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SPACE DISCHARGE AMPLIFIER CIRCUIT

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FIG. 1

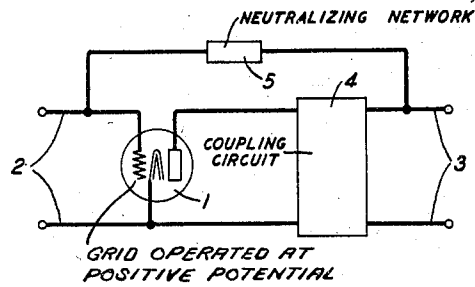


FIG. 2

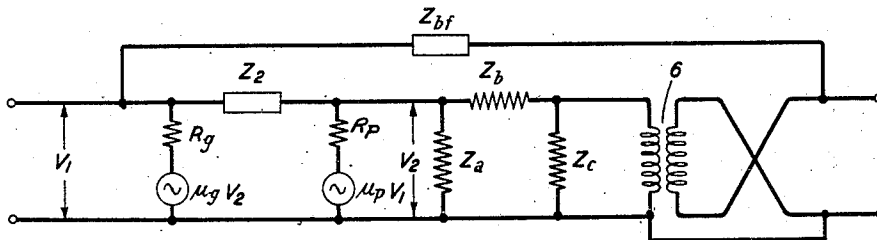
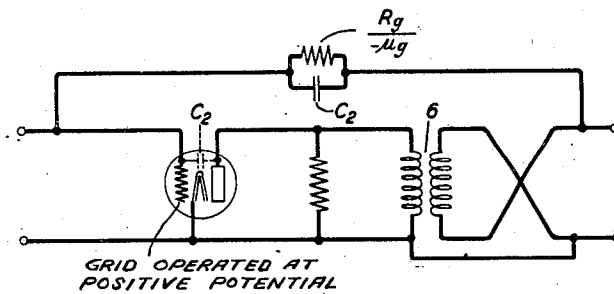


FIG. 3



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SPACE DISCHARGE AMPLIFIER CIRCUIT

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6 Claims. (Cl. 179-171)

The present invention relates to the neutralization of the inherent grid-to-plate coupling of a space discharge tube and more particularly to the case in which the tube is operated with the grid at positive potential so that the grid draws current.

The invention comprises, in a preferred form, a neutralized tube circuit in which the neutralizing impedance or network is designed to take account of the entire interelectrode coupling including that due to the effect of the grid current.

The general object of the invention is to secure a more complete neutralization of the interelectrode coupling of a tube by including compensation for the component of the coupling that is caused by the fact of grid current flow.

In a tube in which there is grid current flow there are in effect two transconductances, both of which are real, one of which is positive and the other negative. The positive transconductance is from grid to plate and represents the useful transmission through the tube. The negative transconductance represents a loss in the useful transmission in that it is in the direction from plate to grid. It occurs when the grid is drawing current, in which case the grid may be thought of as a secondary anode, the current to which is controlled by the plate voltage variations very much as the grid voltage ordinarily controls the plate current of a tube. The sign of the plate-to-grid transconductance of the tube is taken as negative since this transconductance is opposite to the useful transconductance of the tube. This effect may be looked upon as an electron coupling between the grid and plate circuits, due to which there is a loss in useful transmission through the tube.

In a grid-controlled tube there is also an impedance coupling, usually a capacity coupling, directly between the grid and plate elements and this coupling produces undesirable results particularly at high frequencies. Heretofore, circuits have been devised for neutralizing this capacity coupling but so far as applicant is aware, no provision has been made for counteracting the electron coupling due to the positive grid effect.

In accordance with the present invention a neutralizing network is provided which compensates for the undesired effect upon useful transmission or loss in effective transconductance of the circuit due to both of these couplings.

The invention will be more fully understood from the following detailed description of a specific form as illustrated in the drawing, in which:

Fig. 1 is a schematic diagram of the basic tube

network presenting a problem of design to be solved;

Fig. 2 is the equivalent impedance diagram from which the formula of design is derived; and

Fig. 3 is a schematic diagram of a specific circuit embodying the invention.

In Fig. 1 a three-electrode vacuum tube is conventionally represented at 1, with its input terminals at 2 and its terminals for connecting to an external load circuit at 3. Between the output terminals of the tube itself, that is, between the plate and cathode terminals and the load terminals 3, there is included a coupling circuit 4 which may be the usual output transformer or some other suitable coupling element or network. The circuit 4 is intended to be represented as perfectly general and may include additional elements such as a filter or other type of impedance. Neutralizing network 5 is shown as connected from the output side of coupling circuit 4 back to the grid. The problem is, therefore, to discover what must be provided in the network 5 in order to neutralize the circuit on the assumption that the grid of tube 1 is operated at positive potential so that there is grid current flow.

Fig. 2 shows the circuit of Fig. 1 redrawn in the form of a diagram of equivalent impedances. The grid current is pictured as resulting from the action of a fictitious generator of voltage $\mu_g V_2$ connected in series with a resistance R_g representing the internal grid-to-cathode resistance, V_2 being the voltage developed across the plate-to-cathode terminals as a result of application of a voltage V_1 at the input terminals. Similarly, there is a fictitious plate generator $\mu_p V_1$ acting in series with the internal plate resistance R_p to produce the flow of the plate current. The internal grid-to-plate coupling impedance is represented at Z_2 and would ordinarily be a capacity.

This circuit has two transconductances, one from grid to plate and the other from plate to grid.

The former is given as

$$\frac{\mu_p}{R_p} = \frac{\text{Amplification factor, grid to plate}}{\text{Internal plate resistance}}$$

in which μ_p and R_p are both real and positive.

The other transconductance is given by

$$\frac{\mu_g}{R_g} = \frac{\text{Amplification factor, plate to grid}}{\text{Internal grid resistance}}$$

in which μ_g and R_g are both real but μ_g is negative so that $\frac{\mu_g}{R_g}$ is negative.

The coupling circuit is represented as a π network consisting of shunt arms Z_a and Z_c and series arm Z_b with a phase reversing transformer 6, the impedances of which are included in the coupling network, this transformer being drawn out merely to show that a reversal of phase is effected at this point. The neutralizing network is shown as Z_{bf} .

Fig. 2 gives an impedance diagram of passive impedances to which Kirchoff's laws can be applied by writing down the mesh equations and solving for Z_{bf} in terms of the given impedances. The solution while straightforward is quite long and laborious and it is not deemed necessary to follow through the steps for the purposes of this disclosure. The formula turns out to be (referring to Fig. 2):

$$Z_{bf} = \frac{R_g}{R_p} \frac{(R_p + Z_2)Z_b + R_p Z_2 \left(1 + \frac{Z_b}{Z_a}\right)}{R_g - \mu_g Z_2}$$

Where the coupling network is of some other form, for example, a T network or other known type, the necessary conversion of the above formula to fit such a case can be made in known manner, so that this formula is quite general.

If Z_b is zero, the neutralizing network is connected directly between plate and grid through the reversing transformer 6 as represented in Fig. 3. The network impedance is then defined simply as

$$\frac{1}{Z_{bf}} = \frac{1}{Z_2} - \frac{\mu_g}{R_g}$$

Further, if the coupling impedance Z_2 is the impedance of a capacity C_2 , this formula reduces to

$$\frac{1}{Z_{bf}} = 2\pi f C_2 - \frac{\mu_g}{R_g}$$

which corresponds to the parallel combination, shown in Fig. 3, of a capacity C_2 and resistance. Since μ_g is intrinsically negative, the resistance

$$-\frac{R_g}{\mu_g}$$

is positive.

This network is seen to consist of a resistive element which compensates the electronic component of the grid-to-plate coupling and an element (specifically a capacity) which compensates for the component of the coupling which exists by virtue of the coupling impedance.

The invention is not to be construed as limited to the details given in this specification. Its scope is defined in the claims.

What is claimed is:

1. In combination with a space discharge device having a grid-cathode and an anode-cathode circuit, and having positive transconductance from grid to plate and negative transconductance from plate to grid, coupling impedance from grid to plate which lowers the first-mentioned transconductance, means connected between grid and

plate for compensating the effect of said coupling impedance, and means connected between grid and plate for reducing the plate-to-grid transconductance.

2. In combination, a space discharge device having a cathode, an anode and a discharge control element or grid, means making the grid potential positive with respect to the cathode, whereby the grid draws current, a grid-to-plate coupling impedance, and a network for compensating the loss in transmission caused by both said positive grid voltage and said coupling impedance, said network being connected between said plate and grid and comprising a resistance compensating the effect of said positive grid voltage in parallel with an impedance compensating said coupling impedance.

3. In combination, a space discharge device having a cathode, an anode or plate and a discharge control element or grid, means making the grid positive whereby grid current flows tending to reduce the grid-to-plate transconductance, and a connection from the anode to the grid including a resistance which is a function of the plate-to-grid transconductance for compensating the reduction in grid-to-plate transconductance.

4. In combination, a space discharge device having a cathode, an anode or plate and a discharge control element or grid, means making the grid positive, said tube having inherent grid-to-plate capacity, and a network connected between said anode and grid through a reversing transformer, said network comprising a capacity in parallel with a resistance, for compensating the reduction in transmission through the device caused by said inherent capacity and by said positive grid potential.

5. In combination, a space discharge device having an input circuit including a grid and an output circuit including an anode, means making the grid positive, said device possessing inherent capacity coupling between grid and anode, and a feedback connection from said output to said input circuit including a means for compensating the effect of said inherent capacity and a means for compensating the anode-to-grid transconductance.

6. In combination, a space discharge device having an input circuit and an output circuit and having useful input-to-output transconductance and unwanted output-to-input transconductance, and a feedback connection including a resistance for neutralizing said unwanted transconductance, said resistance being of the order of

$$\frac{R_g}{-\mu_g}$$

where R_g is the internal resistance of the input circuit of said device and μ_g is the output-to-input amplification factor of said device.

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