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THERMIONIC VALVE AND OTHER ELECTRIC CIRCUITS

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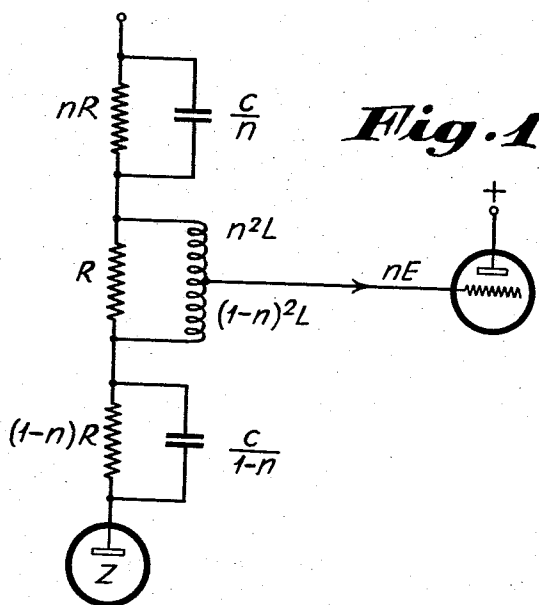
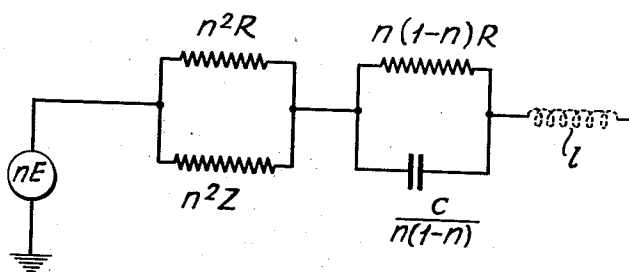


Fig. 2



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THERMIONIC VALVE AND OTHER ELECTRIC CIRCUITS

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5 Claims. (Cl. 178-44)

This invention relates to thermionic valve and other electric circuits.

In many cases it is desired to feed from a source a wide frequency band of electrical signals, generated or handled by the source, to a load which may be constituted by a thermionic valve, a cable, or other device. With such a wide frequency band it is found that if the load has an impedance which substantially varies with frequency then the potentials of the signals applied to the load will also vary with frequency. For example, where the load comprises a thermionic valve, the input capacity of the valve tends at high frequencies to cause the input impedance of the valve to decrease. If the coupling device connecting the source to the load has an impedance which is substantially greater than the valve input impedance at high frequencies then the signals will be attenuated. It is necessary therefore that the coupling device should have a low impedance at high frequencies.

The difficulties outlined arise in practice in various circuits, for example, in coupling the output circuit of one thermionic valve to the input circuit of another thermionic valve, or in coupling a thermionic valve to a cathode ray tube used for generating electrical signals, such as a television transmitting tube constituting the said source. The difficulty also arises when a cable has to be connected to a thermionic amplifier. In the case where the load comprises a cable which is electrically short at low frequencies and is substantially open-circuited at the far end, it is necessary that the cable be fed from an impedance which matches the characteristic impedance of the cable at high frequencies in order to prevent reflection effects which distort the frequency response characteristic though it is not necessary to terminate correctly at low frequencies. Since the terminating impedance for a cable is usually very low, it is difficult with normal circuits to obtain efficient amplification from the valve feeding the cable at high frequencies. Assuming a valve feeding the cable has a certain maximum current variation then a low value of coupling resistance gives too low an output voltage. A transformer provides a solution for high frequencies but cannot be applied over a wide range of frequencies.

It is the object of the present invention to provide an improved coupling arrangement with a view to overcoming these difficulties.

According to the invention a coupling arrangement coupling a source of electrical current variations over a range of frequencies to a load,

wherein in order to present to the load at least at the higher frequencies of said range, a low impedance, which impedance is lower than that which conveniently develops the requisite output potential from the current available at the source, a coupling resistance is provided having a value such as to develop the requisite output potential, said resistance being associated with a transformer which is such as to transform the value of the coupling resistance to the required low value at the higher frequencies of said range, an additional coupling being provided for the lower frequencies of said range not adequately transmitted by said transformer.

In some cases, where the source of electrical variations is not one which has a substantially infinite impedance, such as may be afforded by a screen grid valve, it is desirable for the coupling arrangement to be designed to present a substantially constant impedance to the source over the range of frequencies.

In order that the said invention may be clearly understood and readily carried into effect, it will now be more fully described with reference to the accompanying drawing in which:

Fig. 1 is a diagram illustrating a circuit constructed in accordance with the invention and Fig. 2 is an explanatory diagram.

As shown in Fig. 1 the invention is applied to a resistance coupled amplifier in which Z represents a valve, the anode of which is coupled through the network shown to the control grid of a further thermionic valve which constitutes the load and to which is fed the voltage nE . The network constitutes in effect the coupling resistance, one end of the network being connected to the anode of valve Z whilst the upper end is connected to the positive terminal of a source of anode current not shown. The network comprises three resistances in series indicated respectively by the symbols $(1-n)R$, R , and nR . The resistance $(1-n)R$ is shunted by a condenser

$$\frac{C}{1-n}$$

The resistance R is shunted by a tapped coil, the tapping being connected to the grid of the further valve whilst the resistance nR is shunted by a condenser

$$\frac{C}{n}$$

The coil shunting the resistance R functions as a transformer for the higher frequencies, and in the example shown the two portions of the coil

are coupled as tightly as possible and have inductances n^2L and $(1-n)^2L$, the mutual inductance between them being substantially $n(1-n)L$. The term n represents the step-down ratio of the transformer constituted by the coil and is any number less than one and from the above it will be understood that the values of the various components of the network are given in terms of n . The values of the resistances of the network are such that the voltage output at low frequencies is the same as the voltage which is derived at the tapping point in the coil for the high frequencies, this voltage being of a value nE . In choosing the values of the components the relationship $L=CR^2$ should hold.

In some cases the resistance $(1-n)R$ and the associated shunt condenser

$$\frac{C}{1-n}$$

may be omitted if the impedance Z of the valve is substantially infinite, such as would be the case if the valve were a screen grid valve or a pentode, so that the network need not be a substantially constant resistance.

The effective generator circuit presented to the load is shown in Fig. 2 in which the generator of open circuit voltage nE (E being the voltage produced on the anode of the valve shown in Fig. 1) is shown in series with a reduced anode load n^2R in parallel with n^2Z and in series with a resistance $n(1-n)R$ in parallel with a condenser

$$\frac{C}{n(1-n)}$$

A further coil L is shown in dotted lines which represents the leakage inductance of the tightly coupled coil in Fig. 1.

It will be appreciated from the above that the impedance at high frequencies is that due only to the resistance n^2R in parallel with the resistance n^2Z of Fig. 2, together with any effects due to the leakage inductance. Owing to the transformer or potentiometer effect of the whole network, a reduction of the open circuit voltage results, such reduction being proportional to the step down ratio of the tightly coupled coil and the resistances shown in Fig. 1, but as the value of the resistance R can be raised considerably for the same output impedance at high frequencies, a higher effective output voltage can be obtained. For example, if the impedance Z of the valve shown in Fig. 1 is substantially infinite and it is necessary to have an effective impedance presented to the load of about 500 ohms at high frequencies, the step-down ratio may be 2:1, that is to say, $n=0.5$ and in that case R would be 2000 ohms. The value of the voltage produced at the anode of the valve Z would be raised to four times its value for the case of a simple anode resistance of 500 ohms and the effective output voltage would therefore be double that for the plain 500 ohms anode resistance, whilst the desired 500 ohms impedance to the load is maintained. If the valve capacity is low, it may be found possible to use a yet higher anode impedance, say 4500 ohms, with a 3:1 ratio transformer.

The invention has been described above as applied to a resistance coupled amplifier. In some cases the valve Z may be replaced by a cathode ray tube, as for example, a television transmitting tube, or some other generating device.

The network shown in Fig. 1 is not only useful for feeding into a capacity such as a valve capacity, but may be used for feeding signals over a

wide frequency range into cables when such cables are electrically short at the low frequencies. With such cables it is necessary that either the sending end, or the receiving end, or both, match the characteristic impedance of the cable, at least at the high frequency end of the range, in order to prevent reflection losses. For transmitting television signals with frequencies extending up, say, one megacycle per second a reasonably flat characteristic can be obtained from a cable of approximately 150 ohms impedance working into the input of a valve with lengths of cable up to 1000 feet provided the cable is fed from an impedance substantially equal to its characteristic impedance at the high frequencies. Such an impedance may be formed by the anode impedance of a valve, but since it is inconvenient to make a cable with a characteristic impedance much over 150 ohms the anode impedance of the valve must be 150 ohms in order to obtain good matching. Thus with a valve which will only provide a maximum anode current change of 50 milliamperes the maximum anode output voltage change is restricted to 7.5 volts.

By using the network according to the invention with an auto-transformer having a step-down ratio of 2:1, the anode load for the valve may be made 600 ohms giving an anode output voltage of 30 volts, which is transformed into the cable as 15 volts. The values of the components are then chosen as outlined in the previous example. With such an arrangement the transformer may consist of a small core of laminations of an alloy such as Rho metal and wound with two or more layers of fine wire forming the two halves of the auto-transformer. The total inductance of both windings in series may be, for example, 20 milli-henries. The resultant series impedance facing the cable, assuming that the valve impedance is substantially infinite, is then 150 ohms in series with another 150 ohms shunted by a capacity of approximately $0.22\mu F$.

At frequencies above 5000 cycles per second the impedance due to the parallel condenser and resistance will fall rapidly and in the neighbourhood of 100,000 cycles per second and upwards it will be practically negligible, so that the cable will be terminated by the correct impedance and will function without reflection losses. The leakage inductance as seen by the cable will be the parallel opposing impedance of the coil windings, which in the present case would be approximately 5 micro-henries. This leakage inductance can be corrected for by suitable shunt capacities between the anode of the valve feeding the cable and ground, and between the cable input and ground, although such capacities already existing will be more than enough to "build-out" the leakage inductance to form a section of a low pass filter as is well known in cable loading practice.

If desired, the output end of the cable may be loaded and in order to keep a flat characteristic over the whole frequency range down to zero, the impedance terminating the cable should be of the same type as that at the input end, that is, the cable may be terminated by a resistance of 150 ohms in series with another 150 ohms shunted by a capacity of $0.22\mu F$. Alternatively the line may be terminated by a resistance of 300 ohms in shunt with a resistance of 70 300 ohms and series capacity of $0.055\mu F$, which is a well known equivalent.

It may be desired to place a potentiometer across the output end of the cable for controlling the amplitude of the output signals. A suit-

able potentiometer can have a value of 1000 ohms (assuming it is not necessary to terminate the output end of the cable with its characteristic impedance to prevent reflection at high frequencies). If such a potentiometer is placed across the cable end, an additional impedance of 1000 ohms in series with a capacity of approximately $0.016\mu\text{F}$ should be placed across the end of the cable to maintain the same law of variation of impedance for the cable termination as for the input impedance of the source.

Of course it is not necessary that an autotransformer be used, because in some cases it is possible to use a transformer having two or more windings for the purpose.

I claim:

1. A coupling arrangement for connecting a source to a load comprising a first resistance in series with the source, a condenser shunted across said first resistance, a second resistance in series with the source and the first resistance, said second resistance being shunted by a transformer, and a connection between the load and said transformer serving as the sole means for impressing on said load the sum of the voltage drops across said first resistance and said transformer.

2. A coupling arrangement for coupling a source to a load comprising a first resistance in series with the source, a condenser shunted across the first resistance, a second resistance in series with the source and the first resistance, an autotransformer shunted across the second resistance and a connection between the load and said autotransformer serving as the sole means for impressing on said load the sum of the voltage drops across the first resistance and the secondary portion of the transformer.

3. A coupling arrangement for coupling a source to a load comprising a first resistance in series with the source, a condenser shunted across the first resistance, a second resistance in series with the source and the first resistance, a winding shunted across the second resistance, and a connection from an intermediate portion

of said winding serving as the sole means for impressing on said load the sum of the voltage drops across the first resistance and said portion of the winding.

4. An arrangement as described in claim 2 wherein the first resistance is equal to nR , the capacity across said first resistance is equal to

$$\frac{L}{R^2 n}$$

where R is the value of the second resistance, L the inductance value of the primary of the transformer and n the stepdown voltage ratio of the said transformer, whereby the impedance of the source and coupling arrangement as seen from the load is substantially independent of frequency and is of a value determined by the values chosen for R , L and n .

5. A coupling arrangement for coupling a source to a load comprising three resistors in series with the source, one of said resistors being equal to nR , a capacity shunted across said last named resistance having a value equal to

$$\frac{L}{R^2 n}$$

another of said resistors having a resistance equal to R , a transformer having a primary portion and a secondary portion, said primary portion being shunted across the last named resistor and having a value of inductance L , means for connecting the load across the secondary portion of said transformer, said secondary portion and primary portion of the transformer being related so that the transformer is, in effect, a stepdown transformer, the stepdown voltage ratio of which is n , the other of said resistors having a value $(1-n)R$, and a capacity shunting said last named resistor having a value

$$\frac{L}{R^2(1-n)}$$

whereby the impedance of the coupling network as seen from the source is substantially constant.

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