The invention herein described and claimed relates to an improved electronic alternating current supply having high internal impedance. It will be understood, of course, that a high-impedance power supply is one whose impedance is high relative to that of the load impedance.

As is known, high-impedance power supplies may be employed to advantage where it is desired to maintain the amplitude of the alternating load current substantially constant irrespective of variations in the load impedance. High-impedance power supplies may also be advantageously employed where it is desired that, in response to a varying control voltage, the load current varies linearly despite the fact that the load may be inherently non-linear.

The A-C impedance of a power supply may, of course, be increased by the addition of a series resistor of high value. The insertion of a series resistor has the disadvantage, however, of simultaneously increasing the D-C resistance of the supply, thus making it necessary to provide a higher D-C supply voltage than would otherwise be required to deliver the desired amount of current to the load.

In accordance with the present invention, a high-impedance A-C power supply is provided which requires but relatively low D-C supply voltage to deliver the desired amount of current to the load.

We have knowledge of one prior art circuit capable of functioning as such a high-impedance power supply without requiring a high supply voltage. Such a circuit is shown and described in the text book "Vacuum Tube Amplifiers" edited by George E. Valley, Jr. and Henry Wallman, and published in 1948 by McGraw-Hill Book Company, Inc. as volume 18 of the Radiation Laboratory Series. On pages 432-484 of that book there is described and illustrated (Figure 11.16) a constant-current device functioning as a pentode load resistor.

The present invention constitutes an improvement over the prior art circuit shown and described in the above textbook; and to facilitate an understanding of the present invention, a brief description of that prior art circuit will first be given.

In the prior art circuit referred to above, a pentode is shown having a cathode-loaded triode connected between the source of direct-current plate voltage and the anode of the pentode. The cathode-loaded triode is biased positively by a battery connected between the grid of the triode and the pentode-anode end of the cathode load resistor.

As will be readily understood by those skilled in the art, the positively biased cathode-loaded triode has a very high impedance to alternating current but a relatively low impedance to direct current. It will be seen then that, if the output load impedance of the pentode be connected between the pentode-anode and ground, the impedance of the power supply will comprise the high impedance of the pentode in parallel with the high alternating-current impedance of the cathode-loaded triode. Thus, while the A-C impedance of the power supply will be high, a relatively low value of D-C plate voltage will be sufficient to deliver a relatively high value of current to the load.

The fact that a relatively low value of D-C plate voltage may be employed is advantageous from a cost standpoint, since it is possible to use standard types of low voltage tubes as well as other less expensive circuit elements.

Utilization of the prior art circuit arrangement has, however, been impeded by the necessity of using either a battery or a floating power supply to provide the constant potential difference required to obtain between the grid of the cathode-loaded triode and the pentode-anode end of the cathode load resistor. Neither of these forms of constant potential is satisfactory for certain applications. For example, while a high-impedance power supply may be desirable for use in an airborne radar installation to supply current to the sweep circuits of a cathode-ray display tube, the use of a battery as a source of constant potential may be undesirable because of aging and weight considerations. A floating power supply requires the use of either a battery or a high-voltage power transformer and hence may be likewise objectionable as too bulky and heavy.

The present invention provides novel electronic means for providing a constant potential difference between the grid of the cathode-loaded triode and the pentode-anode end of the cathode load resistor, neither a battery nor a transformer being required.

It is the primary object of the present invention to provide a novel and improved power supply whose A-C impedance is high relative to the load impedance.

A more specific object of this invention is to provide an improved form of low-voltage high-impedance power supply which is less bulky and less weighty and which requires less maintenance than prior art low-voltage high-impedance power supplies.

These and other objects, advantages and fea-
tures of the present invention will become more clearly evident from the following description when considered in connection with the accompanying single figure of drawing showing a preferred form of high-impedance power supply embodying the present invention.

Referring now to the drawing, the preferred embodiment of the improved power supply comprises the elements within the dashed-line rectangle and includes a pentode 10, a triode 11, a triode 12, and a voltage-regulator tube 13. In the preferred embodiment, pentode 10 operates as a triode, its screen grid being connected directly to its anode, and its suppressor grid being connected to its cathode. While these connections reduce the inherently high impedance of the pentode, the tube 10 is re-established as high-impedance device by virtue of the cathode load resistor 14. This arrangement is advantageous in that it permits the effective plate impedance of tube 10 to be controlled, over a wide range, through selection of the value of the cathode load resistor 14. For, as is well understood by those skilled in the art, the effective plate impedance is related to the cathode load impedance in the manner indicated by the equation

$$Z_p = r_p + \mu (s+1) R_k$$

where

$Z_p$ = the effective plate impedance

$r_p$ = the internal plate resistance of the tube

$R_k$ = cathode load impedance, and

$s$ = the amplification factor of the tube.

The anode of tube 10 is connected to a suitable source of plate-supply voltage, $B^+$, by way of the cathode-loaded triode 11, resistor 15 constituting the cathode load.

The grid of triode 11 is, in accordance with the present invention, maintained at a substantially fixed potential with respect to the anode of tube 10 by novel means which include the voltage regulator tube 13 and the cathode-follower tube 12.

The voltage-regulator tube 13 may be a conventional two-electrode gas-filled tube having the well-known property of maintaining a substantially constant voltage across its electrodes despite variations in the amount of current flowing therein. The anode of the voltage-regulator tube 13 is connected directly to the grid of triode 11, and is also connected, by way of resistor 16, to the source of plate-supply voltage, $B^+$. The cathode of the voltage-regulator tube 13 is connected to the cathode of the cathode-follower tube 12. The grid of the cathode-follower tube 12 is connected directly to the anode of tube 10. The plate of cathode-follower tube 12 is connected to a source of plate-supply voltage, $B^+$, whose potential may be lower than that of the previously-mentioned source of plate voltage, $B^+$. Resistor 17 constitutes the cathode load of tube 12.

Since tube 12 is operating as a cathode follower, the positive potential of its cathode follows cophasally any variations which may occur in the potential of the anode of tube 10. And since the voltage across the regulator tube 13 remains substantially constant, the voltage on the grid of tube 11 will also vary cophasally with the voltage on the anode of tube 10, the voltage difference between the grid of tube 11 and the anode of tube 10 therefore remaining substantially constant. Stated another way, the potential of the grid of tube 11 is maintained positive with respect to that of the anode of tube 10 by an amount substantially equal to the voltage drop across the regulator tube 13, the voltage difference between the grid and the cathode of tube 12 being negligible. And the potential of the grid of tube 11, relative to that of the cathode of tube 11, is preferably such as to permit tube 11 to conduct on the linear part of its grid-voltage-plate current characteristic.

By the arrangement described above, the anode of tube 10 is supplied with D-C plate voltage through means offering high impedance to alternating current but low impedance to direct current. The alternating-current impedance of the cathode-loaded tube 11 is given approximately by the same equation as that given above, namely,

$$Z_p = r_p + (s+1) R_k$$

where the values of $Z_p$, $r_p$, $s$ and $R_k$ are those pertaining to the cathode-loaded triode 11. Thus, by suitable choice of $R_k$ and $s$, the A-C impedance of the cathode-loaded triode 11 may be made as large as desired.

It will be seen, then, that if the useful output load 19 be connected between the anode of pentode 10 and ground, the internal impedance of the power supply comprises the high A-C impedance of tube 10 in parallel with the high A-C impedance of the arrangement comprised of tubes 11, 12 and 13 and their associated elements.

The function of the cathode-follower tube 12 will become clear by considering what the effect would be if the voltage regulator tube 13 were to be connected directly between the grid of tube 11 and the anode of tube 10. If that were done, the resistor 16 and the regulator tube 13 would be serially connected in shunt with the cathode-loaded tube 11, and since the A-C impedance of the resistor 16 and regulator tube 13 is relatively low, the impedance of the power supply would be low rather than high. In the arrangement proposed by the present invention, the high A-C input impedance of the cathode-follower tube 12 is effectively in series with the relatively low A-C impedance of the regulator tube 13 and resistor 16, thus providing a high A-C impedance in shunt with the cathode-loaded tube 11.

The provision of the cathode-follower tube 12 creates no additional plate-voltage supply problem, since the plate potential, $B^+$, required for the cathode-follower tube 12 may be obtained from the source of plate voltage, $B^+$, by way of a suitable voltage divider.

It will be understood that, in a practical arrangement of this type, provision must be made for exciting, in the power supply, the alternating current signals which it is desired to deliver to the load.

This is preferably accomplished by providing a source of alternating current control signals, which may here be schematically represented by box 18 and which is usually coupled to the control grid of tube 10. The current through load 19 will then vary linearly in response to the variations of the aforesaid control signals and its amplitude will be substantially independent of variations in the load impedance.

Alternatively, the A-C control signals may, of course, be generated within the power supply itself by incorporating tube 10 in a suitable regenerative circuit.

It will be understood that the choice of tube
characteristics, plate voltage, and other circuit parameters will depend upon the specific values of current output, or degree of linearity, which it is desired to obtain. Determination of these parameters is well within the skill of those versed in the art.

By way of example, in a particular case it was desired to supply a total current swing of 2 milliamperes to a slightly non-linear load in response to a 200 volt swing in control voltage. In that case, we employed a triode-connected 6AG5 pentode for tube 10, the two halves of a 2C51 double triode for tubes 11 and 12, and a 5651 voltage-regulator tube for tube 13. The plate-supply voltages B+ and B+ were respectively 15 600 volts and 450 volts positive with respect to ground. Resistor 14 had a value of 100,000 ohms; resistor 15, 70,000 ohms; resistor 16, 86,000 ohms; and resistor 17, 40,000 ohms.

While apparatus constructed according to our invention has been described with reference to a single embodiment it will be understood that alternative arrangements will suggest themselves to those skilled in the art. We, therefore, desire our inventive concept to be limited only by the scope of the appended claims.

We claim:
1. A high-impedance alternative-current power supply comprising a first vacuum tube having at least anode, cathode and control grid electrodes; means for applying a unidirectional plate-supply voltage to the anode of said first tube, said means including a second vacuum tube having at least anode, cathode and control grid electrodes, said cathode of said second tube being connected to said anode of said first tube by way of a resistor; means for maintaining said control grid of said second tube at a predetermined potential with respect to the anode of said first tube, said last-named means comprising a voltage-regulator tube having anode and cathode electrodes and a cathode-follower circuit, said circuit including a tube having at least anode, cathode and control grid electrodes, the anode of said regulator tube being connected to the control grid of said second tube, and to the anode of said second tube by way of a resistor, the cathode of said regulator tube being connected to the cathode of said tube in said cathode-follower circuit, and the control grid of said cathode-follower tube being connected to the anode of said first tube; means for applying an alternating-current signal to the control grid of said first tube; and means for taking an output load current from the anode of said first tube.
2. Apparatus according to claim 1 characterized in that said first tube has pentode electrodes, its screen grid being connected to said anode and its suppressor grid being connected to said cathode.
3. In a high impedance alternating-current supply, a first vacuum tube having at least anode, cathode, and control grid electrodes, a second vacuum tube having at least anode, cathode and control grid electrodes, the cathode of said first tube being connected to the anode of said second tube via a resistor; and a cathode follower circuit comprising a third vacuum tube having at least anode, cathode and control grid electrodes and a cathode load resistor connected to said last-named cathode, said last-named grid constituting the input electrode of said cathode follower circuit and being connected to the anode of said second tube and said cathode of said third tube constituting the output electrode of said cathode follower circuit and being connected to the grid of said first tube, thereby to reproduce variations in the anode potential of said second tube co-phasally at said last-named grid.

4. Apparatus according to claim 3 and further including means for maintaining a constant potential difference between said output electrode and the grid of said first tube.

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