June 3, 1941. S. G. JOHANSSON 2,243,907

AMPLIFYING CIRCUIT

Filed Jan. 20, 1940 2 Sheets-Sheet 1

FIG. 1

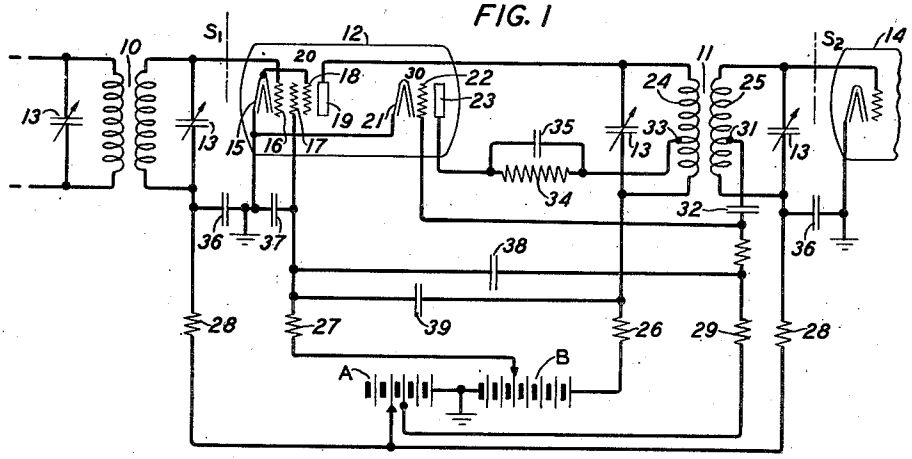


FIG. 2

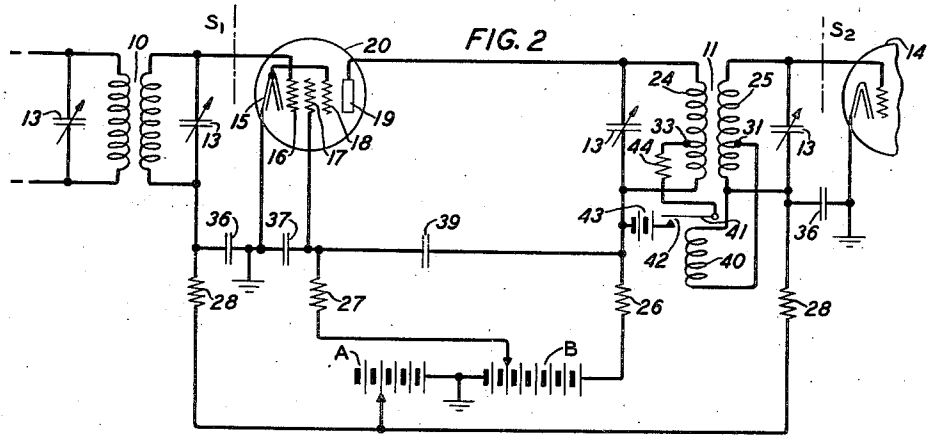


FIG. 3

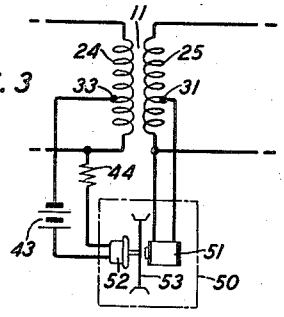
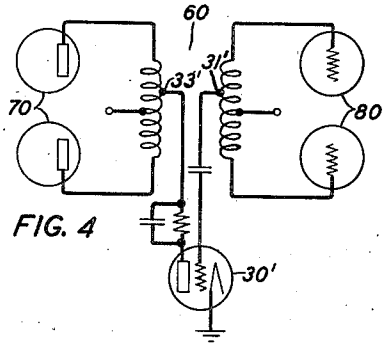


FIG. 4



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June 3, 1941. S. G. JOHANSSON 2,243,907

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Filed Jan. 20, 1940 2 Sheets-Sheet 2

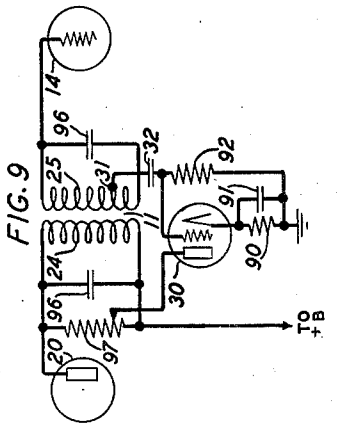


FIG. 9

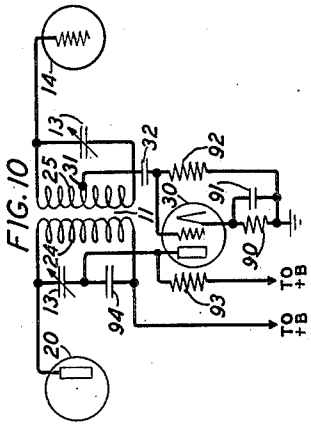


FIG. 10

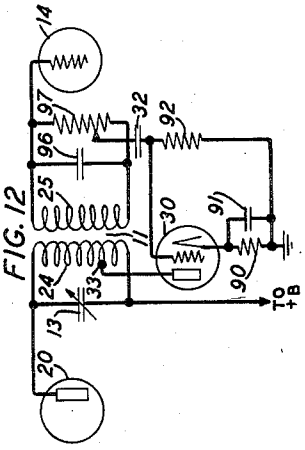


FIG. 12

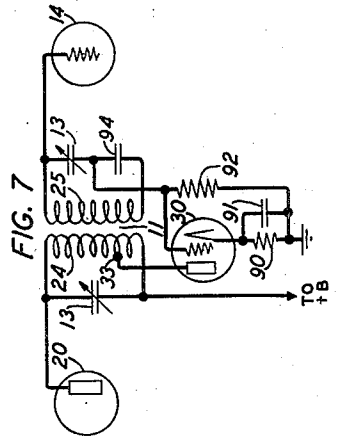


FIG. 7

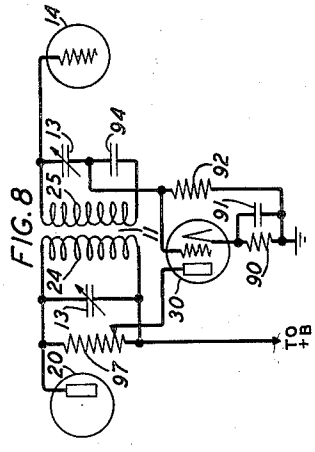


FIG. 8

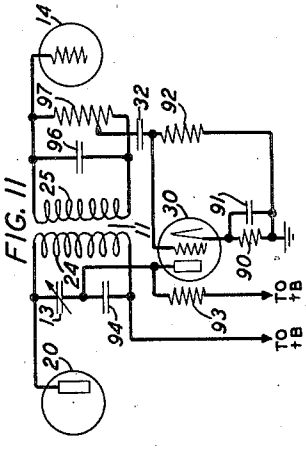


FIG. 11

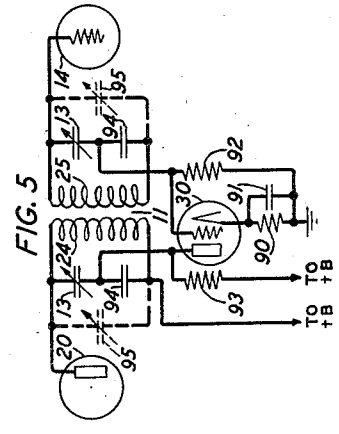


FIG. 5

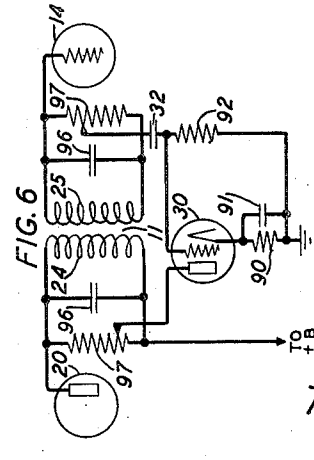


FIG. 6

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AMPLIFYING CIRCUIT

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Application January 20, 1940, Serial No. 314,781

3 Claims. (Cl. 178—44)

This invention relates to electron discharge device circuits, and, more particularly, to a method and means for improving the gain and selectivity of amplifying circuits utilizing said devices.

An object of the invention is to increase the gain and selectivity of amplifying circuits.

A feature of the invention comprises increasing the gain and selectivity of an amplifier circuit that comprises an amplifying electron discharge device and an output transformer therefor, by feeding back a portion of the transformer output winding energy to the transformer input winding side of the circuit.

In a multistage transformer-coupled amplifier, the individual amplifier stage may be considered as including that portion between the input circuit of the amplifying device thereof to the output side of the output transformer for the amplifying device. The gain of the stage will depend, of course, upon the mu of the electron discharge device, or tube, used as the amplifying device, and upon the impedance of the transformer. It may be shown that the stage gain $N=KQ\omega L$, where K is a constant dependent on the particular amplifying device used; Q is equal to the effective reactance of the transformer divided by its effective resistance; $\omega=2\pi$ times frequency; and L is the effective inductance of the transformer; where the impedance of the amplifying device's output circuit is small compared to the impedance of the amplifying device. The Q of the transformer may be increased and, therefore, the output circuit or external impedance of the amplifying device, either by an increase of its effective reactance, or by a decrease of its effective resistance.

In accordance with the invention, by feeding back a portion of the transformed output of the amplifying device from the secondary to the primary winding side of the transformer and amplifying it, the effective resistance of the transformer may be decreased, and, therefore, its Q increased. This results in an increase in the gain of the amplifying stage without affecting the gain of the amplifying device per se. The gain of the latter, of course, may be changed or adjusted by adjustment of the fixed bias on its input control grid. Since the band width of the transformer coupling is determined by its resonant frequency divided by its Q, the higher Q is, the sharper, or the narrower, the band width, i. e., selectivity, also, is improved by the feedback of energy between the windings of the transformer.

A more complete understanding of this invention will be derived from the detailed description which follows, taken in conjunction with the appended drawing, wherein:

Fig. 1 shows an amplifying circuit arrangement embodying this invention;

Figs. 2 and 3 show modifications of the circuit of Fig. 1;

Fig. 4 shows how this invention may be applied to transformer-coupled amplifier stages of the so-called push-pull type; and

Figs. 5 to 12, inclusive, show modifications of the circuit arrangements associated with the windings of the output transformer of Fig. 1.

Fig. 1 is a circuit showing of a portion of a multistage, transformer-coupled amplifier. It comprises an input transformer 10, an output transformer 11, and a so-called pentode-triode electron discharge device 12. The windings of the transformers are shunted by variable condensers 13 for tuning them to the frequency or frequency band to be amplified, the transformer 10 coupling the device 12, for example, to a preceding stage, not shown, of the amplifier and the transformer 11 coupling the device 12, for example, to a succeeding electron discharge device 14, shown fragmentarily.

The device 12 comprises a first amplifying means 20 constituted by the cathode 15, input control grid 16, screen grid 17, suppressor grid 18 and anode 19, and a second amplifying means 30 constituted by the cathode 21, control grid 22 and anode 23. The cathodes are connected together and may be of the indirectly heated type.

The output transformer 11 comprises a primary winding 24 and a secondary winding 25. One end of the winding 24 is connected to anode 19, and the other end through resistance 26 to the high or positive potential terminal of potential source B, for example, a battery. Screen grid potential is provided through resistance 27 from a terminal on source B intermediate the high and ground potential terminals thereof. Negative biasing potential for grids 16, 22 is provided by source A, for example, a battery, through grid resistances 28, 29. From a tap or terminal 31 on the winding 25 of transformer 11 connection is made through blocking condenser 32 to the grid 22, and from a tap or terminal 33 on winding 24 of transformer 11 connection is made through a plate resistance 34, by-passed by condenser 35, to the anode 23. Condensers 36, 37, 38, 39 are by-pass condensers.

The amplifying stage may be considered as that portion of the circuit included between the lines S_1 and S_2, i. e., from the input electrodes of the amplifying means 20 to the output side

of its output transformer 11. Such circuit may be the intermediate frequency stage of, or be used in, an intermediate frequency amplifier of a transmission circuit of the superheterodyne type. As already pointed out hereinbefore, the gain of the stage will depend upon the mu of the means 20, and upon the impedance of the transformer, such gain being expressible as $N=KQ\omega L$. The taps 31, 33 on the transformer windings 24, 25 permit the feeding back through the amplifying means 30 of a preassigned portion of the amplified output of means 20 appearing across the transformer secondary, to the primary winding of transformer 11. The reduction in the effective resistance of the transformer results in an increased Q, increasing the gain of the amplifying stage without affecting the gain of the amplifying means 20, and also increasing the selectivity of the amplifying stage. Although the amplifying means 30 is shown as included within the same envelope or enclosure as the amplifying means 20, it may be in a separate enclosure. The means 20 functions to amplify the signal, e. g., a radio frequency signal, arriving through the transformer 10 from a preceding portion of the circuit, whereas the means 30 functions as a part of a regenerative circuit associated with the output transformer for the means 20 so as to improve the gain and sensitivity of the amplifying stage.

Instead of an electron discharge amplifying device in the feedback path, the feedback arrangement of Fig. 2 may be employed. The latter arrangement would be most useful for increasing the gain and selectivity of a stage at low frequencies, for example, of the order of up to about 1000 cycles per second. Numerals 40 and 41 indicate the energizing winding and the armature respectively of a relay operating on low audio frequency current. The winding 40 is connected between the tap 31 and the lower end of the winding 25. The armature 41 has an associated normally-open contact 42 connected through current source 43 to the lower end of the primary winding. The armature 41 is connected through a resistance 44 to tap 33. The impedance of the relay winding and of the resistance 44 should be sufficiently large so as not to affect the Q of the transformer circuit.

A portion of the amplified low frequency output of device 20 developed across the winding 25 is effective across the winding 40 and causes armature 41 to vibrate at corresponding frequency and, in vibrating, to engage with contact 42 to complete the circuit from source 43, contact 42, armature 41, resistance 44, tap 33, winding 24 to source 43, resulting in alternating current corresponding to the armature vibration being induced in the portion of the transformer secondary across which the winding 40 is connected. A low frequency regenerative circuit is thus associated with the transformer 11 to give, as in the case of the circuit of Fig. 1, an effective reduction in the transformer resistance and an effective increase in the Q of the transformer.

An alternative to the feedback circuit of Fig. 2 is shown in Fig. 3. The feedback circuit includes an electro-mechanical amplifier 50, whose receiver winding 51 is connected in shunt with a portion of the transformer secondary winding 25. The variable resistance element or button 52 is coupled to the diaphragm 53 of the receiver, and is included in a series circuit with a resistance 44, a portion of the transformer primary winding and current source 43. This arrangement permits of a wider frequency range than that of Fig. 2, for example, of the order of up to about 5000–7000 cycles per second.

The invention is applicable, also, to transformer-coupled amplifying stages of the so-called push-pull type. As shown in Fig. 4, the transformer 60 coupling the pairs of electron discharge devices 70, 80 is provided with taps or terminals 31', 33' to which are connected the control grid and anode of an amplifying means 30', as and for the purpose described with reference to the one-side amplifying circuit of Fig. 1. The feedback circuit connections to the transformer windings are shown as fixed, but, as in the case, also, of the circuits previously described, they could, of course, be adjustable.

It will be understood by those skilled in the art that, as already indicated hereinabove, in the feeding back of a portion of the potential drop across the output winding side of the transformer 11, it is not necessarily required that the feedback connections be made directly to the windings of the transformer. Some preferred modifications are shown by Figs. 5 to 12, inclusive.

In each of Figs. 5 to 12, parts or circuit elements the same or similar to those of the circuit of Fig. 1 are designated by like identifying characters. The amplifying means 30 is shown as provided with a separate enclosure, an alternative referred to in the specific description of Fig. 1; biasing resistor 90 and by-pass condenser 91 are connected in the lead to its cathode 21; a control grid-cathode circuit resistor 92 is connected between its cathode 21 and its grid 22; and, where desirable because of an otherwise direct connection of its anode 23 to the source B of anode potential, an anode circuit resistance 93 is connected between the anode and the source B.

In the circuit of Fig. 5, a condenser 94 is connected in series with each condenser 13 across each winding of the transformer 11. The anode of the amplifying means 30 is connected to the junction of the condensers on the primary winding side, and its grid is connected to the junction of the condensers on the secondary winding side of the transformer. The condensers 94 are shown as of the fixed type, but may be variable. Addition of the condensers 95, shown by dotted lines, renders the regeneration adjustable about the initial fixed adjustment for the circuit.

In the circuit of Fig. 6, the transformer is tuned to the desired frequency or band of frequencies by means of condensers 96 connected across the transformer windings, and the feedback connection is from an adjustable point on the resistance potential divider 97 through blocking condenser 32 and the amplifying means to an adjustable point on a second resistance potential divider 97 on the primary winding side of the transformer. Of course, condensers 96 may be of the variable type, and the connections to the resistance 97 may be fixed.

The circuit arrangement of Fig. 7 combines features of that of Figs. 1 and 5, in that the feedback connection is from the junction of the condensers 13, 94 of the capacitance potential divider across the winding 25 side of the transformer (as in Fig. 5), to a tap on the primary winding 24 (as in Fig. 1); that of Fig. 8 combines features of Figs. 5 and 6, in that the feedback connection extends between a capacitance potential divider on the secondary winding side (as in Fig. 5), to a point on a resistance connected across the primary winding side of the transformer (as in Fig. 6).

The circuit arrangement of Fig. 9 combines features of Figs. 1 and 6 in that the feedback connection on the secondary winding side of the transformer is to a tap on the transformer secondary winding (as in Fig. 1), and on the primary winding side is to a resistance 37 (as in Fig. 6); that of Fig. 10 combines features of the circuits of Figs. 1 and 5 in utilizing a capacitance potential divider on the primary winding side (as in Fig. 5), and a connection to a tap on the transformer secondary winding (as in Fig. 1).

The circuit arrangement of Fig. 11 combines features of Figs. 5 and 6, in that a capacitance potential divider is connected across the primary winding 24 (as in Fig. 5), and a resistance potential divider is connected across winding 25 (as in Fig. 6), with the feedback connection between an adjustable point on the latter to the junction of the condensers of the former; that of Fig. 12 combines features of Figs. 1 and 6, in that the feedback connection is from a resistance potential divider on the secondary winding side (as in Fig. 6), to a tap on the primary winding of the transformer (as in Fig. 1).

The circuits of Figs. 7 to 12 will be recognized as involving combinations of features of the circuit arrangements of Figs. 1, 5 and 6; and will suggest to those skilled in the art other and further modifications, and that, in particular circuit arrangements, it may be desirable to utilize a multigrid discharge device, a gas-filled tube, or a discharge device other than the three-electrode amplifying means 30. The particular circuits described are believed at this time, however, to be the preferred embodiments of the invention.

Although this invention has been disclosed with reference to several specific embodiments, it is to be understood that it is not limited thereto, but is of the scope embraced by the appended claims.

What is claimed is:

1. A transmission system comprising a transformer having a plurality of windings; a series circuit including a portion of one of said windings, a source of direct current and normally-open circuit-closing means; means connected across a portion of a second of said windings and adapted to operate said circuit-closing means at an audio frequency rate; and means to impress an audio frequency electric wave across said first winding, whereby a portion of the audio frequency energy developed in said second winding is effective to energize the means connected across a portion of said second winding to operate said circuit closing means at an audio frequency rate so that audio frequency energy in said second winding is increased.

2. A transmission system comprising a transformer having a primary winding and a secondary winding; a relay having an energizing winding, an armature and an associated contact; and a source of current, said relay winding being connected across a portion of the transformer secondary winding, said source of current being connected in a circuit across a portion of the transformer primary winding, and said armature and associated contact being included in said circuit and being normally out of engagement, whereby low audio frequency electric energy developed in said relay winding when electric wave energy is applied to the transformer primary winding causes engagement of said armature and contact at a corresponding rate to produce current flow in said primary winding from said current source and an increase in the low frequency electric energy in the secondary winding.

3. A transmission system comprising a transformer having a plurality of windings and means to decrease the effective resistance of said transformer for frequencies in the lower part of the audio frequency range, said means comprising a normally-open direct current circuit including a portion of one transformer winding, and a second circuit including a portion of a second transformer winding, said second circuit being energized by audio frequency energy developed in said second transformer winding and adapted to close said direct current circuit at a rate corresponding to the audio frequency.

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