March 8, 1927. 1,620,609

G. SOMERSALO

RADIO APPARATUS

Filed Feb. 9, 1926

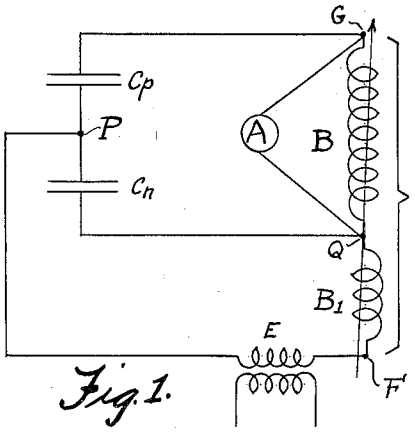

Fig. 1.

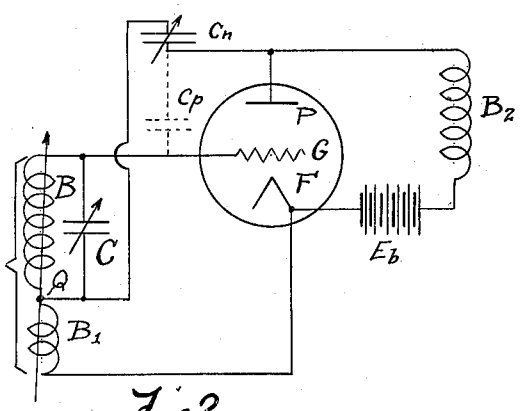

Fig. 2.

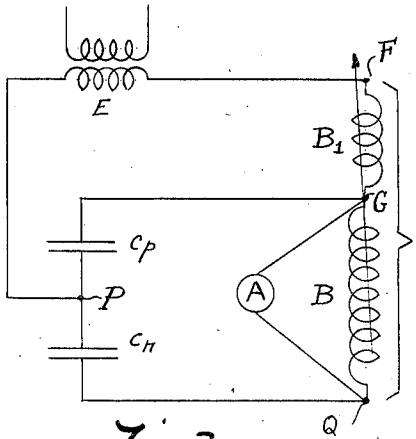

Fig. 3.

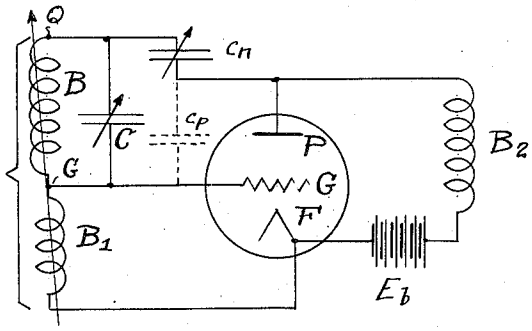

Fig. 4.

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Patented Mar. 8, 1927. 1,620,609

UNITED STATES PATENT OFFICE.

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Application filed February 9, 1926. Serial No. 86,985.

This invention relates to electrical circuits, particularly of the type in which a three-element vacuum tube thermionic device may be included, and more particularly to radio circuits of this nature.

One of the objects of this invention is to provide a simple and thoroughly practical form of circuit of the above-mentioned character in which certain undesired effects, such as, for example, inherent capacities between the electrodes of the thermionic device, may be not only quickly but also completely eliminated. Another object is to provide a circuit of the above-mentioned character which may be rapidly and simply adjusted to achieve the desired action and which may be readily and inexpensively incorporated in thoroughly practical form. Another object is to provide an electrical network of few individual parts or elements and in which a balancing-out of undesired effects, such as capacity effects, may be quickly and efficiently achieved. Another object is to provide a circuit arrangement of the above-mentioned character which is well adapted to meet the varied conditions of practical use and which may be easily embodied in thoroughly commercial form, and particularly adapted for the reception, detection or amplification of radio signals. Other objects will be in part obvious or in part pointed out hereinafter.

The invention accordingly consists in the features of construction, combinations of elements, arrangements of parts and in the several steps and relation and order of each of the same to one or more of the others, all as will be illustratively described herein, and the scope of the application of which will be indicated in the following claims.

In the accompanying drawing, in which are shown several of various possible embodiments of the electrical features of my invention,

Figure 1 is a diagrammatic representation of an alternating current network embodying certain features of my invention, and

Figure 2 is a like diagrammatic representation of the system or network of Figure 1 but as embodying a three-element thermionic device or vacuum tube.

Figure 3 is illustrative of a modified form of the circuit arrangement of Figure 1, and

Figure 4 is illustrative diagrammatically of the arrangement of Figure 3 but having embodied therein a three-element vacuum tube or so-called audion.

Similar reference characters refer to similar parts throughout the several views in the drawing.

As conducive to a clearer understanding of certain features of this invention, it may at this point be noted that in many circuits having embodied therein a three-element thermionic device, such as the so-called audion, the desired action of the circuit is oftentimes but inappreciably attained by reason of the undesired or detrimental effects on the circuit and its action due to such factors, for example, as the inherent capacity or capacities between the electrodes of the device and which act as unintended couplings between different parts of the circuit. Many attempts have been made to devise circuits or methods whereby such detrimental effects may be avoided, but such attempts have been characterized by the achievement of their corresponding objects to only a moderate extent. Particularly has this been true in circuits devised to "neutralize" inherent capacity between electrodes of the vacuum tube, as the latter is used in the translation or amplification and the like of radio signals. Such prior attempts are further characterized by the vital deficiency that they do not achieve or even approach complete neutralization, since they proceed upon the erroneous assumption that, in practice, unity coupling may be achieved between two coupling coils inductively related one to the other. Such prior attempts, therefore, achieve neutralization of these undesired effects to no greater extent than it is possible in practice to achieve unity coupling. One of the dominant aims of this invention is to provide a circuit arrangement and a method whereby such deficiencies as those pointed out above may be avoided, and complete neutralization achieved in a thoroughly practical and simple manner.

Referring now to the drawing and more particularly to Figure 1, there is shown diagrammatically a circuit arrangement in which the several parts thereof may be so balanced that the effect of one element in the circuit upon another element or part of the circuit may be completely eliminated. This network of Figure 1 is arranged to constitute a bridge, and, for purposes of illustration, the bridge circuit includes the

following elements arranged in the following manner:—In Figure 1, c_p and c_n represent two capacities or condensers arranged in series and bridged across the points G and Q which points are in effect the terminals of an inductance B. Bridged across the inductance B and hence across the points G and Q is a current indicating device A. Connected to point Q is one end of an inductance B_1; this inductance B_1 is inductively related to the inductance B and as indicated in Figure 1, the two inductances, when placed end to end as shown in Figure 1, will be seen to be wound oppositely. The other terminal of the inductance B_1, indicated by the points F, is connected to a point P intermediate of the condensers c_p and c_n, but through a device adapted to produce an electro-motive force, such as the secondary winding of a transformer E.

With such a circuit arrangement or network of elements as is above described in connection with Figure 1, the current indicator A, when the device such as the transformer winding E is operative, will indicate zero current when the following relation has been established:—

$$\frac{M}{L_1}=\frac{c_n+c_p}{c_p},$$

where L_1 is the self-inductance of the coil B_1 and where M is the mutual inductance between the coils B and B_1. This relation will be seen to include factors which are in practice actually capable of realization. In other words, the self-inductance of the coil B is a definite calculatable factor and the capacities of the two condensers are likewise definte factors. The mutual inductance M is not a factor that is based on the erroneous assumption that unity coupling is achievable in practice, but is one that may be directly realized. Hence, by making the coupling between the coils B and B_1 variable, assuming all the other factors above set forth in this relation to be fixed, the factor M may be adjusted to a value to establish the above-mentioned relation and hence to establish a complete balance in the electrical network.

Or, on the other hand, assuming that the coupling between the two coils B and B_1 is fixed, the condition for complete balance may be achieved by varying either of the capacities c_n or c_p, or by varying both, Or, as will now be clear, both the coupling (and hence the mutual inductance) and a capacity may be varied to bring about the condition of balance.

In Figure 2 I have shown the bridge circuit arrangement of Figure 1 as embodied in a circuit in which is included a three-element thermionic device having a plate P, a grid G, and a filament F. These three elements of the vacuum tube will be seen to correspond to the points P, F and G of Figure 1. The inductance B of Figure 1 will be seen to be, in Figure 2, part of the input circuit of the vacuum tube and across the inductance B is connected a variable condenser C, to indicate that the input circuit of the network embodying my invention may be a tuned circuit. The inductance B_1 of Figure 1 will be seen in Figure 2 to be connected between the filament F and the point Q forming one terminal of the inductance B; the two inductances B and B_1 of Figure 2 are shown in the latter figure inductively related to each other but placed end to end substantially, and hence, to achieve the same electrical action as they do in Figure 1, the windings of one inductance, in Figure 2, are shown as coiled or wound oppositely from those of the other inductance. The inductive relation of these two coils B and B_1 is preferably variable.

The capacity c_n of Figure 1 will be seen in Figure 2 to be interposed between the point or plate P and the point Q, just as in Figure 1, while the capacity c_p of Figure 1 is shown in Figure 2 as being the inherent capacity between the plate P and the grid G of the audion. Between the point or plate P of Figure 2 (intermediate of the condensers c_p and c_n, as is also the case in Figure 1) and the point F, the filament in Figure 2, is interposed a source of direct current electromotive force, indicated by the battery E_b, and to further illustrate the embodiment of my invention in a circuit well adapted for radio communication purposes, I have shown in the plate circuit also a coil B_2; this latter coil may be the primary winding of a coupling transformer, the secondary of which forms part of the input circuit to a subsequent vacuum tube or it may be, for example, any suitable form of translating device. The coil or inductance B, of Figure 2, may be associated with a suitable channel of communication, such as an antenna circuit, for example, and the association may be made in any suitable manner, such as by a conductive or inductive coupling, for example. The capacity c_n is shown in Figure 2 as variable.

To neutralize completely the effect of the inherent capacity c_p between the plate P and the grid G, which capacity acts as a coupling or feed-back between the output or plate circuit of the audion to the input or grid circuit and thus acts to cause the system to oscillate undesirably and with detrimental effects, such a relation, with the arangement or network of Figure 2, is established that an alternating electromotive force between the plate P and the filament F can have no effect whatever upon the input circuit; such a condition would correspond with an adjustment of the parts such that, in Figure 1, there would be zero indication of current

flow in the indicating device A. The device A of Figure 1 finds, in a sense, its counterpart in the network of Figure 2 in the condenser C. Accordingly, the coupling between the coils B and B_1 is so adjusted that the relation hereinabove set forth is established, or this relation may be achieved by an adjustment of the variable condenser c_n or by making both of these adjustments. In either of these instances, and as long as the above-mentioned relation is established, the network or system of Figure 2 becomes balanced and neutralization of the inherent capacity between the grid and the plate is completely and absolutely achieved, as distinguished from neutralization to an extent only commensurate with that to which unity coupling may be achieved in practice as is characteristic of prior attempts to eliminate the retroactive effect due to the inherent capacities between the electrodes of the vacuum tube.

In Figure 3 of the drawing I have shown a modified form of network and this balancing network of Figure 3 will be seen to be substantially identical in action with that of Figure 1 excepting that one terminal of inductance B_1 is connected to the inductance B at the point G, instead of point Q as in Figure 1. The coils B and B_1 of Figure 3 are otherwise, as to relation inductively and as to directions of winding, the same as in Figure 1. The relation of balancing, pointed out above in connection particularly with respect to Figure 1 and also in connection with Figure 2, holds true for the balancing network of Figure 3, and in deriving from the network of Figure 3 a network in which is included a three-element vacuum tube (similarly as the balancing network of Figure 2 is derived from the balancing network of Figure 1), there results a circuit arrangement shown in Figure 4. This balancing network of Figure 4 will be seen to be distinguished from the network of Figure 2 by the connection of one terminal of coil B_1 to the coil B, not at point Q, as in Figure 2, but at the point or terminal G, just as is the distinction between the networks of Figures 3 and 1.

The condition for balancing, in the network of Figure 4, and to achieve complete neutralization of the effect of the inherent capacity between certain of the electrodes of the vacuum tube remains, however, the same as that relation which must be established to achieve balance in the elementary circuits of Figures 3 and 1.

It will thus be seen that neutralization of inherent capacity effects in the three-element thermionic device may thus be achieved as such, and not merely in part or to an extent, as has been characteristic of prior attempts, commensurate with that to which unity coupling may be arrived at in practice. In accordance with my invention, therefore, undesired and detrimental effects and actions in the circuit of a vacuum tube may be completely eliminated and prevented, since their elimination is made dependent upon such electrical factors as may be actually and totally realized in practical circuits of this nature. The achievement of true neutralization, as I am able to do by reason of my invention, results in many thoroughly practical advantages; among the latter may be noted the fact that greater sensitiveness of the apparatus is brought about, the apparatus, when used for the reception of radio signals, is inherently made capable of handling, at the input, far greater amounts of initial energy, and even though much greater amounts of energy may thus be initially utilized, the adjustment, manipulation or handling of the apparatus is not in any way impaired or made additionally complicated. It is a known fact that, with receiving systems or apparatuses embodying arrangements corresponding to prior attempts to achieve neutralization, the turns included in the primary coils of transformers which couple one stage of amplification to another have to be maintained at a number very low; this results in the transfer of very small amounts of energy from one stage to a subsequent stage of amplification, with the result that the apparatus is operated at not only a very small proportion of the load which it could carry but also at very low efficiency. Any increase in the number of turns thus employed with corresponding increase in the amount of energy handled causes such apparatuses to become promptly inoperative in so far as neutralization is concerned; they are thus rapidly brought into a condition of oscillation or "squeeling", with its well-known defects.

By reason of my invention, however, the achievement of neutralization imposes no limits upon the amounts of energy handled or transferred from one stage of amplification to the other, and thus complete utilization of the full capacity of the vacuum tube or tube and its circuit to handle a load may be achieved, and this without danger of bringing about feed-back action and resultant oscillation or "squeeling". Thus, also, no restrictive limitations as to amplification are imposed upon the system or apparatus. Furthermore, it will be seen that the apparatus or circuit arrangement is simple, may be readily and conveniently manipulated or adjusted, and may be readily incorporated in commercial form.

As many possible embodiments may be made of the mechanical features of the above invention and as the art herein described might be varied in various parts all without departing from the scope of the invention, it is to be understood that all matter herein-

above set forth or shown in the accompanying drawings is to be interpreted as illustrative and not in a limiting sense.

I claim as my invention:

1. In a signaling system, the combination of a three-element thermionic device with an input circuit and an output circuit, said input circuit including a coil, one terminal of which is connected to the grid of said device and said output circuit connecting the plate and filament of said device; and means for preventing feed-back of energy from the output circuit to the input circuit through the inherent capacity between electrodes of the device, said means including a capacity interposed between the other terminal of said coil and the plate of said device, and a separate coil electrically interposed between one terminal of said first-mentioned coil and the filament of said device, said coils being inductively related to each other and the one wound oppositely with respect to the other, the coupling between said two coils being less than unity.

2. In a signaling system, the combination of a three-element thermionic device with an input circuit and an output circuit, said input circuit including a coil, and said output circuit connecting the plate and the filament of said device; and means for preventing feed-back of energy from the output circuit to the input circuit through the inherent capacity between the grid and plate electrodes of said device, said means including a capacity interposed between one terminal of said input coil and the plate, the other terminal of said coil being connected to the grid, and a second coil wound oppositely with respect to said input coil and interposed between one terminal of the said input coil and the filament of said device, and inductively coupled to said input coil, the inductive coupling between said two coils being less than unity, and means for predetermining at will the relation between said coupling and said capacity so that the terminals of said input coil are at substantially the same potential.

3. In a signaling system, the combination of a three-element thermionic device with an input circuit and an output circuit, said input circuit including a coil, one terminal of which is connected to the grid of said device and said output circuit connecting the plate and the filament of said device; and means for preventing feed-back of energy from the output circuit to the input circuit through the inherent capacity between electrodes of the device, said means including a condenser interposed between the other terminal of said coil and the plate of said device, and a separate coil electrically interposed between one terminal of said first-mentioned coil and the filament of said device, said two coils being inductively related to each other and the one wound oppositely with respect to the other and means for changing at will the coupling between said two coils, said coupling being less than unity.

4. In a signaling system, the combination of a thermionic amplifying device having plate, grid, and filament electrodes, with an input circuit and an output circuit, said input circuit including a coil connected between the grid and plate electrodes of said device, and said output circuit connecting the plate and the filament of said device, whereby, when an alternating electromotive force is impressed on the input circuit, said electromotive force is amplified and said output circuit responds thereto; and means for preventing the amplified electromotive force in the output circuit from reacting upon the input circuit through the inherent capacity between plate and grid electrodes of said device, said means including a condenser arranged to form with the input coil a series connection between the grid and plate electrodes, a coil wound oppositely with respect to said input coil and inductively related thereto and interposed between one terminal of the input coil and the filament of said device, and means for relating the mutual inductance of said two coils to the capacity of said condenser so that the terminals of said first-mentioned coil will be at substantially the same potential.

5. In a signaling system, the combination of a three-element thermionic device with an input circuit and an output circuit, said input circuit including a coil, one terminal of which is in electrical connection with the grid of said device, and said output circuit connecting the plate and the filament of said device whereby, when an alternating electromotive force is impressed on the input circuit, said electromotive force is amplified and said output circuit responds thereto; and means for preventing the electromotive force in the output circuit from affecting the input circuit through the inherent capacity between the plate and grid electrodes of said device, said means including a condenser interposed between the other terminal of said input coil and the plate of said device and a separate coil wound reversed with respect to said input coil and inductively related thereto, the coupling therebetween being less than unity, said separate coil being interposed between one terminal of the input coil and the filament of said device; and means for establishing such a relation between the said coupling and the capacity of said condenser that the terminals of said input coil will be at substantially the same potential.

6. In a signaling system, the combination of a thermionic amplifying device having plate, grid, and filament electrodes, with an input circuit and an output circuit, said

input circuit including a coil B connected between the grid and plate electrodes of said device, and said output circuit connecting the plate and the filament electrodes of said device, whereby, when an alternating electromotive force is impressed on the input circuit, said electromotive force is amplified and said output circuit responds thereto; and means for preventing the amplified electromotive force in the output circuit from reacting upon the input circuit through the inherent capacity c_p between plate and grid electrodes of said device, said means including a condenser arranged to form with the input coil B a series connection between the grid and plate electrodes, and a coil B_1 wound oppositely with respect to said input coil B and inductively related thereto and interposed between one terminal of the input coil B and the filament electrode of said device, the mutual inductance M between the coils B and B_1 being related to the self inductance L_1 of the coil B_1 so that

$$\frac{M}{L_1}=\frac{c_n+c_p}{c_p},$$

where c_n is the capacity of said condenser.

7. In a signaling system, the combination of a three-element thermionic device with an input circuit and an output circuit, said input circuit including a coil, one terminal of which is connected to the grid of said device, and said output circuit connecting the plate and the filament of said device whereby, when an alternating electromotive force is impressed on the input circuit, said electromotive force is amplified and said output circuit responds thereto; and means for preventing the electromotive force in the output circuit from affecting the input circuit through the inherent capacity between the plate and grid electrodes of said device, said means including a condenser interposed between the other terminal of said input coil and the plate of said device and a separate coil wound reversed with respect to said input coil and inductively related thereto, the coupling therebetween being less than unity, said separate coil being interposed between said other terminal of the input coil and the filament of said device; and means for establishing such a relation of coupling that the terminals of said input coil will be at substantially the same potential.

In testimony whereof, I have signed my name to this specification this 8th day of February, 1926.

GEORGE SOMERSALO.