoupling arrangements for preventing interaction between the various stages resulting from the impedance of the source. The reason for the interaction is

that the anode current variations produced by the signals passing through any stage cause corresponding potential variations in the impedance of the source, which potential variations are applied to the other stages. The decoupling arrangements are in effect filtering or smoothing arrangements for preventing the communication of these variations between the source and the stages.

It will be evident that these potential variations are of exactly the same nature as those represented by the battery E_a in Figures 1 and 2. Thus the use of the impedances Y_a and Y_c, proportioned in the manner explained, can take the place of the usual decoupling arrangements (or can at least supplement them so that they can be simplified), while at the same time suppressing the anode voltage variations due to other causes.

In a multi-stage amplifier, each stage may be provided with neutralizing arrangements in the manner shown in Fig. 3, but a single neon tube circuit may be used to provide the counteracting positive grid bias for all the stages. An example of an arrangement of this kind is shown in Fig. 6.

This is a selective amplifier having three stages similar to Fig. 3 and corresponding elements are similarly designated. The neon tube N supplies the counteracting bias for all the control grids. The anode circuit impedances Z_a are shown as parallel tuned circuits. As all the valves are supposed to be similar, the control grids can all be connected to the same point of the potential divider, shunted across the neon tube N. However, the valves could be of different types, in which case the grid resistances could be connected to different points on the same potential divider; and the impedances Y_a and Y_c used for the various stages would not necessarily be the same for all.

In this amplifier the impedances Y_a and Y_c may, for example, take the form shown in Fig. 5, or any other form appropriate to the conditions.

Fig. 7 shows a simple oscillator circuit stabilized according to the invention. The anode of the valve V is connected to the current supply source through the tuned primary winding of a transformer T, the secondary winding of which is connected to the control grid. The stabilizing impedances Y_a and Y_c may consist of parallel resistance and condenser combinations as previously shown, or may take any other suitable forms.

The effect of a variable anode supply source on the performance of an oscillator may be rather less simple than in the case of an amplifier. If, for example, the supply source has only a superposed hum, then for the purpose of eliminating the hum the valve can be practically considered as acting like a simple amplifier and the impedances Y_a and Y_c can be proportional according to the value of μ as already explained. But if the voltage of the supply source varies irregularly, the effect on the frequency and output of the oscillator may be determined by other factors besides μ; and in such a case the proper values of Y_a and Y_c cannot easily be determined beforehand, and they will therefore be best found by trial in this case. In this circuit, the grid may be automatically biassed by the grid leak Z_g and condenser C_1. No counteracting positive bias for the grid in the manner shown in Fig. 3 may then be necessary so long as the bias introduced by the cathode resistance R_c is not so great as to prevent the oscillations from starting.

Fig. 8 shows a valve voltmeter circuit to which the principles of the invention are applied. The measuring circuit comprises a Wheatstone bridge of which the upper arms include respectively a resistance R_5 and a neon tube N_1 (or other like device), and the lower arms comprise respectively the anode-cathode impedance of the valve V and another resistance R_6. The anode voltage supply is connected at the terminals HT+ and HT−, to one pair of diagonal points of the bridge, and a direct current indicating instrument M connects the remaining diagonal points of the bridge.

An alternating voltage to be measured is connected to terminal I and is applied through the blocking condenser C_1 to a rectifying diode D to produce a unidirectional voltage across the load resistance R_7, which voltage is smoothed by the resistance R_8 and condenser C_2 and applied to the control grid of the valve V. A second neon or similar gas discharge tube N_2 is connected across the anode voltage supply source in series with a resistance R_4 and provides, by means of the potential divider R_1 and R_2 shunted across it, an adjustable positive bias for the control grid. The condenser C_3 is a bypass condenser. It also serves the purpose of the condenser C_g shown in Figs. 3 and 6.

A resistance R_3 is introduced according to common practice for providing an appropriate voltage for the screen grid of the valve V. If a triode valve were used, R_3 would, of course, not be necessary.

The neon tube N_1 provides a substantially constant voltage, and the resistance R_5 will be adjusted so that when no alternating voltage is applied the bridge is balanced so that the meter M reads zero. This will occur when the anode current potential drop in the resistance R_5 is equal to the constant voltage produced by the neon tube N_1. If, however, the anode supply voltage varies, the current flowing through the resistance R_5 will in general be changed so that the bridge is no longer balanced. The balance may, however, be maintained according to the invention in the manner already explained, by connecting a resistance R_c in series with the cathode and a resistance $R_a=(\mu-1)R_c$ between the cathode and the terminal HT+. Since the bridge circuit is substantially a direct current arrangement, nothing would be gained by shunting the resistances R_a and R_c by condensers.

As explained in connection with previous figures, the cathode resistance R_c over-biasses negatively the control grid, and the adjustable positive bias provided by the neon tube N_2 is therefore required. It is to be noted also that the diode D produces an additional negative grid bias owing to the current which flows through R_7 even when no alternating voltage is applied to terminal I.

The cathode resistance R_c also provides negative feedback which stabilizes the calibration of the arrangement.

In a practical case of the circuit of Fig. 8, the elements used were as follows:

Valve V
Neon tubes N_1 and N_2 } as before specified
Meter M

$R_1+R_2=0.7$ megohm	$R_7=10$ megohms
$R_3=20{,}000$ ohms	$R_8=2$ megohms
$R_4=300{,}000$ ohms	$R_c=1{,}000$ ohms
$R_5=26{,}000$ ohms	$R_a=67{,}000$ ohms
$R_6=250{,}000$ ohms	

With this arrangement, a full scale deflection

(200 microamperes) of the meter M was produced when 0.45 volt alternating voltage was applied to terminal 1. It was found that the anode supply voltage could be changed from 220 to 300 volts without any detectable change in the zero setting or in the calibration of the valve voltmeter.

The various different examples of valve circuits which have been given show that the invention is applicable over a wide range of arrangements employing valves, and do not exhaust all the possibilities. It will be appreciated that the invention requires only the addition of resistances and/or condensers which are cheap components not requiring any source of power. Where a neon tube is required for providing the counteracting bias, a very small and cheap tube of the kind commonly used in television apparatus is satisfactory and this does not require any additional source of power for its operation, and only increases the load on the existing operating source by a negligible amount.

What is claimed is:

1. An electrical circuit including a thermionic valve, said valve including an anode, a cathode, and a grid, a source of variable voltage, two impedances connected in series with one another to the terminals of said source, and means connecting the cathode of said valve to the common junction point of said impedances, and connections from said anode and said grid, respectively, to opposite ends of said impedances, the ratio of the electrical values of said impedances being so chosen that the performance of the valve circuit is independent of the variation of said voltage, a gas discharge tube connected across said source, and a potentiometer shunted across said tube with a tap connected to said grid to supply a steady bias to the grid from said source of variable voltage.

2. A circuit according to claim 1, in which said ratio is chosen to be substantially equal to $1/(\mu-1)$, where μ is the amplification factor of the valve.

3. A circuit according to claim 1, in which each of said impedances is substantially wholly resistive in character.

4. Circuit according to claim 1 in which each of said impedances comprises a resistance and capacity connected in shunt with one another.

5. An electrical circuit including a thermionic valve, with an anode, a cathode, and a grid, means for connecting the anode-cathode circuit of said valve to a source of variable voltage, two impedances connected in series with one another to the terminals of said source, and means connecting the cathode of said valve to the common junction point of said impedances, and connections from the opposite ends of the impedances to the grid and anode the first impedance comprising a parallel connected resistance and a first condenser having, at the frequency of variation of said voltage, an impedance small compared with that of said resistance and the second impedance comprising only a second condenser, and in which the capacity of said first condenser is substantially equal to $(\mu-1)$ times that of said second condenser, where μ is the amplification factor of the valve and means for applying to said grid adjustable positive bias derived from the said source, said bias being made substantially independent of the variations of said source.

6. Electrical circuit according to claim 5, also including a gas-filled discharge tube supplied with current from said source of variable voltage, a voltage divider connected across said discharge tube, and means for deriving from said divider a positive bias for said valve, whereby the voltage of said positive bias remains substantially unaffected by the voltage variations of said source.

7. An electrical signal amplifier including at least two thermionic valve stages, each stage comprising a circuit according to claim 1, and including a common anode current source of variable voltage, whereby interstage feedback is substantially eliminated by the action of said means connected between said source and said cathode of each valve.

8. An electrical signal amplifier including at least two thermionic valve stages, each stage comprising a circuit according to claim 1, and including a common anode current source of variable voltage, whereby interstage feedback is substantially eliminated, and also including adjustable positive grid biassing means common to all the stages, said biassing means comprising a gas-filled discharge tube supplied with current from said source, said current remaining substantially constant due to gas discharge characteristics, a voltage divider connected across said gas discharge tube, and a tapped connection from said voltage divider to the grids of said valves.

9. A thermionic valve circuit according to claim 1, also including a bridge output circuit, means for connecting said anode and cathode of said valve in series with one arm of said bridge, means for connecting one pair of diagonal points of said bridge to said source, an indicator, and means for connecting the other pair of diagonal points to said indicator.

10. Thermionic valve circuit including a thermionic valve, means for connecting the anode-cathode circuit thereof to a source of variable voltage, and means connected between one terminal of said source and said cathode for applying to said cathode such a fraction of the variable component of said voltage that the performance of the valve circuit is unaffected by the variation of said voltage, also including a bridge output circuit, means for connecting said anode and cathode of said valve in series with one arm of said bridge, means for connecting one pair of diagonal points of said bridge to said source, an indicator, and means for connecting the other pair of diagonal points to said indicator, another arm of said bridge comprising a gas discharge tube, whereby the potential across said last-mentioned arm is kept substantially constant and independent of said variable component of said voltage source.

11. A valve voltmeter according to claim 10 for measuring an alternating voltage, also including means for deriving a rectified voltage from said alternating voltage and means for applying said rectified voltage to the control grid of said valve.

12. Thermionic valve voltmeter including a thermionic valve, means for connecting the anode-cathode circuit thereof to a source of variable voltage, and means connected between one terminal of said source and said cathode for applying to said cathode such a fraction of the variable component of said voltage that the performance of the valve circuit is unaffected by the variation of said voltage, also including a bridge output circuit, means for connecting said

anode and cathode of said valve in series with one arm of said bridge, means for connecting one pair of diagonal points of said bridge to said source, an indicator and means for connecting the other pair of diagonal points to said indicator, another arm of said bridge comprising a gas discharge tube, and also including grid biassing means including a gas-filled discharge tube supplied with current from said anode current source, whereby the grid bias is kept substantially independent of said variable component of said anode current source.

13. Electrical circuit according to claim 1, also including feedback means whereby said circuit functions as an oscillator.

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