

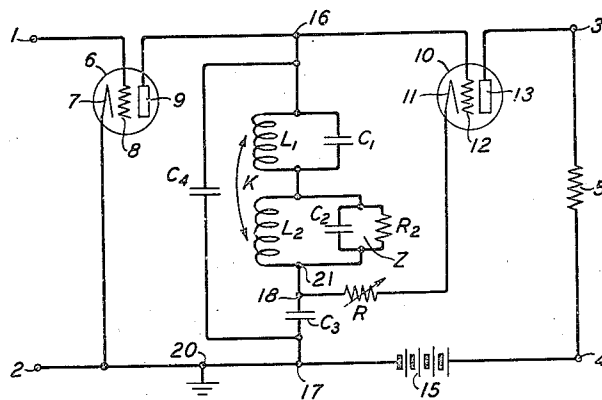
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THERMIONIC TUBE AMPLIFIER

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THERMIONIC TUBE AMPLIFIER

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This invention relates to multistage thermionic tube amplifiers and more particularly to interstage networks for coupling together two stages in such amplifiers.

The principal objects of the invention are to reduce the cost and size of interstage networks and to increase the range of transmission characteristics obtainable.

A multistage thermionic tube amplifier requires one or more interstage networks to couple the output or plate circuit of one tube to the input or grid circuit of the next succeeding tube. The chief function of such networks is to provide the required transmission characteristic for the amplifier. It is also important that the networks be economical as to both cost and space requirements.

The interstage network of the present invention is capable of providing a wide variety of desirable transmission characteristics in a comparatively simple structure which is reasonable in cost and small in size. The network includes two inductively coupled inductors connected in either the series aiding or the series opposing relationship in a shunt impedance branch between the two tubes to be connected. An impedance branch, usually including a capacitor and in some cases a resistor, may be connected in shunt with one or with each of the inductors. Another capacitor may be connected in shunt with both of the inductors. The required capacitance may be partly or wholly furnished by the stray capacitances associated with the component elements and the wiring of the amplifier.

The two coupled inductances may be furnished by two separate inductors. To save cost and space, however, a single tapped winding or two windings on the same core may be used. Furthermore, a change in the coefficient of coupling between the inductors, or in the sense of the connection, effects a change in the values of the component impedance elements constituting the network, and in practice these factors are so chosen that the most advantageous values are secured. This is another important factor in reducing the size and cost. In some cases, by the use of coupled inductors, there may be provided transmission characteristics which are otherwise unattainable. This is due to the fact that the inherent stray admittances associated with the circuit may be successfully incorporated into the interstage network, whereas without using inductive coupling these admittances would be too large for inclusion.

The nature of the invention will be more fully

understood from the following detailed description and by reference to the accompanying drawing the single figure of which is a schematic circuit of a multistage thermionic tube amplifier comprising two stages coupled by an interstage network in accordance with the invention.

The amplifier has a pair of input terminals 1, 2 upon which are impressed the signals to be amplified and a second pair of terminals 3, 4 to which is connected a load impedance 5 which may include the input circuit of a succeeding stage. The amplifier includes a thermionic tube 6 having a cathode 7, a grid 8 and a plate 9 and a second tube 10 having a cathode 11, a grid 12 and a plate 13. The plate voltage, supplied by the battery 15, is impressed on the two tubes in series. It is necessary, of course, that the load 5 have a direct current path for the plate current of the tube 10. The amplifier may be grounded, if desired, as indicated at the point 20.

The tubes 6 and 10 are coupled by an interstage network comprising the shunt impedance branch connected between the point 16, in an electrical path between the plate 9 and the grid 12, and the point 17, in an electrical path between the two cathodes 7 and 11. The network includes the series connected inductors L_1 and L_2 which, in the example shown, are in a path common to the output circuit of the tube 6 and the input circuit of the tube 10. The inductors L_1 and L_2 may, for example, be a single tapped winding or two windings on a single core and they are coupled by a mutual inductance M the value of which may be found from the expression

$$M = K\sqrt{L_1 L_2}$$

where K is the coefficient of the coupling. The inductor L_1 is shunted by a capacitor C_1 and the inductor L_2 is shunted by an impedance branch Z which includes a capacitor C_2 and a resistor R_2 connected in parallel.

The capacitance of the capacitor C_1 may be furnished in whole or in part by the stray capacitance associated with the inductor L_1 , including the wiring, and likewise the capacitance of the capacitor C_2 may be partially or entirely supplied by the stray capacitances associated with the inductor L_2 , the impedance branch Z and the wiring. The capacitor C_3 has a comparatively large capacitance and its function is to block the flow of direct current while freely passing all frequencies within the band of interest. In analyzing the performance of the interstage network it may, therefore, be considered that the points 17 and 18 are common. The capacitance

of the capacitor C_4 includes the stray capacitance of the remainder of the network connected between the points 16 and 17, the capacitance between the high side wiring and the ground point 20, the capacitance between the cathode 7 and the plate 9 of the tube 6, the capacitance between the cathode 11 and the grid 12 of the tube 10 and the capacitance associated with the tube sockets. These last-mentioned capacitances may add up to such a value that no physical capacitor C_4 is required.

The value of the biasing voltage on the grid 12 of the tube 10 is dependent upon the resistive component of the impedance between the points 16 and 18 and upon the size of the resistor R . The resistor R may be made variable, as indicated by the arrow, to allow an adjustment of this voltage. In some cases, if the direct current resistances of the inductors L_1 and L_2 are given the proper values, the resistor R may be omitted. It is also obvious that the resistor R will be just as effective for voltage control if placed in series with the inductors, as, for example, if connected between the points 18 and 21.

The inductors L_1 and L_2 may be connected in either the aiding or the opposing relationship and the coefficient of coupling may have any value up to and including unity. If the series aiding connection is used, as K is increased in value the number of turns of wire required for the inductors is reduced and as a result the size and cost are decreased and better coil constants are secured. Furthermore, the required impedance of the branches shunting the inductors is decreased. On the other hand, if the series opposing connection is employed, the required impedances of the shunt branches are increased. In practice the sense of the connection and the value of K are chosen to provide a network which is the most satisfactory as to cost of component elements and size.

It is to be understood, of course, that the impedance branches shunting the inductors L_1 and L_2 , represented in the figure respectively by C_1 and Z , may have any degree of complexity. The number and type of the component elements in each of the branches, and their disposition, depend only upon the transmission characteristic to be provided by the network. The configurations shown are to be considered only as an illustrative example.

The values of the component elements required for a typical interstage network designed in accordance with the invention will now be presented. The network has the circuit shown in the figure and is capable of providing a substantially flat gain characteristic over the frequency range of 10 to 72 kilocycles when working out of a plate impedance of 250,000 ohms for the tube 6. The values of the elements are as follows:

$L_1 = 1.032$ henries
 $L_2 = 0.1455$ henry
 $C_1 = 2.5$ micro-microfarads
 $C_2 = 380.5$ micro-microfarads
 $C_3 = 50,000$ micro-microfarads
 $C_4 = 30$ micro-microfarads
 $R = 0$
 $R_2 = 12,180$ ohms

The inductors L_1 and L_2 are connected series aiding and the coefficient of coupling K is 0.73. The value given for C_4 is the average over the frequency range of 10 to 72 kilocycles. The sum of the direct current resistance of the inductors is

1100 ohms, which is the proper value to provide the required grid bias for the tube 10 when the battery 15 is 150 volts; and therefore the resistance R may be omitted.

What is claimed is:

1. In a multistage amplifier comprising a plurality of thermionic tubes each having a cathode, a grid and a plate, an interstage network for coupling two of said tubes comprising an electrical path between the plate of one of said two tubes and the grid of the other of said two tubes, a second electrical path between the cathodes of said two tubes and a third electrical path connected between a point in said first-mentioned path and a point in said second path, said third path including two inductively coupled inductors connected in the series opposing relationship and an impedance branch connected in shunt with one of said inductors.

2. In a multistage amplifier comprising a plurality of thermionic tubes each having a cathode, a grid and a plate, an interstage network for coupling two of said tubes comprising an electrical path between the plate of one of said two tubes and the grid of the other of said two tubes, a second electrical path between the cathodes of said two tubes and a third electrical path connected between a point in said first-mentioned path and a point in said second path, said third path including two inductively coupled inductors connected in series, an impedance branch including a capacitance and a resistance connected in shunt with one of said inductors and a second capacitance connected in shunt with the other of said inductors.

3. A network in accordance with claim 2 which includes a third capacitance connected in shunt with both of said inductors.

4. A network in accordance with claim 2 in which said first-mentioned capacitance and said resistance are connected in parallel.

5. In a multistage amplifier comprising a plurality of thermionic tubes each having a cathode, a grid and a plate, an interstage network for coupling two of said tubes comprising an electrical path between the plate of one of said two tubes and the grid of the other of said two tubes, a second electrical path between the cathodes of said two tubes and a third electrical path connected between a point in said first-mentioned path and a point in said second path, said third path including two inductively coupled inductors connected in series, an impedance branch including the parallel combination of a capacitance and a resistance connected in shunt with one of said inductors and a second capacitance connected in shunt with both of said inductors.

6. A network in accordance with claim 2 in which said inductors are connected in the series aiding relationship.

7. A network in accordance with claim 2 in which said inductors are connected in the series opposing relationship.

8. A network in accordance with claim 2 which includes a third capacitance connected in shunt with both of said inductors and in which said inductors are connected in the series aiding relationship.

9. A network in accordance with claim 2 which includes a third capacitance connected in shunt with both of said inductors, and in which said inductors are connected in the series opposing relationship.

10. A network in accordance with claim 5 in

which said inductors are connected in series aiding relationship.

11. A network in accordance with claim 5 in which said inductors are connected in the series opposing relationship.

12. In a multistage amplifier comprising a plurality of thermionic tubes, each having a cathode, a grid and a plate, an interstage network for coupling two of said tubes comprising two inductively coupled inductors connected in series in an electrical path which is common both to

the output circuit between the cathode and the plate of one of said tubes and to the input circuit between the cathode and the grid of other of said tubes, an impedance branch including a capacitance connected in shunt with one of said inductors, a second capacitance connected in shunt with the other of said inductors, a third capacitance connected in shunt with both of said inductors and a resistance connected in said input circuit in series with said inductors.

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