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ELECTRON-TUBE STABILIZED AMPLIFYING CIRCUIT

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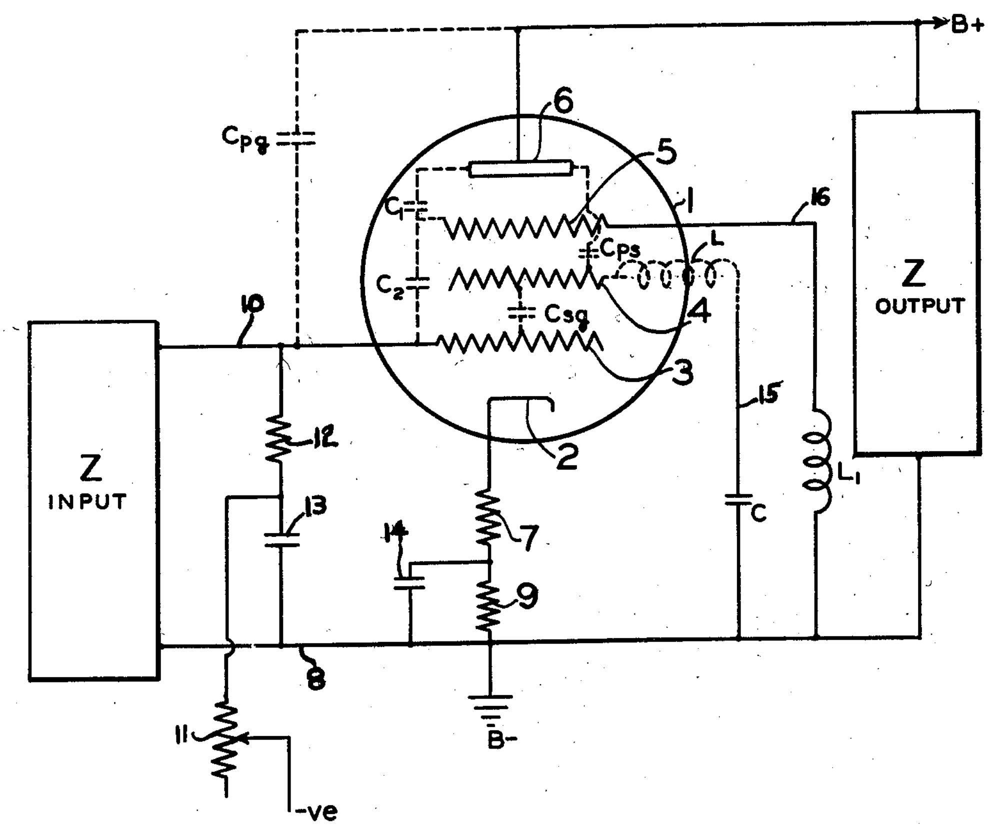

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ELECTRON-TUBE STABILIZED AMPLIFYING CIRCUIT

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6 Claims. (Cl. 179—171)

The present invention relates to electron-tube circuits and, more particularly, to radio-frequency circuits embodying electron tubes having at least five electrodes, such as pentodes.

In many present-day electron- or vacuum-tube radio-frequency amplifier circuits, and particularly in those employing pentodes, deleterious de-tuning and bandwidth-variation effects take place as the gain of the tube is varied. This de-tuning effect is caused by improper neutralization of feedback between the output and input circuits of the pentode, and the bandwidth-variation effect results from a negative-resistance phenomenon attributable to regeneration in the cathode, control-grid electrode and screen-grid electrode portion of the tube as the effect of radio-frequency inductive loading between the screen-grid electrode and the cathode varies with variation in gain of the tube. Various proposals have heretofore been made for attempting to neutralize some of the feedback effects in pentodes and resort has been had to such techniques as utilizing degeneration of an un-by-passed portion of a cathode resistor to compensate, in part, for detuning in the input circuit. No satisfactory proposal, however, has heretofore been advanced for eliminating the detuning effects caused by feedback through both the anode-to-control-grid capacitance and the path defined by both the anode-to-screen-grid capacitance and the screen-grid-to control-grid capacitance, simultaneously with elimination of bandwidth-variation effects resulting from changes in radio-frequency loading in the screen-grid-to-cathode circuit.

An object of the present invention, accordingly, is to provide a new and improved electron-tube circuit that shall not be subject to either of the above-described deleterious effects of de-tuning or bandwidth variation.

A further object is to provide a new and improved pentode electron-tube circuit that simultaneously compensates not only for all feedback effects in radio-frequency pentode amplifiers but also for negative input resistance effects resulting from the triode operation of the cathode, control grid and screen grid portions of the pentodes. In summary, this end is achieved by providing a circuit connection from the screen-grid electrode to ground having negligible radio-frequency reactance, as by resonating out the inductance of the screen-grid electrode itself and the connection to ground through appropriate capacitance; and providing a circuit connection from the suppressor-grid electrode to ground having an impedance of sufficient reactance to shift the phase of the radio-frequency energy fed from the output circuit to the input circuit through the anode-to-suppressor-grid electrode and suppressor-grid electrode-to-control-grid electrode capacitances, substantially one-hundred eighty degrees with respect to the phase of the radio-frequency energy fed from the output to the input through the anode-to-control-grid electrode capacitance.

Other and further objects will be explained hereinafter and will be more particularly pointed out in the appended claims.

The invention will now be described in connection with the accompanying drawing the single figure of which is a schematic circuit diagram illustrating the invention in preferred form.

A conventional pentode electron tube or vacuum tube, as of the beam type, is schematically shown at **1** provided with an electron-emitting cathode electrode **2**, a control-grid electrode **3**, a screen-grid electrode **4**, a suppressor-grid electrode **5** and a plate or anode electrode **6**. A source of anode potential or voltage is applied between the anode **6** and the cathode **2**, the positive or B+ terminal of the voltage source being connected, preferably through a radio-frequency choke, not shown, to the anode **6**, and the negative or B— terminal being connected through cathode-load resistors **7** and **9** to the cathode **2**. The B— terminal may be connected to ground, as shown, if desired. The term "ground," indeed, as utilized in this specification and in the claims, is intended to connote not only actual earthing, but chassis or any other reference potential. In order not to detract from the features of novelty, the well-known details of the voltage sources for the electrodes and other circuit refinements are not illustrated.

Connected between the anode **6** and cathode **2** is an output circut Z_{output}. Similarly, an input circuit Z_{input} may be connected between the B— terminal and the control-grid electrode **3** by conductors **8** and **10**, respectively. The input and output circuits are shown in generalized block-diagram form since the present invention may be utilized with any desired type of radio-frequency circuits, including any well-known type of tuned radio-frequency input and output circuits. As an illustration, the input and output circuits may comprise resonant networks such as shunt or series-connected combinations of inductance and capacitance, not shown. The gain of the pentode stage may be varied by varying the amount of negative bias voltage applied from a source of negative potential $-ve$ through a potentiometer **11** and a fixed resistor **12** to the control-grid electrode **3**. The resistor **12** is shown decoupled to ground by a by-pass condenser **13**. The bias voltage may, of course, be controlled automatically by an automatic gain control circuit, as is well known.

The deleterious feedback effects that, as before mentioned, result in de-tuning, take place through two paths. The first and principal path is provided by the inherent capacitance within the tube envelope **1** between the plate or anode **6** and the control grid **3**, represented by the dotted capacitor C_{pg}. Feedback from the output circuit Z_{output} to the input circuit Z_{input} takes place, also, however, from the plate or anode **6** to the control grid **3** through the inherent anode-to-screen-grid electrode capacitance C_{ps} and the screen-grid electrode-to-control-grid electrode capacitance C_{sg}. It has before been proposed to minimize the feedback along the path C_{ps}, C_{sg} by grounding the screen-grid electrode **4**. Minimizing of the feedback effect along the path C_{pg} has been attempted through elaborate shielding between the grid and plate connections.

Unfortunately, however, at the higher radio frequencies above, say, tens of megacycles, the physical structure of the screen grid **4** in conventional pentodes and the like and of the above-described connection therefrom to ground, even if kept very short, may present a substantial inductive reactance. Neutralization along the path C_{ps}, C_{sg}, by these prior proposals, is thus incomplete at such frequencies in view of the fact that this inductive reactance prevents the screen grid **4** from actually being at ground potential and thus an effective shield between C_{ps} and C_{sg}. More than this, however, the inductive reactance presented at such radio frequencies by the physical structure of the screen grid **4** and the connection thereof to ground produces the earlier-mentioned further deleterious phenomenon of a negative input resistance effect resulting from the operation of the cathode **2**, the control grid **3** and the screen grid **4** as a triode. Despite resort to such de-generation-compensating expedients as by-passing a portion **9** only of the cathode-resistor load **7, 9**, as at **14**, the effect of the inductive reactance between the screen grid **4** and ground with variation in the gain of the tube, results in a change in the radio-frequency loading of the triode portion **2, 3, 4** of the pentode **1**. This loading change will produce a corresponding change in the Q of the input circuit Z_{input} and hence will result in an undesirable variation of the bandwidth of the input circuit.

In accordance with the present invention, the matter of rendering the feed-back path C_{ps}, C_{sg} ineffective and of obviating the bandwidth-variation effect in the triode operation of the portion **2, 3, 4** of the pentode, is accomplished in the following way. Though it is not possible to ground the physical center of the screen grid **4** directly, since the grid is within the envelope **1**, this result is effectively achieved electrically by resonating the inherent inductance L of the structure of the screen grid **4** and the inductance of the physical connection **15** to ground from the terminal of the tube socket, not shown, in which the tube **1** is mounted, with appropriate series-connected capacitance C. This resonance at the desired radio frequency places the screen grid **4** at radio-frequency ground and effectively shields the capacitance C_{ps} from the capacitance C_{sg}, thereby preventing feedback energy from passing therebetween. In addition, however, this resonance has caused the impedance between the screen grid **4** and ground to change from a reactance, the effect of which caused a negative input resistance, into substantially a low resistance with negligible reactance. Since there is now negligible impedance between the screen grid **4** and ground, the radio-frequency loading of the triode portion **2, 3, 4** of the pentode **1** will not change with change in gain of the pentode and the undesirable bandwidth-variation effect is simultaneously substantially eliminated, also.

It now remains to vitiate the effects of the feedback path including the capacitance C_{pg}, which may have a very small capacitance value of, for example, 0.02 micromicrofarad. This could theoretically be done by utilizing a large parallel-connected inductor; but, in actual practice, particularly at high frequencies, it is not feasible to construct such a large inductor that will not inherently have distributed capacitance which is even greater than the small-valued capacitance C_{pg}. In accordance with the present invention, therefore, an entirely different technique is employed. A circuit connection **16** is made from the suppressor-grid electrode **5** to ground through an inductance L_1 of sufficient value to produce a predetermined shift in the phase of the radio-frequency energy of the desired frequency fed from the anode **6** through the anode-to-suppressor-grid electrode capacitance C_1 to the suppressor grid **5**. The amount of phase shift required is that which will bring the energy fed from the suppressor grid **5** to the control grid **3** through the suppressor-grid electrode-to-control-grid electrode capacitance C_2 in substantially phase opposition to (i. e. substantially one-hundred eighty degrees out of phase with) the energy coupled back from the output to the input through the interelectrode capacitance C_{pg}. The one-hundred eighty degree out-of- phase voltage at the suppressor grid **5** will cause a current to flow through the suppressor grid-to-control grid capacitance C_2 to the control grid **3** which is substantially equal and opposite to the current flowing from the anode **6** to the control grid **3** through capacitance C_{pg}. The result is that substantially zero net feedback current flows from the output to the input circuit. To achieve such a phase shift, the reactance of the inductance L_1 at the desired high frequency will be made smaller than the reactance of either of the interelectrode capacitances C_1 or C_2.

As an illustration, the above results can be achieved with a 6CB6-type pentode operating with input and output circuits tuned in the neighborhood of about 200 megacycles with an inductance L_1 formed of about a one-inch loop of number twenty-four wire. The screen-grid resonating capacitance C may have a value of about 39 micromicrofarads and the length of the conductor-lead **15** may be about one-eighth of an inch.

At much lower frequencies, the reactance of the screen grid **4** and its connection **15** to ground may be sufficiently negligible that a direct short connection **15** may suffice without the necessity for the resonating capacity C. While the plate-to-control grid feedback will then not be reduced to so low a value as can be attained with the resonating capacity C, the results may, in some instances, be adequate. It is also to be understood that external neutralizing elements could be employed to replace the interelectrode capacitances and the suppressor-to-ground inductance, but since such external elements would increase the tube input and output capacitance and thus reduce the gain, this is not a preferred construction.

Further modifications will occur to those skilled in the art and all such are considered to fall within the spirit and scope of the invention as defined in the appended claims.

What is claimed is:

1. In an electron-tube circuit for operation at a predetermined radio frequency having at least five electrodes, namely, an anode, a grounded cathode, a control-grid electrode, a screen-grid electrode and a suppressor-grid electrode, and radio-frequency input and output circuits connected from the cathode to the control-grid electrode and to the anode, respectively; the combination of a circuit connection from the screen-grid electrode to ground having negligible impedance at the said predetermined radio frequency, and a circuit connection from the suppressor-grid electrode to ground having an impedance of sufficient reactance at the said predetermined radio frequency to shift the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-suppressor-grid electrode capacitance and the suppressor-grid electrode-to-control-grid electrode capacitance substantially one hundred eighty degrees with respect to the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-control-grid electrode capacitance.

2. In an electron-tube circuit for operation at a predetermined radio frequency having at least five electrodes, namely, an anode, a grounded cathode, a control-grid electrode, a screen-grid electrode and a suppressor-grid electrode, and radio-frequency input and output circuits connected from the cathode to the control-grid electrode and to the anode, respectively; the combination of means for shielding the anode-to-screen-grid electrode capacitance from the screen-grid electrode-to-control-grid electrode capacitance, means for presenting a negligible impedance at the said predetermined radio frequency between the screen-grid electrode and ground, and a circuit connection from the suppressor-grid electrode to ground having an impedance of sufficient reactance at the said predetermined radio frequency to shift the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-suppressor-grid electrode capacitance and the suppressor-grid electrode-to-control-grid electrode capacitance substantially one hundred eighty degrees with respect to the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-control-grid electrode capacitance.

3. In an electron-tube circuit for operation at a predetermined radio frequency having at least five electrodes, namely, an anode, a grounded cathode, a control-grid electrode, a screen-grid electrode and a suppressor-grid

electrode, and radio-frequency input and output circuits connected from the cathode to the control-grid electrode and to the anode, resspectively; the combination of a circuit connection from the screen-grid electrode to ground provided with capacitance of sufficient value to resonate at the said predetermined radio frequency with the inductance in the said circuit connection, including the inductance of the screen-grid electrode itself, in order not only to ground the screen-grid electrode but to do so through a circuit of negligible impedance at the said predetermined radio frequency, and a circuit connection from the suppressor-grid electrode to ground provided with inductance of sufficient value to shift the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-suppressor-grid electrode capacitance and the suppressor-grid electrode-to-control-grid electrode capacitance substantially one hundred eighty degrees with respect to the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-control-grid electrode capacitance.

4. In an electron-tube circuit for operation at a predetermined radio frequency having at least five electrodes, namely, an anode, a grounded cathode, a control-grid electrode, a screen-grid electrode and a suppressor-grid electrode, and radio-frequency input and output circuits connected from the cathode to the control-grid electrode and to the anode, respectively; the combination of a circuit connection from the screen-grid electrode to ground having negligible impedance at the said predetermined radio frequency, and a circuit connection from the suppressor-grid electrode to ground provided with inductance of reactance at the said predetermined radio frequency less than the reactance of the anode-to-suppressor-grid electrode capacitance and of the suppressor-grid electrode-to-control-grid electrode capacitance but sufficient to shift the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-suppressor-grid electrode capacitance and the suppressor-grid electrode-to-control-grid electrode capacitance substantially one hundred eighty degrees with respect to the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-control-grid electrode capacitance.

5. In an electron-tube circuit for operation at a predetermined radio frequency having at least five electrodes, namely, an anode, a cathode, a control-grid electrode, a screen-grid electrode and a suppressor-grid electrode, and radio-frequency input and output circuits connected

from the cathode to the control-grid electrode and to the anode, respectively; the combination of a circuit connection from the screen-grid electrode to ground having negligible impedance at the said predetermined radio frequency, a circuit connection from the suppressor-grid electrode to ground having an impedance of sufficient reactance at the said predetermined radio frequency to shift the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-suppressor-grid electrode capacitance and the suppressor-grid electrode-to-control-grid electrode capacitance substantially one hundred eighty degrees with respect to the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-control-grid electrode capacitance, and a cathode load connected between the cathode and ground and part only of which is by-passed to ground.

6. In an electron-tube circuit for operation at a predetermined radio frequency having at least five electrodes, namely, an anode, a cathode, a control grid electrode, a screen-grid electrode and a suppressor-grid electrode, and radio-frequency input and output circuits connected from the cathode to the control-grid electrode and to the anode, respectively; the combination of a circuit connection from the screen-grid electrode to ground having negligible impedance at the said predetermined radio frequency, a circuit connection from the suppressor-grid electrode to ground provided with inductance of reactance at the said predetermined radio frequency less than the reactance of the anode-to-suppressor-grid electrode capacitance and of the suppressor-grid electrode-to-control-grid electrode capacitance but sufficient to shift the phase of the radio frequency energy fed from the said output circuit to the said input circuit through the anode-to-suppressor-grid electrode capacitance and the suppressor-grid electrode-to-control-grid electrode capacitance substantially one hundred eighty degrees with respect to the phase of the radio-frequency energy fed from the said output circuit to the said input circuit through the anode-to-control-grid electrode capacitance, and a cathode load connected between the cathode and ground and part only of which is by-passed to ground.

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