March 30, 1943. W. J. BROWN 2,315,312

ELECTRON DISCHARGE DEVICE CIRCUITS

Filed Jan. 21, 1939

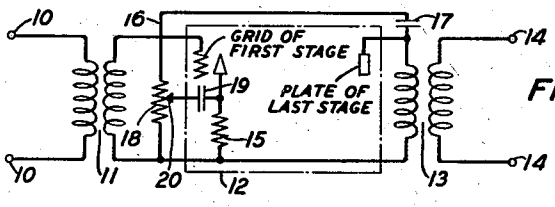

FIG. 1

FIG. 2

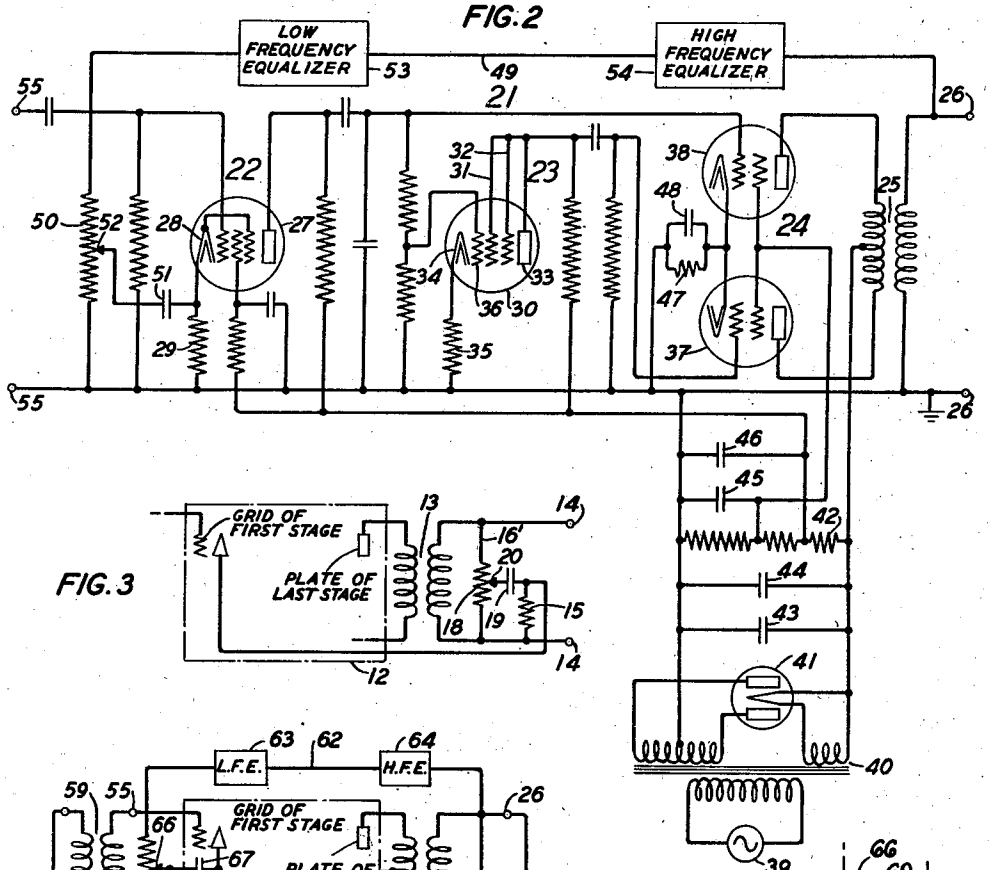

FIG. 3

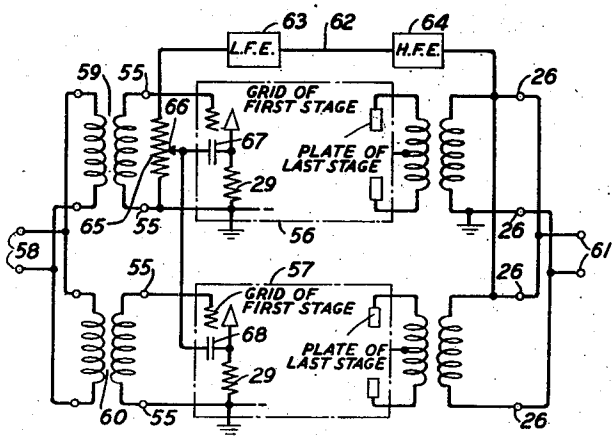

FIG. 4

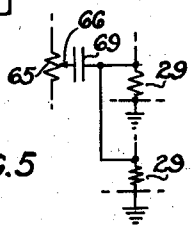

FIG. 5

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Patented Mar. 30, 1943 2,315,312

UNITED STATES PATENT OFFICE

2,315,312

ELECTRON DISCHARGE DEVICE CIRCUITS

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Application January 21, 1939, Serial No. 252,113

23 Claims. (Cl. 179—171)

This invention relates to electron discharge device circuits, and, more particularly, to electric wave amplifying circuits or systems using electron discharge devices and to a method and means for regulating or controlling the volume or level of the output of such amplifying circuits or systems.

A conventional method of and arrangement for obtaining amplifier volume control is to utilize a negative feedback by taking or deriving a portion of the output voltage of the amplifier and feeding it back through a sliding or adjustable contact to a cathode resistor in a preliminary stage. A difficulty in doing this is that variation in the slider's position on the cathode resistor produces considerable noise if the amplifier has even a moderate amount of gain.

An object of the invention is to regulate or control the output volume of an amplifying circuit or system utilizing negative feedback, and yet eliminate or minimize the introduction of noise as a result of adjustments of the control means.

Amplifiers have been operated in parallel heretofore, but the most satisfactory results have been obtainable only when the amplifiers have been matched closely in all their characteristics.

Another object of the invention, therefore, is to operate in parallel amplifiers of dissimilar gain and response characteristics, and yet obtain substantially the same effects as if the amplifiers had exactly similar characteristics.

It is frequently desirable to be able to use an amplifier of push-pull type, but the input available may be unbalanced. If means are interposed between the source of unbalanced input and the amplifier for deriving a balanced input to the push-pull amplifier, this difficulty is obviated. In order to obtain the advantages of a stabilized negative feedback amplifier, it may be desired to provide a negative feedback connection, but the manner in which this is to be done is not an obvious one.

Still another object of this invention, therefore, is to enable a source of unbalanced input signal to be coupled to a balanced or push-pull amplifier, and to provide negative feedback of energy around the amplifier.

The manner in which these and other objects of the invention are realized will be evident, and a more complete understanding of the invention will be obtained, from the detailed description which follows, taken in conjunction with the appended drawing, wherein:

Figs. 1 and 3 are simplified showings of a circuit embodying the invention;

Fig. 2 shows the circuit arrangement of a two-stage amplifier with an intermediate inverter stage coupling a single tube amplifier with a push-pull amplifier, embodying the invention;

Fig. 4 shows a circuit arrangement of two amplifiers connected for operation in parallel and having a common feedback connection in accordance with this invention; and

Fig. 5 shows a modification of the feedback resistance and cathode resistors circuit of the circuit arrangement of Fig. 4.

The circuit arrangement of Fig. 1 comprises input terminals 10; an input transformer 11; an electron discharge device circuit or system 12, more specifically, an amplifying circuit or system embodying a negative feedback connection of the type disclosed and claimed in H. S. Black Patent 2,102,671, issued December 21, 1937, i. e., one in which a portion of the output energy is fed back to a preliminary part of the circuit in such phase and of such magnitude that the overall gain of the amplifier is reduced substantially below what it would have been if there were no feedback of any kind present; an output transformer 13; and output terminals 14. The amplifier 12 is shown as general in character and as one whose output volume is regulatable or controllable by variation in the amount of energy fed back to a preliminary part of the amplifier from a part nearer the output. It is assumed, however, for the purpose of this disclosure, that the amplifier 12 is a multistage amplifier having an even number of stages, and that the cathode of the initial stage is provided with a cathode resistor 15. The feedback connection 16, in accordance with this invention, is from the plate of the last stage of the amplifier through a blocking condenser 17 and resistance 18 to the low potential end of the cathode resistor, a condenser 19 being connected between the feedback resistance 18 and the cathode resistor, one side of the condenser being connected to the end of cathode resistor nearest the cathode and the other side of the condenser being connected to

a slide or contact 20 adapted for adjustable engagement with and along the length of resistance 18.

The arrangement heretofore used to obtain output volume control by variation of the amount of negative feedback in a stabilized negative feedback amplifier has been one in which the condenser 19 and resistance 18 were not used, the feedback connection 16 being made through a slide or contact directly to the cathode resistor 15. As pointed out hereinbefore, that arrangement has been found to introduce considerable noise in the output when the slide or contact is altered. There is a potential drop across the cathode resistor; as the slide is moved along it, there will be sudden or abrupt changes in potential from one slider position to the next, i. e., between taps; or between turns, if the resistor is of the wire-wound type; or, if the resistor is of the composition type, due to the shunting out of a small section as the slide is moved along it. These changes are amplified by the amplifier and appear as noise in the output. By use of the additional resistor or resistance 18 and the condenser 19, extremely quiet operation of the volume control is obtained.

In addition to having the advantage of quiet operation, the amount of feedback around the output tube of a multistage amplifier is not reduced as much as the gain of the amplifier is increased. This occurs because the condenser 19 acts as a by-pass condenser around the cathode resistor. In an amplifier to be described more particularly with reference to Fig. 2, it was found that, over the major portion of the volume control range, the feedback voltage around the final stage is altered approximately one-half the amount of the change in gain. By appropriate selection of resistance and capacitance values for resistors 15 and 18 and condenser 19, it is possible to obtain considerable variation in the relationship between the amount of feedback and the change in gain.

In Fig. 3, the subject-matter of Fig. 1 is presented in somewhat different aspect. The feedback connection may be represented as a shunt across the secondary of the output transformer 13. The blocking condenser 17 is not required since the connection is no longer on the primary side of the transformer. The cathode resistor 15 and the coupling condenser 19 bear the same relation to the resistance 18 as they do in Fig. 1.

In each of Figs. 1 and 3, it will be noticed that, as the slide or contact 20 is adjusted along the feedback resistance, a greater or lesser portion of it is in series with the condenser 19 and resistor 15, with a consequent change in the portion in parallel with such condenser and resistor.

Fig. 2 shows a circuit arrangement for a voice and music frequency amplifier 21 suitable for use in sound reproducing systems for sound picture systems. The amplifier 21 comprises an initial amplifying stage 22 coupled through a phase inverter stage 23 to a push-pull amplifier stage 24 the output of the latter being coupled through the output transformer 25 with the output terminals 26. Amplifying stage 22 comprises a pentode 27 whose cathode 28 is provided with a cathode resistor 29. This amplifying stage is resistance-capacity coupled to the inverter and the push-pull stages. The inverter stage comprises a pentode 30 whose screen and suppressor grids 31, 32 are tied to the plate 33, and whose cathode 34 is provided with an unbypassed resistor 35 for biasing the control grid 36 and for providing a local degenerative feedback. The inverter stage is resistance-capacity coupled to the lower tetrode 37 of the tetrodes 37, 38 connected in opposition to constitute the push-pull stage. Although shown as of the indirectly heated type, the tubes, if desired, may be of the type having filamentary cathodes. Power supply for the screen grids and the plates of the tubes may be supplied from an alternating current source 39, through transformer 40, full wave rectifier 41, potentiometer 42, and associated by-pass condensers 43—46. Control grid bias for the tubes 37, 38 is provided by biasing resistor 47, shunted by signal frequency by-pass condenser 48.

The connection 49 is a negative feedback connection similar to that of Fig. 3, the feedback resistor or resistance 50, the condenser 51, the cathode resistor 29 and slide or contact 52, corresponding to the parts designated by numerals 18, 19, 15 and 20 in Fig. 3, but includes a low and a high frequency equalizer 53, 54, which were employed in an amplifier constructed in accordance with Fig. 2, so that the energy feedback was equally effective over the entire frequency range.

Not only does the amplifier 21 embody the volume control feature of this invention, it also embodies the feature of an amplifier having an over-all stabilized negative feedback connection, and a local degenerative or negative feedback in an inverter stage coupling a single amplifying tube to a push-pull amplifier stage.

The circuit arrangement described with reference to Fig. 2 enables application of an unbalanced input to the input stage of the amplifier and the deriving of push-pull or balanced output therefrom by use of a phase inverting stage and the amplification of such balanced output in a push-pull amplifying stage, with an over-all negative feedback connection from the output of the amplifier to the input circuit of the stage of which the unbalanced input is applied.

Fig. 4 is a circuit arrangement embodying this invention as applied to the operation in parallel of two stabilized negative feedback amplifiers of different characteristics. The amplifiers 56, 57 may be the same type as amplifier 21 but of different gain and/or response characteristics, and modified as pointed out hereinafter. The common input terminals 58 are coupled through the transformers 59, 60 to the input terminals 55 of the amplifiers and the common output terminals 61 are connected to the amplifier output terminals 26. Instead of a separate feedback connection such as connection 49 of Fig. 2, a common feedback connection 62 for the parallel amplifiers is provided, this connection comprising the low and high frequency equalizers 63, 64, and the feedback resistor or resistance 65. The connection 62 is terminated at the low potential end of the cathode resistor 29 of one amplifier, and connection is made from the slide or contact 66 through the condensers 67, 68 with the ends of the cathode resistors 29 near the cathode. As shown in Fig. 5, a single condenser 69 could be substituted for the two condensers 67, 68, one terminal of such condenser 69 being connected to the slide 66 and the other to the high potential ends of the resistors 29.

Experiments conducted upon two similar amplifiers resulted in an exact doubling of their load capabilities when parallel through a common feedback path. Deliberately making the gain and the response characteristics of one differ from that of the other made substantially no

difference, the results being comparable to those obtained when the amplifiers had exactly similar characteristics.

The fact that this invention has been disclosed with reference to various specific embodiments is not intended as a limitation of the invention thereto, the scope of the invention being evidenced by the appended claims.

What is claimed is:

1. An audio frequency amplifier comprising an initial amplifying stage, a second amplifying stage, means coupling said stages together, said initial stage comprising an electron discharge device having a cathode, an anode and a control grid, a resistor common to the grid-cathode and cathode-anode circuits of said device, and means for adjusting the over-all gain of said coupled stages comprising a gain reducing feedback connection from the output of said second stage to the end of said resistor remote from said cathode, said connection including means to equalize the feedback in the frequency range to be amplified and a second resistor, the two resistors being connected together through a condenser one terminal of which is connected to the cathode end of said first resistor and the other terminal of which is connected to means making an adjustable contact with said second resistor, adjustments of said latter means varying the amount of negative feedback and the over-all gain of the combination with substantially no noise being added to the amplified output.

2. In a sound reproducing system, the combination with a plurality of amplifiers having their inputs and outputs connected together, of a single negative feed-back circuit feeding back a portion of the combined outputs to the inputs of both amplifiers.

3. The combination with a plurality of power amplifiers having their inputs and combined end outputs arranged in parallel, of a single negative feed-back circuit feeding back a portion of the combined outputs to the inputs of both amplifiers.

4. The combination with a plurality of amplifiers having their inputs and their outputs connected together, of a common feed-back circuit feeding back a portion of the combined outputs to the inputs of both amplifiers.

5. In a sound reproducing system, the combination with a plurality of amplifiers having their inputs and outputs connected together, of a single negative feed-back circuit connecting the combined outputs of the amplifiers back to their inputs and an attenuation equalizer arranged in the feed-back circuit.

6. The combination with a plurality of amplifiers having their inputs and outputs arranged in parallel, of a single negative feed-back circuit feeding back a portion of the combined outputs to the inputs of both amplifiers and means, arranged in the feed-back circuit, for controlling the frequency response characteristic of the amplifiers.

7. The combination with a plurality of amplifiers having their inputs and their outputs connected together, of a single feed-back circuit common to said amplifiers and means, arranged in the feed-back circuit for determining the frequency response characteristic of the amplifiers.

8. In combination, two multistage amplifiers of dissimilar characteristics having common input and common output circuits, and means for equalizing said amplifiers so that their combined output is substantially what it would be if the amplifiers had exactly similar characteristics, said means comprising a single circuit connection common to said amplifiers for feeding back a part of their combined output to their input circuits.

9. In combination, two amplifiers of dissimilar characteristics having common input and common output circuits, and means for equalizing said amplifiers so that their combined output is substantially what it would be if the amplifiers had exactly similar characteristics, said means comprising a single circuit connection common to said amplifiers for feeding back a part of their combined outputs to their input circuits, the initial stage of each amplifier comprising a cathode resistor, and said feedback connection including a resistance having a portion thereof in series and another portion in parallel with each cathode resistor.

10. In combination, two amplifiers of dissimilar characteristics having common input and common output circuits, and means for equalizing said amplifiers so that their combined output is substantially what it would be if the amplifiers had exactly similar characteristics, said means comprising a single circuit connection common to said amplifiers for feeding back a part of their combined outputs to their input circuits, the initial stage of each amplifier comprising a cathode resistor, and said feedback connection including a resistance having a portion in series and another portion in parallel with each cathode resistor, capacitance means being connected between said feedback resistance and the cathode resistors.

11. In the amplification of an electric wave by a plurality of multistage amplifiers each having an input circuit and an output circuit, the amplifiers being of dissimilar frequency response characteristics, the input circuits being connected in parallel and the output circuits being connected in parallel, the method of equalizing for the effect of the separate amplifier characteristics on the combined output from the amplifiers of the electric wave being amplified, that comprises applying to each input circuit in phase opposition to the electric wave applied thereto a portion of the combined amplified output of the amplifiers.

12. In the amplification of an electric wave by a plurality of multistage amplifiers of dissimilar frequency response characteristics, each having an input circuit and an output circuit, the method that comprises applying the electric wave to the input circuits simultaneously, combining the amplified wave outputs appearing in the output circuit of each amplifier, deriving the amplified electric wave from said combined output, and applying a portion of said derived wave to the input circuit of each amplifier in phase opposition to the electric wave to be amplified.

13. In the amplification of an electric wave by a plurality of multistage amplifiers of dissimilar frequency response characteristics, each having an input circuit and an output circuit, the method that comprises applying the electric wave to the input circuits simultaneously, combining the amplified wave output appearing in the output circuit of each amplifier, deriving the amplified electric wave from said combined output, and applying a portion of said derived wave to the input circuit of each amplifier in phase opposition to the electric wave to be amplified and in magnitude such as to reduce substantially the over-all gain of said amplifiers compared to the over-all gain thereof if no derived wave were applied to the input circuits of the amplifiers.

14. In the amplification of an audio frequency electric wave by a plurality of audio frequency amplifiers of dissimilar gain and frequency response characteristics, each amplifier having an input circuit and an output circuit, the method that comprises applying the audio frequency wave to the input circuits simultaneously, combining the amplified wave output appearing in the output circuit of each amplifier, deriving the amplified electric wave from said combined output, and applying a portion of said derived wave to the input circuit of each amplifier in phase opposition to the electric wave to be amplified and in magnitude sufficient to reduce substantially the over-all combined gain of said amplifiers compared to their combined gain if no derived wave were applied to the input circuits of the amplifiers.

15. The combination with a plurality of audio frequency amplifiers having their input circuits connected together and their output circuits connected together, of a feedback circuit common to said amplifiers feeding back a portion of the combined output of said amplifiers to the input circuits of said amplifiers.

16. The combination with a plurality of audio frequency amplifiers having their input circuits connected together and their output circuits connected together, of a feedback circuit common to said amplifiers feeding back a portion of the combined output of said amplifiers to the input circuits of said amplifiers to reduce the overall combined gain of said amplifiers.

17. The combination with a plurality of audio frequency amplifiers having their input circuits connected together and their output circuits connected together, of a feedback circuit common to said amplifiers feeding back a portion of the combined output of said amplifiers to the input circuits of said amplifiers in phase opposition to the audio frequency electric wave applied to the amplifier input circuits.

18. The combination with a plurality of audio frequency amplifiers having their input circuits connected together and their output circuits connected together, of a feedback circuit common to said amplifiers feeding back a portion of the combined output of said amplifiers to the input circuits of said amplifiers, said feedback circuit including means to control the frequency response characteristic of said combined amplifiers.

19. The combination with a plurality of audio frequency amplifiers having their input circuits connected together and their output circuits connected together, of a feedback circuit common to said amplifiers feeding back a portion of the combined output of said amplifiers to the input circuits of said amplifiers, said feedback circuit including an attenuation equalizer.

20. In combination, two multistage audio frequency amplifiers of dissimilar characteristics having common input and common output circuits, and means for equalizing said amplifiers so that their combined output is substantially what it would be if the amplifiers had exactly similar characteristics, said means comprising a single circuit connection common to said amplifiers for feeding back a part of their combined output to their input circuits.

21. In combination, two multistage audio frequency amplifiers of dissimilar characteristics having common input and common output circuits, and means for equalizing said amplifiers so that their combined output is substantially what it would be if the amplifiers had exactly similar characteristics, said means comprising a single circuit connection common to said amplifiers for feeding back a part of their combined output to their input circuits in phase opposition to the audio frequency electric wave applied to said input circuits to be amplified.

22. In combination, two multistage audio frequency amplifiers of dissimilar characteristics having common input and common output circuits, and means for equalizing said amplifiers so that their combined output is substantially what it would be if the amplifiers had exactly similar characteristics, said means comprising a single circuit connection common to said amplifiers for feeding back a part of their combined output to their input circuits to reduce substantially the combined gain of said amplifiers compared to what the combined gain would be if no feedback connection were provided.

23. In combination, two amplifiers of dissimilar characteristics having common input and common output circuits, and means for equalizing said amplifiers so that their combined output is substantially what it would be if the amplifiers had exactly similar characteristics, said means comprising a single circuit connection common to said amplifiers for feeding back a part of their combined output to their input circuits to reduce the combined gain of said amplifiers below what the combined gain would be if no feedback connection were provided.

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