

Sept. 3, 1946.

E. GREEN

2,407,074

FEEDBACK CONTROL ARRANGEMENT FOR COUPLED TUNED CIRCUITS

Filed May 16, 1944

3 Sheets-Sheet 1

Fig. 1.

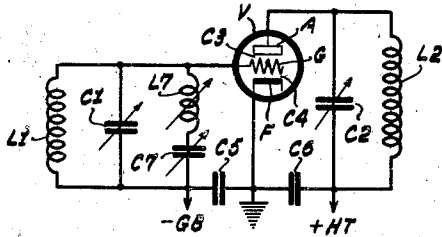


Fig. 2.

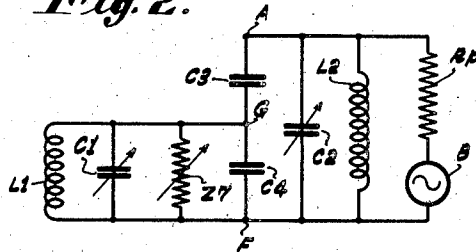


Fig. 3.

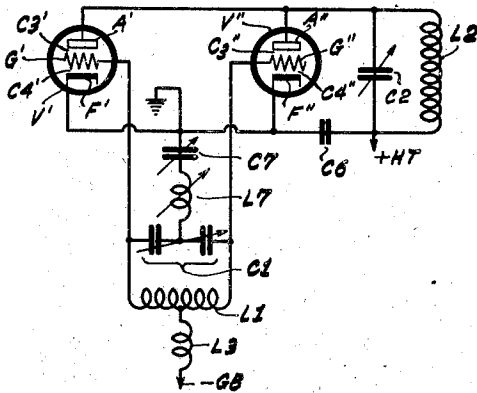


Fig. 4.

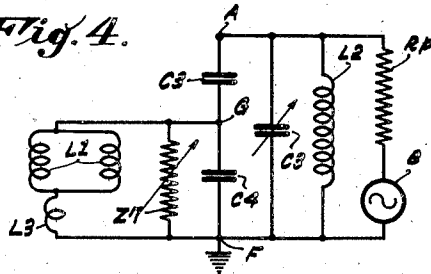


Fig. 5.

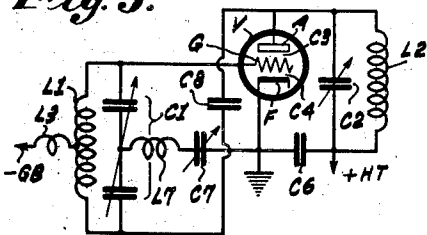


Fig. 7.

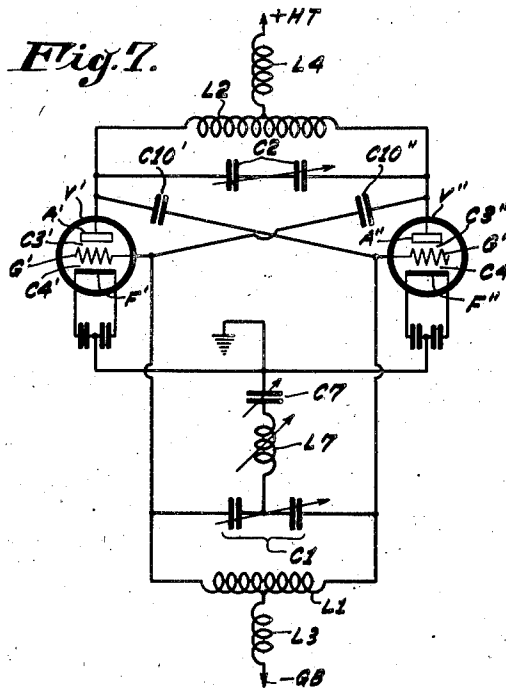
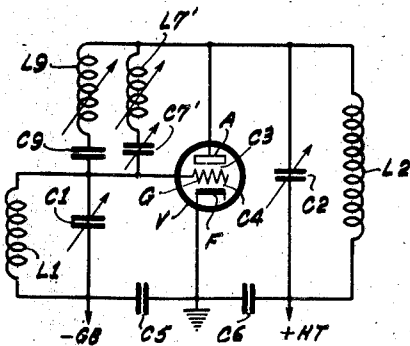


Fig. 6.



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Fig. 8.

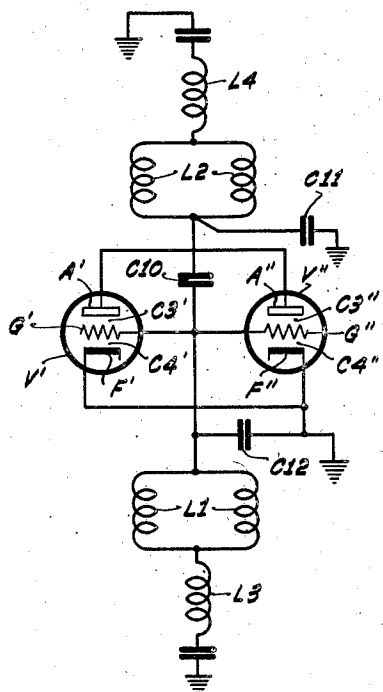


Fig. 10.

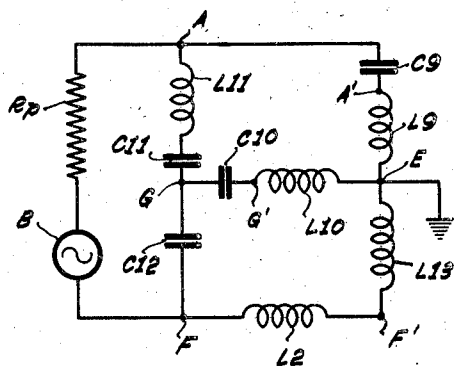


Fig. 9.

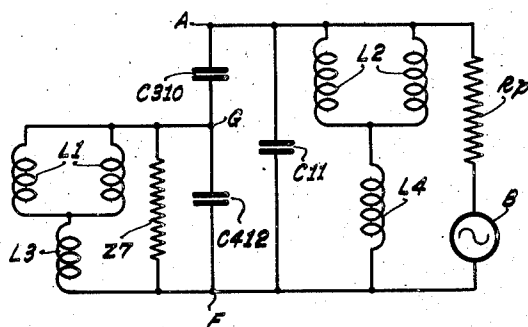
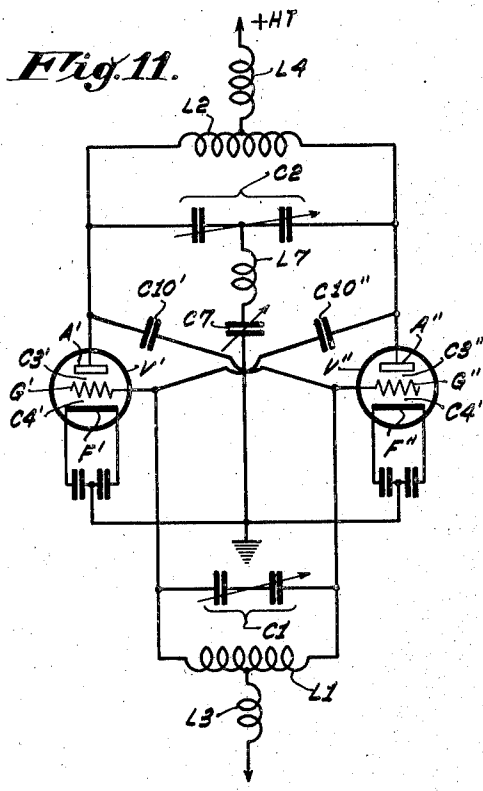


Fig. 11.



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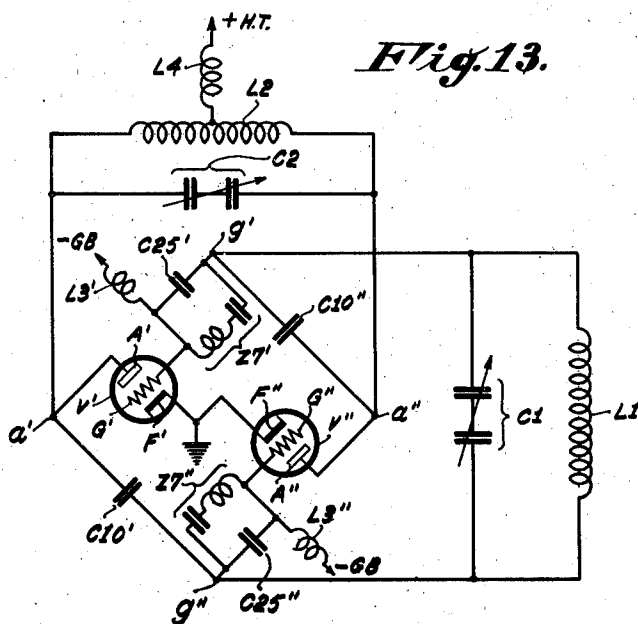
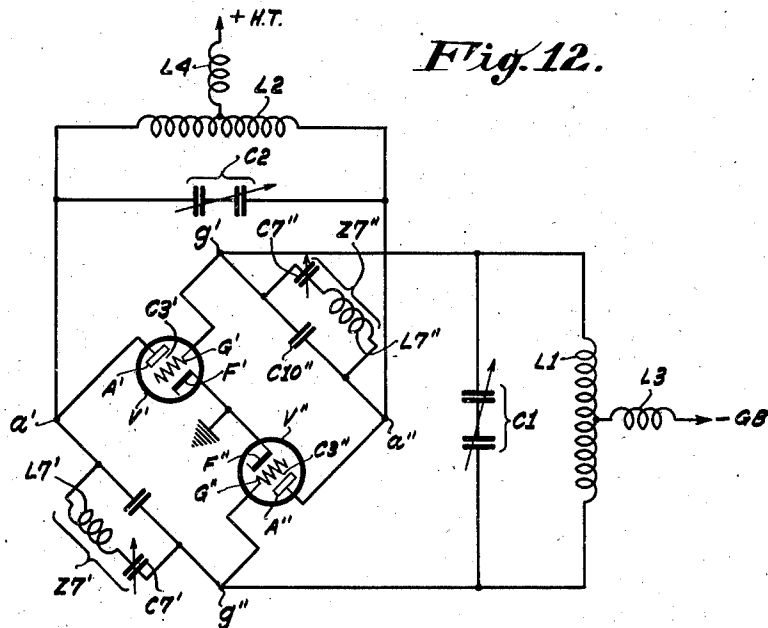
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FEEDBACK CONTROL ARRANGEMENT FOR COUPLED TUNED CIRCUITS

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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FEED-BACK CONTROL ARRANGEMENT FOR
COUPLED TUNED CIRCUITSErnest Green, Chelmsford, England, assignor to
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4 Claims. (Cl. 179-171)

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This invention relates to coupled tuned circuits, and provides means for controlling the effect of feed-back from one of the tuned circuits to the other.

The present invention is particularly suitable for controlling the effect of feed-back of energy from a tuned output circuit to a tuned input circuit, when these two circuits are coupled by means of one or more thermionic valves. The tuned output circuit may be tuned to the same frequency (fundamental frequency) as is the input circuit, or it may be tuned to a frequency which is, or to frequencies which are, in harmonic relationship to that to which the input circuit is tuned. It may be that in tuned circuits thus coupled there is a measure of feed-back from the output tuned circuit to the input circuit, and this feed-back may be regenerative or it may be degenerative. Moreover, feed-back may or may not be desirable, depending upon its nature, for example whether it is regenerative or degenerative, and also upon the purpose for which the coupled circuits are to be employed.

The present invention is mainly, though not exclusively, concerned with those cases in which in the output circuit there are components which it is desirable should not be fed back to the input circuit. These components which are not desired to be fed back may be the fundamental, or odd harmonics, or even harmonics. For the purposes of explanation the fundamental frequency may be regarded as an odd harmonic since it behaves, generally, in the same manner as do the odd harmonics. Moreover, since the anode-grid space and the grid-cathode space of a valve may be regarded as capacitors in series, with a tapping point at the grid, the invention will be stated, in general, as being applied to tuned circuits coupled by a capacity-potentiometer.

According to the invention in one aspect, a circuit arrangement including a tuned input circuit and a tuned output circuit coupled together by means of a capacity-potentiometer, wherein the input circuit is connected across part of the capacity-potentiometer while the tuned output circuit is connected across the whole of the capacity-potentiometer, is provided with an impedance connected effectively across the said part of the capacity-potentiometer, said impedance being constituted as a series-L/C circuit element resonant at a frequency near to the frequency of the component of frequency in the output circuit, the effect of feed-back of which it is desired to control, for example reduce or eliminate.

According to a first modification of the inven-

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tion the capacity-potentiometer may consist of two capacity-potentiometers effectively in parallel, with the tuned input circuit connected from a tapping point on one capacity-potentiometer to a similarly placed tapping point on the other capacity-potentiometer, and with its mid-point connected to one end (conveniently referred to as the lower end) of the parallel-connected capacity-potentiometers so that each of the two electrical halves of the tuned input circuits is connected across part of a different one capacity-potentiometer, while the tuned output circuit is connected across the whole of the parallel-connected capacity-potentiometers; the said impedance being connected from the electrical mid-point of the tuned input circuit to the lower end of the parallel-connected capacity-potentiometers.

According to a second modification of the invention, one end (conveniently referred to as the upper end) of the capacity-potentiometer may be connected to one end of a neutralization capacitor, and the tuned input circuit may be connected from a tapping point on the capacity-potentiometer to the other end of the neutralization capacitor and have its mid-point connected to the lower end of the capacity-potentiometer, while the tuned output circuit is connected across the whole of the capacity-potentiometer, the said impedance being connected from the electrical mid-point of the tuned input circuit to the lower end of the capacity-potentiometer.

The circuits so far outlined are, insofar as they may involve two capacity-potentiometers, push-push circuits; that is, both capacity-potentiometers look into the same end of the tuned output circuit. There is another group of circuits to which the invention can be applied, namely push-pull circuits; that is circuits in which each capacity-potentiometer looks into a different end of the tuned output circuit.

According to a third modification of the invention, a circuit arrangement including a tuned input circuit and a tuned output circuit coupled together by means of a pair of capacity-potentiometers wherein the tuned input circuit is connected from a tapping point on one capacity-potentiometer to a similarly placed tapping point on the other and has its mid-point connected to the common lower end of the two capacity-potentiometers, while the tuned output circuit is connected at one of its two ends to the upper end of one of the two capacity-potentiometers, at the other of its two ends to the upper end of the other of the two capacity-potentiometers, and

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at its mid-point to the common lower end through a connection including an inductor, is provided with an impedance connected effectively from the mid-point of the tuned input circuit to the common lower end of the two-capacity potentiometers, said variable impedance being constituted as a series-LC circuit element resonant at a frequency near to the frequency of the component of frequency in the output circuit, the effect of feed-back of which it is desired to control, for example, reduce or eliminate.

According to a fourth modification of the invention, in a circuit arrangement organized as set out in the immediately preceding paragraph so far as the input and output circuits are concerned, the said impedance is connected effectively from the mid-point of the tuned output circuit to the common lower end of the two capacity-potentiometers, instead of from the mid-point of the tuned input circuit.

According to a fifth modification of the invention, a circuit arrangement organized as set out in the last but one paragraph so far as the input and output circuits are concerned, and including neutralizing condensers, one connected from the upper end of either capacity-potentiometer to the tapping point on the other, is provided with two impedances, one connected across each neutralizing condenser, said impedances being constituted as series-L/C circuit elements resonant at a frequency near to the frequency of the component of frequency in the output circuit, feed-back of which it is desired to control, for example, to reduce.

If, because the operating frequencies are high, or because the capacities of the constituents of the capacity-potentiometers are large (large valves for example), the inductances in the various leads, particularly in the leads connecting the tuned input circuit to the said tapping points, cannot be neglected but are neutralized by the inclusion of condensers in series in these leads connecting the input circuit to the tapping points, the circuit according to the third modification of the invention may itself be modified, by being provided with impedances connected across the said condensers included in the said leads, the said impedances being constituted as series-L/C circuit elements resonant at a frequency near to the frequency of the component of frequency in the output circuit, the effect of feed-back of which it is desired to reduce or eliminate. This arrangement is known as the sixth modification of the invention.

In the circuit arrangements according to the invention, and to the modifications thereof, the capacity-potentiometer or capacity-potentiometers, as the case may be, may include the anode-grid and grid-cathode capacities of a thermionic valve or of thermionic valves, in series, and in the circuit arrangement according to the invention or its first and second modifications the said part of said capacity-potentiometer or of said capacity-potentiometers, as the case may be, includes the grid-cathode capacity of the said thermionic valve or thermionic valves. Similarly, in the circuit arrangements in which reference is made to tapping points on the capacity-potentiometers and the lower end thereof, the part between this point and lower end may be the grid-cathode capacity of the said thermionic valve, or thermionic valves.

All the circuit arrangements above described may be constituted as frequency multipliers, the tuned output circuit in all such cases being res-

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onant at a frequency higher than, but harmonically related to, that at which the tuned input circuit is resonant. In all the circuit arrangements above described, the said impedance may include series connected inductors and capacitors, either or both of which may be pre-set or variable, tuned about the harmonic frequency at which the tuned output circuit is resonant, or about a harmonic frequency present in the said tuned output circuit.

In the circuit arrangements in which the impedance is stated to be connected to a mid-point of the tuned input circuit, and in the circuit arrangements in which the impedance is stated to be connected to a mid-point of the tuned output circuit, this mid-point may be found on the inductive element of these tuned circuits, or it may be found on the capacitive element thereof. In the former cases, the impedance may be constituted by the choke in the grid bias or anode current leads as the case may be.

In all the circuit arrangements, there may be provided more than one impedance in all of the places where one only is indicated, the impedances being connected in parallel with each other and being constituted as series-L/C circuit elements resonant at a frequency near to the frequencies of different components of frequency in the output circuit, the effect of feed-back of which different components it is desired to control, for example to reduce or eliminate.

In the drawings:

Fig. 1 shows one embodiment and Fig. 2 shows the equivalent circuit thereof,

Fig. 3 shows a modification and Fig. 4 is the equivalent circuit,

Figs. 5 and 6 show two further embodiments,

Fig. 7 shows another modification, while Figs. 8, 9 and 10 are equivalent circuits thereof,

Figs. 11, 12 and 13 show different modifications.

In the circuit illustrated in Fig. 1, which illustrates the aspect of the invention as first set out, a triode V has a tuned input circuit L1, C1 connected across its grid-cathode space G—F, a blocking condenser C5 being included in the connection between the cathode F and the end of the tuned input circuit to which the cathode is connected. The end of this tuned input circuit remote from the grid of the triode is connected to the cathode of the triode through a connection which includes a source of grid bias (not shown, but indicated at —GB), the connection being made at the side of the blocking condenser C5 remote from the cathode F. The tuned input circuit is resonant at an applied fundamental frequency which it is desired to multiply. A tuned output circuit L2, C2, is connected across the anode-cathode space A—F of the triode V, a blocking condenser C6 being included in the connection between the cathode F and the end of the tuned output circuit to which the cathode is connected. The end of the tuned output circuit remote from the anode A of the triode is connected to the cathode of the triode through a connection which includes a source (not shown, but indicated at +HT) of anode current, the connection being made at the side of the blocking condenser C6 remote from the cathode F. The output circuit is tuned to, or the oscillatory energy therein includes, a harmonic frequency.

The equivalent circuit is illustrated in Fig. 2, wherein like references are used to those used in Fig. 1, together with a few additional references. The source of the harmonic fre-

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quency in the tuned output circuit is represented by generator B and resistor R_p. To the harmonic frequency the triode will appear as two capacitors C₃ and C₄ in series, respectively constituted by the capacity between the anode A and grid G and that between the grid G and cathode F, with the tuned input circuit connected across the latter of these two capacitors. The tuned input circuit being tuned to the fundamental frequency, the impedance between the grid and cathode will be capacitive at the harmonic frequency. These two apparent capacitors C₃ and C₄ constitute a capacity-potentiometer, and the potential fed back to the point G (the grid of the triode) is in the same phase as that on the point A (the anode) and is therefore degenerative. For the purpose of the invention variable impedance Z₇ is connected across the capacitor C₄ (that is the grid-cathode capacity) by means of which the potential fed back can be reduced to zero, or adjusted to any desired extent according to the nature and value of the said impedance. Thus if it takes the form of an acceptor circuit at the harmonic frequency, as illustrated in Fig. 1, consisting of an inductor L₇ in series with a capacitor C₇, no potential will be fed back to the grid at that frequency.

In the circuit illustrated in Fig. 3, which illustrates the first modification of the invention, two triodes V' and V'' have their anodes A' and A'' connected together directly, and their cathodes F' and F'' likewise are connected together directly. A tuned input circuit L₁, C₁ is connected in push-pull to the grids G' and G'' of the two triodes. The mid-point of the inductor L₁ in the tuned input circuit is connected to the cathodes F', F'' through a connection which includes a source of grid bias (not shown, but indicated at -GB) and a resistor or (as shown) inductor L₃. The tuned input circuit is resonant at an applied fundamental frequency which it is desired to multiply. A tuned output circuit L₂, C₂ is connected across the parallel related anode-cathode spaces A'-F' and A''-F'' of the two triodes, a blocking condenser C₆ being included in the connection between the cathodes and that end of the tuned output circuit to which they are connected. The end of the tuned output circuit remote from the anodes of the triodes is connected to the cathodes of the triodes through a connection which includes a source (not shown but indicated at +HT) of anode current, the connection being made at the side of the blocking condenser C₆ remote from the cathodes F', F''. The output circuit is tuned to, or the oscillatory energy therein includes, an even harmonic frequency.

The equivalent circuit is illustrated in Fig. 4, wherein the source of harmonic frequency is represented by generator B and resistor R_p. To the harmonic frequency the two triodes and input circuit will appear as two capacitors C₃ and C₄ in series, respectively constituted by the capacities C_{3'} and C_{3''} between anodes A' and A'' and grids G' and G'' and that between the said grids and cathodes F' and F'' together with the bulk capacitance of the tuned input circuit all in parallel, with the two halves of the inductor L₁ of the input circuit in parallel with each other and in series with the resistor or inductor L₃ connected across the latter of these two capacitors C₄. Again, the impedance between the grids and cathodes will be capacitive at the harmonic frequency. The two apparent capacitors constitute a capacity-potentiometer (or two such in par-

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allel) and the potential fed back to the grid is in the same phase as that on the anode and is therefore degenerative. For the purpose of the invention, a variable impedance Z₇ is connected effectively across the apparent capacitor C₄ constituted by the grid-cathode capacitances. Physically this variable impedance is connected from the mid-point of the tuned input circuit to the cathodes of the triodes. The connection may be effected to the mid-point of the inductor L₁ of the tuned input circuit, or as shown in Fig. 3, to the point of junction of two series-connected tuning capacitors C₁. By means of this impedance Z₇, the potential fed back can be reduced to zero or controlled to any desired extent according to the nature and value of the said impedance. Thus, if it take the form of an acceptor circuit at the harmonic frequency, as illustrated in Fig. 3, consisting of an inductor L₇ in series with a capacitor C₇, no potential will be fed back to the grid at that frequency.

In the circuit illustrated in Fig. 5, which illustrates the second modification of the invention, a triode V has one end of a tuned input circuit L₁, C₁ connected to its grid G, the other end of the tuned input circuit being connected to one side of a neutralizing capacitor C₈, the other side of which is connected to the anode A of the triode. The mid-point of the inductor L₁ in the tuned input circuit is connected to the cathode through a connection which includes a source of grid bias (not shown, but indicated at -GB) and a resistor or (as shown) inductor L₃. The tuned input circuit is resonant at an applied fundamental frequency which it is desired to multiply. A tuned output circuit L₂, C₂ is connected across the anode-cathode space A-F of the triode, a blocking condenser C₆ being included in the connection between the cathode F and that end of the tuned output circuit to which it is connected. The end of the tuned output circuit remote from the anode of the triode is connected to the cathode of the triode through a connection which includes a source (not shown, but indicated at +HT) of anode current, the connection being made at the side of the blocking condenser C₆ remote from the cathode F. The output circuit is tuned to, or the oscillatory energy therein includes, a harmonic frequency. Such a circuit can be used for either odd harmonics, including the fundamental frequency, or even harmonics, and it resembles that of the first modification illustrated in Fig. 3, with one of the triodes of that circuit replaced by the capacitor C₈. The degree of feed-back can be controlled in a similar way, by connecting a variable impedance, which may take, and as illustrated takes, the form of a series-L/C circuit L₇, C₇, between the mid-point of the tuned input circuit and the cathode F of the triode V.

The arrangement illustrated in Fig. 1 may be differently modified, as illustrated in Fig. 6. The fundamental circuit is exactly the same as the fundamental circuit of Fig. 1, that is as Fig. 1 without the series-L/C circuit L₇, C₇. It has, however, a series-L/C circuit L₉, C₉ connected across the capacitor C₃ between the anode A and grid G. This series-LC circuit is tuned to provide neutralization of feed-back at the fundamental frequency, and is a known device. In addition, a further series-L/C circuit L₇, C₇, is connected across capacitor C₃ to control the degree of feed-back at the harmonic frequency. In this arrangement, the feed-back will be a mini-

imum when the resultant impedance is a maximum.

In the circuit illustrated in Fig. 7, which illustrates the third modification of the invention, two triodes V' and V'' have their cathodes F' and F'' connected together directly, a tuned input circuit L1, C1 being connected on one of its sides to the grid G' of triode V' and on the other of its sides to the grid G'' of the other triode V''. The mid-point of the inductor L1 in the tuned input circuit is connected to the cathodes F', F'' through a connection which includes a source (not shown, but indicated at -GB) of grid bias and a resistor or (as shown) inductor L3. The tuned input circuit is resonant at an applied fundamental frequency which it is desired to amplify or to multiply to an odd harmonic frequency. A tuned output circuit L2, C2 is connected at its one side to the anode A' of triode V' and at its other side to the anode A'' of the other triode V''. The mid-point of the tuned output circuit is connected to the cathodes F', F'' of the triodes through a connection which includes a source (not shown, but indicated at +HT) of anode current and an inductor L4. The tuned output circuit is in the push-pull mode, resonant to odd (including the fundamental) frequencies, which are those desired. The anode A' of triode V' is coupled through a neutralizing capacitor C10' to a point where the tuned input circuit is connected to the grid G'' of triode V'', and the anode A'' of this triode V'' is connected to a point where the tuned input circuit is coupled through a neutralizing capacitor C10'' to the grid G' of triode V'.

The capacitors C10' and C10'' neutralize the push-pull oscillations fed back from the anodes to the grids through the capacities C3'' and C3' respectively. However, the push-pull excitation of the grids tends to excite the output circuit, in push-push, at the undesired even harmonic frequencies. An equivalent circuit for Fig. 7 is illustrated in Fig. 8, like references are used to those used in Fig. 7, together with a few added references. Thus, capacitors C11 and C12 represent the general capacitances from the anode and grid, respectively to ground. For the even harmonic mode of oscillation, capacitors C3', C3'', C10', and C10'' (the latter two being represented in Fig. 8 as C10) are effectively in parallel, equipotential points for even harmonics being shown connected together. The response of the output circuit to even harmonic oscillations depends upon the impedance which this circuit offers to such oscillations, but it is clear that the neutralizing condensers (C10 in Fig. 8) will not neutralize even harmonics fed back to the grids.

The circuit of Fig. 8, that is ultimately of Fig. 7, can be further simplified to the equivalent circuit illustrated in Fig. 9, wherein again, so far as may be, like references are used to those used in Figs. 7 and 8. It will be seen to have resolved itself substantially to the circuit of Fig. 2. The source of even harmonic frequencies in the tuned output circuit is represented by generator B and resistor Rp. To the even harmonic the triodes will appear as the two capacitors C310 and C412 in series, respectively constituted by the parallel capacitors C3', C3'', C10' and C10'' (C10 of Fig. 8), and the parallel capacitors C4', C4'', and C12, with the two halves of inductor L1 of the input circuit in parallel with each other and in series with inductor L3 connected across capacitor C412, and with the two halves of inductor L2 in parallel with each other and in series with in-

ductor L4 connected across the capacity potentiometer constituted by capacitors C310 and C412. Inductors L3 and L4 offer a high impedance so that generator B produces an even harmonic potential across the capacity potentiometer and a fraction

$$\left(\frac{C310}{C310 + C412} \right)$$

of the anode potential will be fed back to the point G, essentially the grids of triodes V' and V''. The potential fed back to point G will be degenerative.

For the purpose of the invention, a variable impedance Z1 is connected effectively across the apparent capacitor C412 constituted by the grid-cathode capacities, including the capacity between the grids and earth, in Fig. 8 designated C12. The connection may be effected to the mid-point of the inductor L1 of the tuned input circuit, or as shown in Fig. 7 to the point of junction of two series-connected tuning capacitors C1. In Fig. 7 the variable impedance Z1 is represented by the two halves of capacitor C1 in parallel, with the variable capacitor C7 and inductor L7 connected in series to ground. If the connection is made to the mid-point of inductor L1 it consists of the two halves of L1 in parallel, and these parallel halves in series with L7 and C7 to ground. It will be noted that these additions are made at neutral points of the circuit as regards push-pull operation, and so will not interfere with normal working on the fundamental or odd harmonics. If it is necessary to provide control on more than one even harmonic, say 2nd, 4th and 6th, then other variable impedances may be connected in parallel. It is not thought to be necessary to reproduce these arrangements in drawings.

When large valves, or high frequencies are involved, the inductances in the connections within the valves, and those outside the valves by which the various components are connected together and the bulk capacitances to various parts of the framework, cannot be ignored. To the even harmonics, in this case, the circuit of Fig. 9, omitting the impedance Z1, appears as indicated in Fig. 10, in which the various symbols have the following significations: C9 is the bulk capacity between the top A of the potentiometer (the anode of the valves); L9 is the inductance of the connection, including that of the frame, between A and the point on the frame which for high-frequencies is a ground potential; C10 is the bulk capacity between point G (grid of the valves) and frame; L10 is the inductance of the connection, including that of the frame, between G and the point on the frame which for high frequency is at ground potential; C11 and L11 are, respectively, the effective capacity and effective inductance between points A and G (anodes and grids of the valves including anode-cathode capacities) and neutralizing capacitors; C12 is the effective capacity between points G and F (grids and filaments of the valves); and L12 and L13, which apply only in the case of valves, are the effective inductance between the filament and the point on the frame which, for high frequency, is at ground potential; L12 being the effective inductance of the filament leads, and L13 the inductance of the frame between the point at which the filaments are connected thereto through blocking condensers, and the said ground point. For simplicity, the grid-feed chokes, and anode-feed chokes have been disregarded, and are not represented. In such cases, the harmonics fed back to the grid from the anode may have any

phase. However, by connection of a suitable impedance (Z_1 not shown) from point G or G' to point E , or from point A or A' to point E , control of the feed-back may be effected.

In the circuit illustrated in Fig. 11, which relates to the above case and illustrates the fourth modification of the invention, the input and output tuned circuits, respectively L_1, C_1 and L_2, C_2 and triodes V' and V'' are connected as just described, but instead of the variable impedance Z_1 , or variable impedances if more than one are employed, being connected from the mid-point of the input circuit to the common cathode connection, it is connected from the mid-point of the tuned output circuit to the said common cathode connection, so that voltage fed back to the grids of the triodes at even harmonic frequencies can be controlled. In Fig. 11, the variable impedance Z_1 is shown as consisting of series-connected inductor L_7 and capacitor C_7 , connected from the mid-point of capacitor C_2 to the common cathode connection, that is to ground. It could, of course, be connected from the mid-point of inductor L_2 .

In a circuit arrangement according to the fifth modification of the invention, the input and output circuits and the triodes are connected as in Fig. 7, omitting the variable impedance L_7, C_7 . These circuits, so far as odd harmonics and the fundamental are concerned, resolve themselves into a four-armed bridge, as illustrated in Fig. 12 (omitting variable impedances Z_1' and Z_1'') with the anode-grid capacities C_3' and C_3'' in two opposite arms, and with the neutralizing capacitors C_{10}' and C_{10}'' in the other two opposite arms. The tuned input circuit L_1, C_1 are connected to the corners g' and g'' of the bridge to which the grids G' and G'' are connected. The tuned output circuit L_2, C_2 are connected to the corners a' and a'' of the bridge to which the anodes A' and A'' are connected.

Both the fundamental and odd harmonic electromotive forces operate across the diagonal to which the output circuit is connected. Neglecting the inductance in the arms of the bridge, balance will be maintained across the diagonal to which the input circuit is connected, both for the fundamental and the odd harmonics. Hence, there is no feedback from the anode to grid on the fundamental or odd harmonics. Control of feedback on any particular odd harmonic can be provided by connecting variable impedances Z_1' and Z_1'' across the capacitors C_{10}' and C_{10}'' respectively. An alternative to this would be to connect variable impedances between grid and anode of each valve, that is across capacitances C_3' and C_3'' . When large valves, or high frequencies are involved, the inductances in the connections within the valves, and those outside the valves by which the various components are connected together and the bulk capacitances to various parts of the framework, cannot be ignored.

In the circuit illustrated in Fig. 13, which takes care of these considerations and is in accordance with the sixth modification of the invention, two triodes V' and V'' have their cathodes F' and F'' connected together directly, a tuned input circuit L_1, C_1 being coupled on one of its sides by a first grid-coupling capacitor C_{25}' to the grid G' of the triode V' and on the other of its sides by a second grid-coupling capacitor C_{25}'' to the grid of triode V'' . Grid bias potential is provided through a connection which includes a source of grid bias (not shown, but indicated at $-GB$) and resistors

or, as shown, inductors L' and L'' one for each valve. The tuned input circuit L_1, C_1 is resonant at an applied fundamental frequency which it is desired to multiply. A tuned output circuit L_2, C_2 is connected at its one side to the anode A' of triode V' and at its other side to the anode A'' of triode V'' . The mid-point of the tuned output circuit is connected to the cathodes of the triodes through a connection which includes a source of anode current and inductor L_4 . The tuned output circuit is resonant to, or has a component of its oscillations, an odd harmonic frequency. The anode A' of triode V' is coupled through a capacitor C_{10}' to a point g'' where the tuned input circuit is capacitatively coupled to the grid of triode V'' , and the anode A'' of triode V'' is coupled through capacitor C_{10}'' , to point g' where the tuned input circuit is capacitatively coupled to the grid of triode V' .

As is apparent, this circuit also resolves itself into a balanced bridge. The tuned input circuit is connected across one diagonal from points g' and g'' and the tuned output circuit is connected from the points a' and a'' across the other diagonal. Provided the arms of the bridge all contain equal effective values of inductance and capacitance the bridge will remain balanced as regards the points at which the tuned input and output circuits are connected, both for the fundamental and for the odd harmonic frequencies for which the circuit would be used. As indicated above, at high frequencies and with large valves the inductive reactance of the grid leads are appreciable, and it is the function of the grid-coupling capacitors to neutralize this inductive reactance at the fundamental frequency. At the harmonic frequencies a regenerative voltage will be fed back to the grids. This can be controlled at any desired odd harmonic by variable series- L/C impedances Z_1' and Z_1'' connected across the grid-coupling capacitors.

It has not been thought necessary to redraw Figs. 12 and 13 since, unlike the equivalent circuits of other arrangements, the various elements have retained their identities, whereas in the equivalent circuits of the other arrangements some of the elements, as, for example, the two halves of capacitor C_1 in Fig. 13 which has lost its identity in capacitance C_4 of Fig. 4, have apparently ceased to exist as separate entities.

What is claimed is:

1. A circuit arrangement including a tuned input circuit, a tuned output circuit, a pair of capacity-potentiometers coupling said circuits, the tuned input circuit being connected from a tapping point on one capacity-potentiometer to a similarly placed tapping point on the other and having its mid-point connected to the common lower end of the two capacity-potentiometers, the tuned output circuit being connected at one of its two ends to the upper end of one of the two capacity-potentiometers, at the other of its two ends to the upper end of the other of the two capacity-potentiometers, and at its mid-point to the common lower end through a connection including an inductor, wherein neutralizing capacitors are connected from the upper end of either capacity-potentiometer to the tapping point on the other and two impedances are provided, one connected across each neutralizing condenser, said impedances being constituted as series- L/C circuit elements resonant at a frequency near to the frequency of the component of frequency in the output circuit, feed-back of which it is desired to control.

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2. A circuit arrangement including a tuned input circuit coupled to a tuned output circuit by means of a pair of thermionic valves having their cathodes connected together, and from the grid of one of which to the grid of the other of which said input circuit is connected, and from the anode of one of which to the anode of the other of which said output circuit is connected, wherein for the control of feed-back from said output circuit to said input circuit, at least one series L/C impedance network is connected from the mid-point of said input circuit to said cathodes, said impedance network being resonant at a frequency near to the frequency of a component frequency which it is desired to control.

3. A circuit arrangement including a tuned input circuit coupled to a tuned output circuit by means of a pair of thermionic valves having their cathodes connected together, the anode of either being coupled through a capacitor to the grid of the other, and from the grid of one of which to the grid of the other of which said input circuit is connected, and from the anode of one of which to the anode of the other of which said output circuit is connected, wherein for the control of

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feed-back from said output circuit to said input circuit, at least one series L/C impedance network is connected across each of said capacitors, said impedance network being resonant at a frequency near to the frequency of a component frequency which it is desired to control.

4. A circuit arrangement including a tuned input circuit coupled to a tuned output circuit by means of a pair of thermionic valves having their cathodes connected together, and from the grid of one of which to the grid of the other of which said input circuit is connected, and from the anode of one of which to the anode of the other of which said output circuit is connected, wherein, in the connection between said input circuit and either of said grids a capacitor is included, and wherein for the control of feed-back from said output circuit to said input circuit, at least one series L/C impedance network is connected across each of said capacitors, said impedance network being resonant at a frequency near to the frequency of a component frequency which it is desired to control.

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