March 7, 1944. N. P. CASE 2,343,745

DIRECT CURRENT AMPLIFIER STAGE

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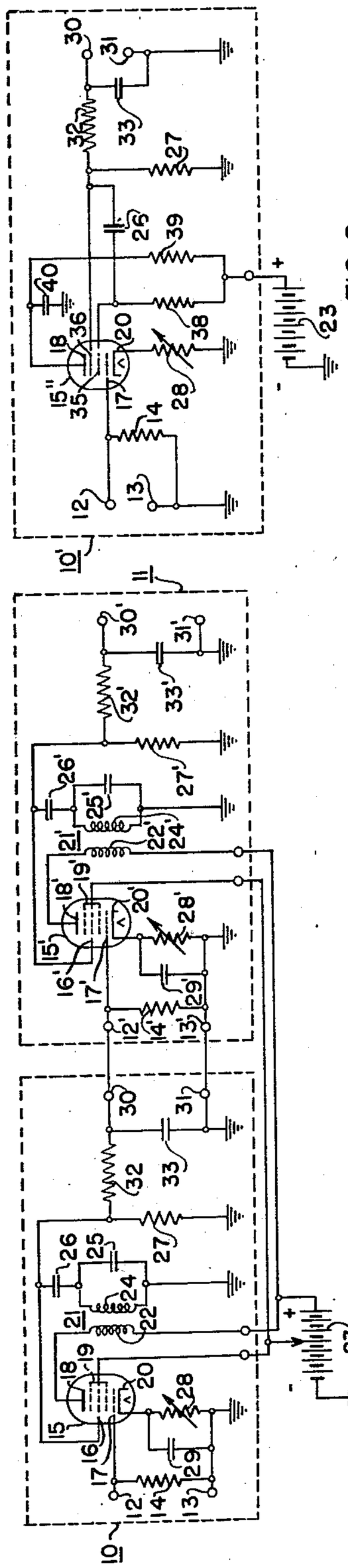

FIG. 2

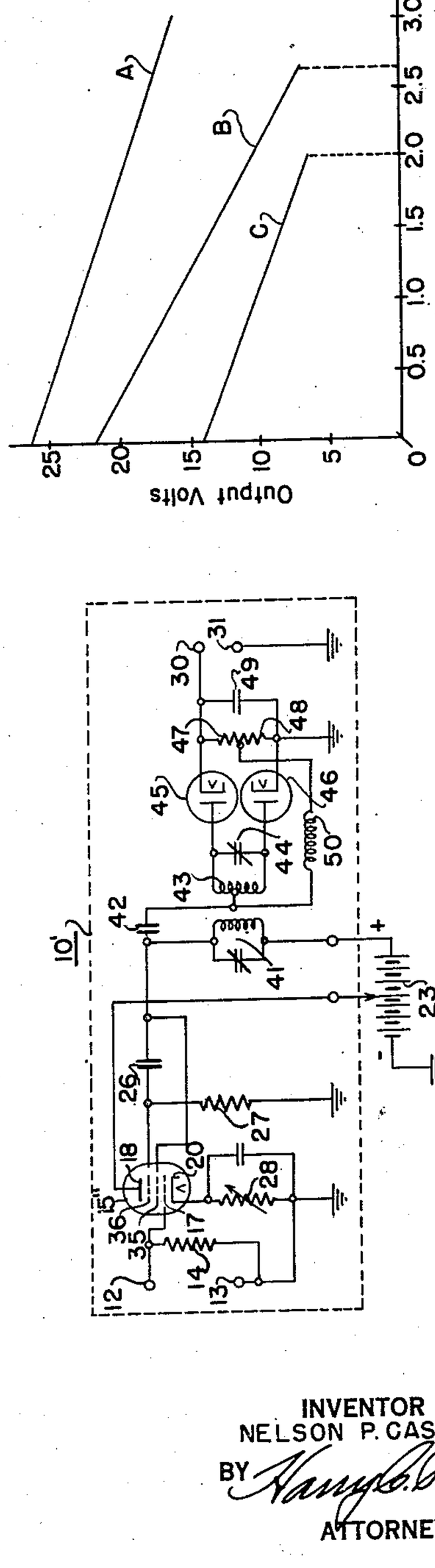

FIG. 3

FIG. 1

FIG. 4

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DIRECT-CURRENT AMPLIFIER STAGE

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The present invention relates to direct-current amplifiers, and, particularly, to direct-current amplifier stages of the type adapted to be coupled in cascade relation with one or more stages of the same type, all of such stages being energized from a common energizing source.

Direct-current amplifiers are so called because they are adapted to amplify unidirectional potentials or to amplify alternating potentials of very low frequency or alternating potentials having a unidirectional component. The input and output circuits of such amplifiers cannot be coupled to preceding and following translating circuits by the use of condensers or transformers, as in conventional alternating-current amplifiers, since coupling media of this type do not translate unidirectional signals or the direct-current component of an alternating-current signal having such component. It is, therefore, necessary that the input and output circuits of a direct-current amplifier stage be directly electrically connected to preceding and following signal-translating circuits.

Conventional amplifier stages of this nature employ a vacuum-tube repeater. Thus, in connecting one or more such stages in cascade, it is necessary that the control grid of a following vacuum-tube repeater be directly electrically connected to the anode of a preceding vacuum-tube repeater. This fact presents no serious problem where separate sources of energization are used for each such amplifier stage. However, it is frequently desirable that all of the cascade-connected amplifier stages operate from a common source of energization. When this is done, the cathode element of a following vacuum-tube repeater must be energized to a potential slightly more positive than that of the anode element of a preceding vacuum-tube repeater. This has the disadvantage that the source of energization must supply an energizing voltage of magnitude equal to the sum of the individual energizing voltages required for the cascade-connected stages of amplification. There is the further disadvantage in such prior art arrangements that where several amplifier stages must be connected in cascade and energized from a common source of energization, small variations of potential of the energizing source, due to the inherent resistance thereof or to the resistance of the voltage divider used therewith, or both, and to filter elements of insufficient size, result in a condition known as "blocking" or "motor-boating" of the cascade-connected amplifier arrangement. This is particularly true where the source of energization comprises a rectifier system for deriving the required high energizing voltage from the relatively low-voltage alternating-current power mains, an arrangement which requires a resistor type of voltage divider by which the high voltage of the energizing source may be reduced to a value suitable for each of the cascade-connected amplifier stages. With the latter type of energizing source, "blocking" or "motor-boating" of the amplifier arrangement can only be avoided by the use of filter condensers having large capacitance which, since they must be able to withstand the relatively high energizing voltages encountered, involve a comparatively expensive construction.

It is an object of the present invention, therefore, to provide a new and improved direct-current amplifier stage which avoids one or more of the disadvantages and limitations of the prior art devices of this nature.

It is a further object of the invention to provide a direct-current amplifier stage which, when used in cascade with one or more like stages having a common energizing source, has relatively high freedom from undesirable "blocking" or "motor-boating" of the cascade-connected amplifier arrangement.

It is an additional object of the invention to provide a direct-current amplifier stage adapted to be connected in cascade with one or more like stages and energized from a common energizing source and one which requires that the voltage of the energizing source be only of sufficient magnitude properly to energize any one stage of such cascade-stage amplifier arrangement.

It is a further object of the invention to provide a direct-current amplifier adapted to be used in a cascade-connected multi-stage amplifier arrangement with one or more similar stages wherein the cathode elements of vacuum tubes used in the amplifier stages are operated at substantially ground potential.

In accordance with the invention, a direct-current amplifier stage comprises an input circuit adapted to have applied thereto a signal to be amplified, means for generating oscillations of a frequency which is high compared to that of any component of the signal to be amplified, and means responsive to the signal for varying the value of a characteristic of the oscillations of the generating means substantially linearly in accordance with the instantaneous value of the signal. The amplifier also comprises means, included in the oscillation-generating means, for substantially linearly rectifying the

oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of the aforesaid characteristic, and an output circuit coupled to the last-named means for utilizing the derived amplified signal.

In a particular form of the invention, a direct-current amplifier stage of the type described includes a relaxation oscillator for generating oscillations of the desired high frequency. In one form of the invention, the signal-responsive means varies the amplitude of the generated oscillations substantially linearly in accordance with the instantaneous value of the signal, and the rectifying means is included in the oscillator and derives an amplified signal the value of which varies substantially linearly in accordance with the amplitude of the generated oscillations.

For a better understanding of the present invention, together with other and further objects thereof, reference is had to the following description taken in connection with the accompanying drawing, and its scope will be pointed out in the appended claims.

Referring now to the drawing, Fig. 1 is a circuit diagram of a two-stage cascade-connected direct-current amplifier arrangement embodying the present invention; Fig. 2 is a circuit diagram of a single-stage direct-current amplifier embodying the invention in a modified form; Fig. 3 comprises a set of graphs representing the input-output characteristics of the Fig. 2 embodiment under several specific conditions of operation; and Fig. 4 is a circuit diagram of a single-stage direct-current amplifier embodying the invention in an additionally modified form.

Referring now more particularly to Fig. 1, there is represented schematically a two-stage cascade-connected direct-current amplifier arrangement embodying the present invention in a preferred form. The two direct-current amplifier stages 10 and 11 are essentially similar and circuit elements of the second stage 11, corresponding to similar circuit elements of the first stage 10, are designated by similar reference numerals primed. Hence, only the circuit arrangement and operation of the first amplifier stage 10 will be described and it will be understood that the arrangement and operation of the second stage 11 is identical except for one feature hereinafter pointed out. The first amplifier stage 10 includes an input circuit adapted to have applied thereto a signal to be amplified, this circuit comprising a pair of input terminals 12, 13 and a resistor 14 connected thereacross, the resistor 14 also being connected between the control electrode 17 and cathode 20 of tube 15. The amplifier stage also includes means for generating oscillations of a frequency which is high compared to that of any component of the signal to be amplified, this means comprising a vacuum tube 15 having a pair of control electrodes 16 and 17, an anode 18, a screen grid 19, and a cathode 20. The control electrode 16 and cathode 20 comprise input electrodes for the vacuum tube 15, and the anode 18 and cathode 20 comprise output electrodes therefor. The oscillation-generating means of the amplifier 10 includes means for coupling the input and output electrodes of vacuum tube 15 to generate oscillations comprising an oscillation transformer 21 having a primary winding 22 connected between the anode 18 of the vacuum tube 15 and the positive terminal of a source 23 of energizing potential. The transformer 21 includes a secondary winding 24 which is tuned by a condenser 25 to the desired frequency of the oscillations to be generated and is coupled through a condenser 26 to the control electrode 16 of the vacuum tube 15. The value of either or both the amplitude and frequently characteristics of the generated oscillations is controlled by potentials applied to the control electrode 17, as will presently be described. There is included in the oscillation-generating means of the amplifier stage means for linearly rectifying the generated oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of one characteristic of the oscillations, this means comprising the coupling condenser 26 and a grid resistor 27 for the control electrode 16. A suitable operating bias for the control electrode 17 is provided from the space current of tube 15 by an adjustable cathode resistor 28 and shunt-connected by-pass condenser 29. The amplified stage 10 includes an output circuit, coupled to the grid resistor 27 for utilizing the amplified signal derived thereacross, comprising a pair of output terminals 30, 31 coupled to the grid resistor 27 through a filter network comprising a series resistor 32 and shunt condenser 33.

As previously stated, the amplifier stage 11 is essentially similar to that of the amplifier stage 10 and will, therefore, not be described, it being only necessary to point out that both of the amplifier stages 10 and 11 are energized from the same energizing source 23.

Considering now the operation of the direct-current amplifier stage 10 just described, the input electrodes 16, 20 and output electrodes 18, 20 of the vacuum tube 15 are coupled by the oscillation transformer 21 to generate oscillations of a frequency, determined primarily by the tuning of the transformer secondary winding 24 and condenser 25, which is high compared to that of any component of the signal to be amplified. The latter signal is applied to the input-circuit terminals 12, 13 and may be an alternating-current signal with or without a direct-current component or may be a unidirectional signal having either positive or negative polarity as applied to one of the input-circuit terminals, for example, the terminal 12. If the applied signal is an alternating current one having no direct-current component, the cathode resistor 28 is adjusted to such value that the bias potential developed thereacross has the correct value for operation of the control electrode 17 over the linear portion of its operating characteristic. If the applied signal is of the unidirectional type, or if it has a unidirectional or direct-current component, the cathode resistor 28 is so adjusted that the applied signal operates the control electrode 17 over the linear portion of its operating characteristic. That is, a unidirectional signal having positive polarity as applied to the input-circuit terminal 12 requires that the potential developed across the cathode resistor 28 bias the contro' electrode 17 in the vicinity of the lower limit of its linear operating characteristic. On the other hand, a unidirectional applied signal having negative polarity as applied to the input-circuit terminal 12 requires that the cathode resistor 28 be so adjusted that the potential developed thereacross biases the control electrode 17 in the vicinity of the upper limit of the linear portion of its operating characteristic.

The control electrode 17 has applied thereto the signal to be amplified and varies both the frequency and amplitude charateristics of the oscillations generated by vacuum tube 15 sub-

stantially linearly in accordance with the instantaneous value of the signal applied to the input-circuit terminals 12, 13 and independently of the rate of change of the signal. Of these, only the amplitude characteristic is utilized in the Fig. 1 embodiment of the invention. The generated oscillations are peak rectified in the circuit of the control electrode 16 to develop across the grid resistor 27 a self-bias potential the magnitude of which varies substantially linearly in accordance with the amplitude of the generated oscillations, whereby the self-bias potential accurately corresponds to an amplified signal. Thus, the control electrode 16, the cathode 20, the condenser 26, and the grid resistor 27 comprise means, included in the oscillation-generating means, for linearly rectifying the generated oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of the amplitude characteristic of the generated oscillations. Since the amplified signal is derived by peak rectification of the generated oscillations, the derived signal will include undesired high-frequency components corresponding to the fundamental frequency of the generated oscillations and harmonic frequencies thereof. These high-frequency components are removed by the filter network comprising the series resistor 32 and shunt condenser 33, whereby there is applied to the output-circuit terminals 30, 31 of the amplifier stage 10 only the amplified input signal. To provide the desired filtering action, the time constant of the resistor 32 and condenser 33 should be short relative to the period of the highest-frequency component of the signal applied to the input-circuit terminals 12, 13, but long relative to the period of the fundamental-frequency component of the generated oscillations.

The amplified signal is applied to the input-circuit terminals 12', 13' of the amplifier stage 11 where it is again amplified by this stage and applied to the output-circuit terminals 30', 31' thereof for utilization. To avoid the occurrence at the output-circuit terminals 30', 31' of amplifier stage 11 of audible beat-frequency currents, which may be produced by slight differences of frequency of the oscillations generated by the amplifier stages 10 and 11, it is preferable that the oscillations generated by the amplifier stage 11 have a frequency different from those generated by the amplifier stage 10 by at least a greater amount than the value of the highest frequency to which the utilization device, coupled to the output-circuit terminals 30', 31', is responsive. This also applies to other similar amplifier stages which may be coupled in cascade with the amplifier stages 10 and 11.

Fig. 2 is a circuit diagram of a modified form of the invention which is essentially similar to either of the amplifier stages 10 or 11 of Fig. 1, identical circuit elements being designated by the same reference numerals and analogous circuit elements by the same reference numerals double-primed, except that the means for generating oscillations comprises, in the present arrangement, a relaxation oscillator. This oscillator, which may be of any well-known type, is shown as a single tube multi-vibrator of the type disclosed in U. S. Letters Patent No. 2,203,519, granted June 4, 1940, to Madison Cawein. Briefly, the generator comprises a vacuum tube 15'' having its screen grid 35 and its suppressor grid 36 coupled together through the condenser 26, the suppressor grid 36 being provided with the grid leak 27. The screen grid 35 and the anode 18 of the vacuum tube 15'' are energized from the energizing source 23 through suitable load resistors 38, 39, respectively. A condenser 40 is connected between the anode 18 and ground, the condenser being periodically and alternately charged through the anode load resistor 39 from the energizing source 23 and discharged through the tube 15''. The adjustable cathode resistor 28 is included in the cathode lead to provide from the space current of the vacuum tube 15'' a suitable operating bias for the control electrode 17.

In considering the operation of the modified form of the invention just described, reference may be had to the aforementioned Patent 2,203,519 for a description of the detailed operation of the relaxation oscillation generator. However, for purposes of the present description of the amplifier operation, it may be stated that the anode current of the vacuum tube 15'' is of pulse wave form and that there is generated a voltage of saw-tooth wave form across the condenser 40. During the time when this occurs, the oscillations of the anode circuit cause a potential of pulse wave form to be produced in the circuit of the screen grid 35, which potential is applied through the condenser 26 to develop across the grid resistor 27 a self-bias potential for the suppressor grid 36. The magnitude of the self-bias potential varies substantially linearly in accordance with the amplitude characteristic of the oscillations generated by the vacuum tube 15''. The amplitude of the generated oscillations, however, varies substantially linearly in accordance with the instantaneous value of the signal applied between the control electrode 17 and cathode 20 of the vacuum tube 15'' from the input-circuit terminals 12, 13. Thus, the instantaneous potential applied to the control electrode 17 is repeated in amplified form across the grid resistor 27. The operation of this modified form of the invention is otherwise essentially similar to the arrangement of Fig. 1. The operating characteristics of a relaxation oscillator, as used in the Fig. 2 arrangement, somewhat simplify the attainment of a linear amplification characteristic for the direct-current amplifier stage as compared to the use of a sinusoidal oscillator, as in the amplifier stages of Fig. 1.

The input-output characteristics of a direct-current amplifier of the type shown in Fig. 2 are represented by the curves of Fig. 3. Except as noted hereinafter, representative circuit constants of an amplifier of this type are listed near the end of this specification. Curve A represents the operating characteristic of the amplifier when the resistor 28 has a value of 220 ohms, the resistor 38 a value of 68,000 ohms, the resistor 39 a value of 100,000 ohms, and the battery 23 a potential of 200 volts. Curve B illustrates the manner in which the operating characteristic of the amplifier is modified by changing the value of the resistor 38 to 100,000 ohms and the value of the resistor 39 to 68,000 ohms. Curve C illustrates the manner in which the operating characteristic is again changed when the amplifier has the circuit constants providing the characteristic represented by curve B, except that the value of resistor 28 is reduced to zero. It may be noted that the maximum input voltage for an amplifier having the circuit constants specified for curve B is slightly more than 2.5 volts at which value of input the vacuum tube 15'' ceases to generate oscillations, as indicated by

the broken-line portion of curve B. Similarly, when the amplifier has the circuit constants specified for curve C, oscillations cease when the input voltage exceeds 2.0 volts as indicated by the broken-line portion of the latter curve. An amplifier operating with the characteristic represented by curve A likewise has a maximum value of input, not indicated on curve A, which for the circuit constants has been found to be approximately 4 volts. The input-output characteristics of the amplifier over its useful range of operation are substantially linear, as indicated by these curves.

It has heretofore been stated that the applied signal varies both the frequency and amplitude characteristics of the oscillation generator used in the direct-current amplifier of the invention. The arrangements of Figs. 1 and 2 both utilize the amplitude characteristic of the generated oscillations by which to derive an amplified signal in the output circuit of the amplifier stage. Fig. 4 is a circuit diagram representing an additionally modified form of the invention in which the frequency characteristic of the generated oscillations is used for this purpose. The arrangement of Fig. 4 is essentially similar to the direct-current amplifier arrangements of Figs. 1 and 2, similar circuit elements being designated by similar reference numerals and corresponding circuit elements by the same reference numerals double-primed, except that there is coupled in circuit with the screen grid 35 of the vacuum tube 15'' a tuned circuit 41 resonant at the fundamental frequency of the oscillations generated by the vacuum tube 15''. One terminal of the tuned circuit 41 is coupled through a condenser 42 to the center point of a winding 43 which is inductively coupled to the winding of the tuned circuit 41 to provide a frequency-discriminator network. The winding 43 is tuned by a condenser 44 to the fundamental frequency of the generated oscillations and the opposite terminals of this winding are coupled to individual ones of a pair of rectifier devices 45, 46 having respective load resistors 47, 48. The load resistors 47 and 48 are shunted by a by-pass condenser 49 and the junction of the resistors is coupled through a high-frequency choke 50 to the center point of the winding 43. The frequency-discriminator network 41, 43, 44 and the rectifier devices 45, 46 and load impedances 47, 48 therefore comprise a conventional frequency detector by which there is derived across the load resistors 47, 48 a unidirectional potential the magnitude and polarity of which vary with the frequency of the generated oscillations from that frequency to which the circuits 41 and 43, 44 are tuned. The derived unidirectional potential is applied to the output-circuit terminals 30, 31 of the direct-current amplifier stage.

Considering now the operation of the Fig. 4 direct-current amplifier arrangement, the signal to be amplified is applied through input-circuit terminals 12, 13 of the amplifier to the control electrode 17 and cathode 20 of the vacuum tube 15'' to vary the frequency of the oscillations generated by the vacuum tube 15'' substantially linearly in accordance with the instantaneous value of the applied signal. The generated oscillations are applied to the frequency-discriminator network 41, 43, 44 of the frequency detector. As previously stated, the tuned circuits 41, 43 and 44 are resonant at the nominal frequency of the generated oscillations; that is, at the frequency which the generated oscillations have in the absence of any signal applied to the input circuit terminals 12, 13. There are derived by the frequency-discriminator network two voltages equal to the vector sum and difference of the voltages developed in the winding of the tuned circuit 41 and in the winding 43. These voltages are applied to individual ones of the rectifier devices 45 and 46 and there is consequently derived across the load resistors 47, 48 and the condenser 49, by linear rectification of the oscillations applied to the rectifier devices, an amplified signal the instantaneous magnitude and polarity of which vary substantially linearly in accordance with the frequency of the generated oscillations from their nominal frequency. The polarity of this derived signal may be of the same or opposite phase with respect to that applied to the input-circuit terminals 12, 13 of the amplifier stage depending upon the connections of the frequency-detector circuit as is well known in the art. The operation of the Fig. 4 arrangement is otherwise essentially the same as that of the arrangements of Figs. 1 and 2.

From the above description of the invention, it will be evident that a direct-current amplifier embodying the invention has the advantage that the cascade-connected stages of amplification may be energized from a common energizing source, the potential of which need only be sufficiently large to energize any one of the amplifier stages. Further, since each such amplifier stage is directly energized from a common energizing source without the need of voltage dividers by which the high voltage of the energizing source is reduced to a value proper for that of the individual amplifier stages, there results a great saving in the number of relatively costly filter condensers needed for use with such voltage divider, and there additionally results a high degree of freedom of a cascade-connected amplifier arrangement from "blocking" or "motorboating" due to variations of the potential of the energizing source. A cascade-connected multistage direct-current amplifier embodying the invention has the additional advantage that the cathode elements of all of the vacuum tubes used therein are operated at substantially ground potential.

As illustrative of a specific embodiment of the invention, the following circuit constants are given for an embodiment of the invention of the type shown in Fig. 2:

Vacuum tube 15''	Type 6SJ7
Condenser 40	0.002 microfarad
Condenser 26	0.002 microfarad
Condenser 33	500 micro-microfarads
Resistor 14	22,000 ohms
Resistor 27	1 megohm
Resistor 28	220 ohms max.
Resistor 32	2.2 megohms
Resistor 38	68,000 ohms
Resistor 39	0.1 megohm
Battery 23	200 volts

While there have been described what are at present considered to be the preferred embodiments of this invention, it will be obvious to those skilled in the art that various changes and modifications may be made therein without departing from the invention, and it is, therefore, aimed in the appended claims to cover all such changes and modifications as fall within the true spirit and scope of the invention.

What is claimed is:

1. A direct-current amplifier stage comprising,

an input circuit adapted to have applied thereto a signal to be amplified, means for generating oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means responsive to said signal for varying the value of a characteristic of the oscillations of said generating means substantially linearly in accordance with the instantaneous value of said signal, means included in said first-named means for substantially linearly rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of said characteristic, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

2. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, means for generating oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means responsive to said signal for varying the value of a characteristic of the oscillations of said generating means substantially linearly in accordance with the instantaneous value of said signal and independently of the rate of change thereof, means included in said first-named means for substantially linearly rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of said characteristic, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

3. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, means for generating oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means responsive to said signal for varying the amplitude of the oscillations of said generating means substantially linearly in accordance with the instantaneous value of said signal, means included in said first-named means for substantially linearly rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the amplitude of said oscillations, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

4. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, means for generating oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means responsive to said signal for varying the value of a characteristic of the oscillations of said generating means substantially linearly in accordance with the instantaneous value of said signal, means included in said first-named means for peak rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of said characteristic, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

5. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, a vacuum tube having input and output electrodes, means coupling said input and output electrodes to generate oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means included in said vacuum tube and responsive to said signal for varying the value of a characteristic of the oscillations generated by said vacuum tube substantially linearly in accordance with the instantaneous value of said signal, means included in said coupling means for substantially linearly rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of said characteristic, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

6. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, a vacuum tube having a control electrode and an anode, means coupling said anode and said control electrode to generate oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means responsive to said signal for varying the amplitude of the oscillations generated by said vacuum tube substantially linearly in accordance with the instantaneous value of said signal, means included in circuit with said control electrode for developing by rectification of said generated oscillations a self-bias potential the magnitude of which varies substantially linearly in accordance with the amplitude of said oscillations, whereby said self-bias potential accurately corresponds to an amplified signal, and an output circuit coupled to said last-named means for utilizing said developed self-bias potential.

7. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, a vacuum tube having a pair of control electrodes and an anode, means coupling one of said control electrodes and said anode to generate oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means including the other of said control electrodes for varying the value of a characteristic of the oscillations generated by said vacuum tube substantially linearly in accordance with the instantaneous value of said signal, means included in said coupling means for substantially linearly rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of said characteristic, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

8. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, a vacuum tube having a pair of control electrodes and an anode, means coupling one of said control electrodes and said anode to generate oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means including the other of said control electrodes for varying the amplitude of the oscillations generated by said vacuum tube substantially linearly in accordance with the instantaneous value of said signal, means included in circuit with said one control electrode for developing by rectification of said generated oscillations a self-bias potential the magnitude of which varies substantially linearly with the amplitude of said oscillations, whereby said self-bias potential accurately corresponds to an amplified signal, and an output circuit coupled to said last-named means for utilizing said developed self-bias potential.

9. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, a vacuum tube having

a pair of control electrodes and an anode, means coupling one of said control electrodes and said anode to generate oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means for biasing the other of said control electrodes to a predetermined operating bias on the linear portion of its operating characteristic, means including said other control electrode for varying the value of a characteristic of the oscillations generated by said vacuum tube substantially linearly in accordance with the instantaneous value of said signal, means included in said coupling means for substantially linearly rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of said characteristic, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

10. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a unidirectional signal to be amplified, said applied signal having negative polarity as applied to one terminal of said input circuit, a vacuum tube having a pair of control electrodes and an anode, means coupling one of said control electrodes and said anode to generate oscillations of a frequency which is high compared to that of any component of the signal to be amplified, the other of said control electrodes being biased in the vicinity of the upper limit of the linear portion of its operating characteristic and being connected to said one terminal of said input circuit to vary a characteristic of the oscillations generated by said vacuum tube substantially linearly in accordance with the instantaneous values of said signal, means for substantially linearly rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of said characteristic, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

11. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a unidirectional signal to be amplified, said applied signal having positive polarity as applied to one terminal of said input circuit, a vacuum tube having a pair of control electrodes and an anode, means coupling one of said control electrodes and said anode to generate oscillations of a frequency which is high compared to that of any component of the signal to be amplified, the other of said control electrodes being biased in the vicinity of the lower limit of the linear portion of its operating characteristic and being connected to said one terminal of said input circuit for substantially linearly varying a characteristic of the oscillations generated by said vacuum tube in accordance with the instantaneous values of said signal, means for substantially linearly rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of said characteristic, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

12. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, a relaxation oscillator for generating oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means responsive to said signal for varying the value of a characteristic of the oscillations of said oscillator substantially linearly in accordance with the instantaneous value of said signal, means included in said oscillator for substantially linearly rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of said characteristic, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

13. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, a vacuum tube having input and output electrodes, means coupling said input and output electrodes to generate relaxation oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means included in said vacuum tube and responsive to said signal for varying the value of a characteristic of the oscillations generated by said vacuum tube substantially linearly in accordance with the instantaneous value of said signal, means included in said coupling means for substantially linearly rectifying said oscillations to derive an amplified signal the value of which varies substantially linearly in accordance with the value of said characteristic, and an output circuit coupled to said last-named means for utilizing said derived amplified signal.

14. A direct-current amplifier stage comprising, an input circuit adapted to have applied thereto a signal to be amplified, a vacuum tube having a control electrode and an anode, means coupling said anode and said control electrode to generate relaxation oscillations of a frequency which is high compared to that of any component of the signal to be amplified, means responsive to said signal for varying the amplitude of the oscillations generated by said vacuum tube substantially linearly in accordance with the instantaneous value of said signal, means included in circuit with said control electrode for developing by rectification of said generated oscillations a self-bias potential the magnitude of which varies substantially linearly in accordance with the amplitude of said oscillations, whereby said self-bias potential accurately corresponds to an amplified signal, and an output circuit coupled to said last-named means for utilizing said developed self-bias potential.

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