

Sept. 12, 1933.

F. K. VREELAND

1,926,129

GOVERNING THE OUTPUT OF ELECTRICAL AMPLIFIERS

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3 Sheets-Sheet 1

Fig. 1.

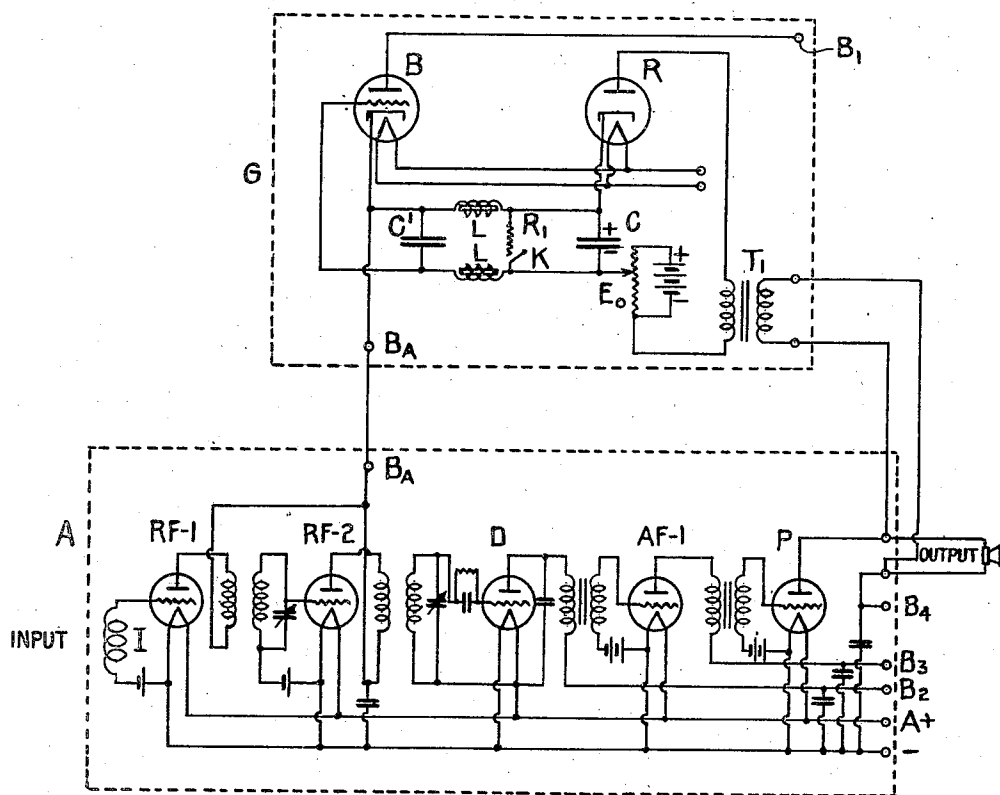
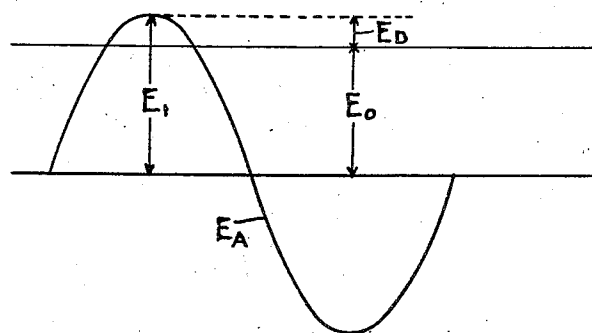


Fig. 2.



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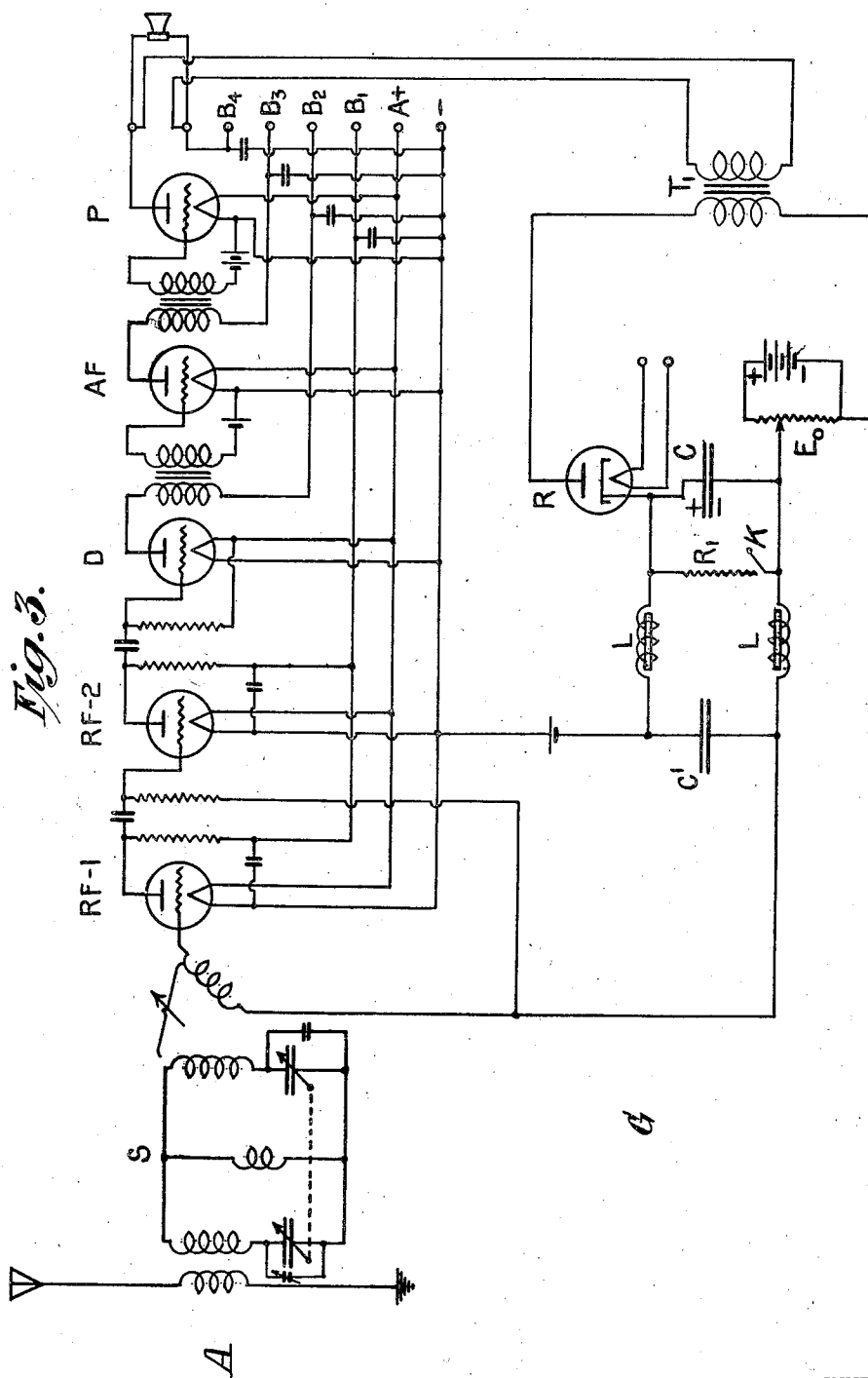
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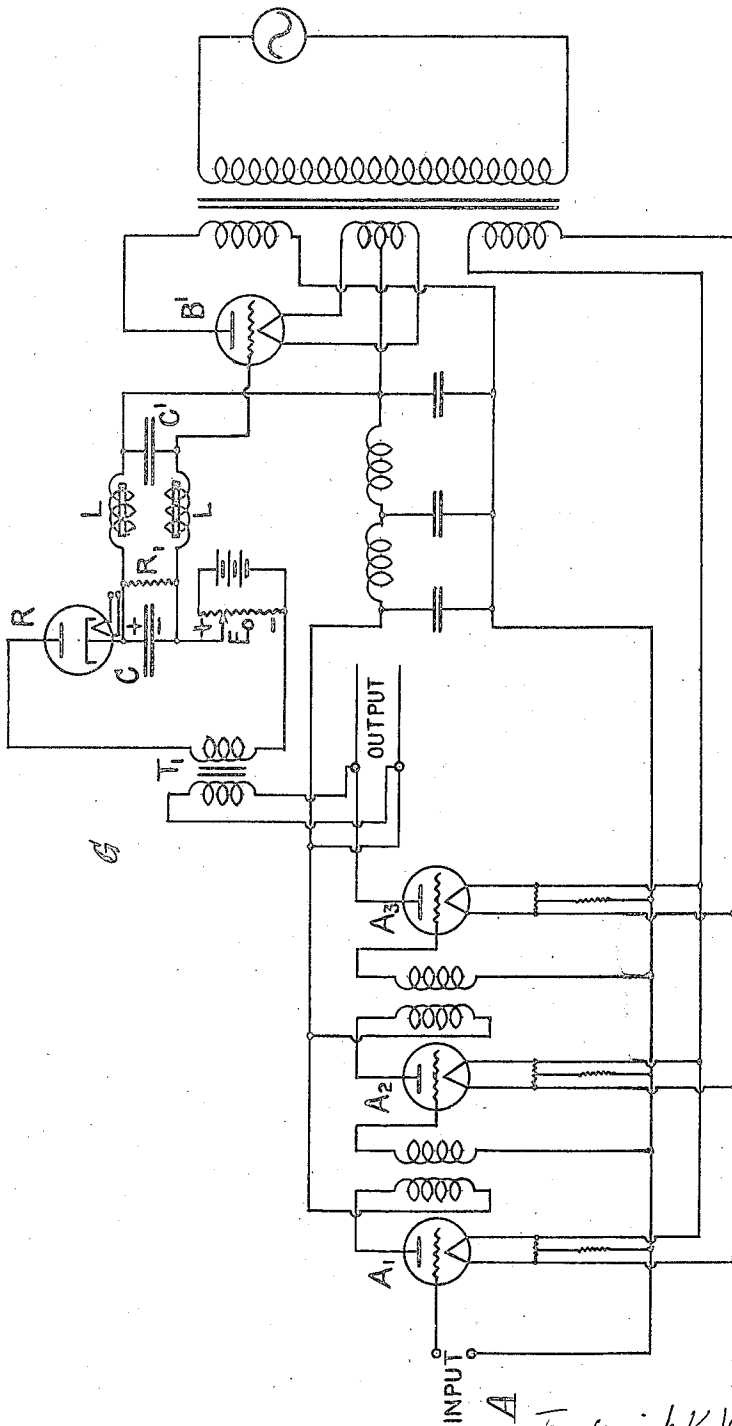
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GOVERNING THE OUTPUT OF ELECTRICAL AMPLIFIERS

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3 Sheets-Sheet 3



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UNITED STATES PATENT OFFICE

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GOVERNING THE OUTPUT OF ELECTRICAL AMPLIFIERS

Frederick K. Vreeland, Montclair, N. J.

Application August 3, 1928. Serial No. 297,337

18 Claims. (Cl. 250-20)

The invention herein described has for its principal object the controlling of the output, or specifically, the volume of sound delivered by an amplifier, and particularly the automatic governing of such output or sound volume.

The invention is applicable to amplifiers of various types but it is particularly useful in connection with radio phone receivers. When so used it permits signals of widely varying strength to be received and amplified, and it governs automatically the output or the volume of the sound delivered by the apparatus. In the preferred arrangement it limits such output or the volume of such sound to a predetermined maximum which is substantially constant and independent of the input strength of the signals applied to the receiver. It also provides for adjustment of the maximum so that the limit may be set at any desired output within the capacity of the apparatus.

The automatic governing feature is particularly useful when applied to radio receivers for broadcast reception which include selecting means for receiving at will any one of a number of different transmissions. In such receivers, as ordinarily constructed, if the volume control is set for a signal of a given strength and the frequency selector is then adjusted to a stronger or weaker signal, the reception usually is not satisfactory until the volume control is readjusted by hand. By means of the present invention it is possible to tune in or select any one of a number of different signals of widely varying strength and in each case the output level will be the same or have the same limiting value, whatever the input signal strength may be. A simple adjustment permits the setting of the output limit at any desired point. In certain cases where it is not always desirable to have the output level constant, the invention may be used to limit the output to any desired maximum while permitting manual control of the output within this limit, in which case the automatic governing feature will prevent excessive output in the case of strong signals or careless adjustment of the manual volume control.

These results are accomplished by deriving from the amplifier a governing E. M. F. (the commonly accepted abbreviation for electromotive force) depending upon the output strength or sound volume and using this governing E. M. F. to control the gain of the amplifier. In the preferred embodiment of the invention the governing is accomplished by deriving from the amplifier an alternating E. M. F. depending upon, and

preferably proportional to, the output strength or sound volume, rectifying such portion of this output E. M. F. as exceeds a given value, producing by the rectification a floating charge in a governor element and using the E. M. F. of the floating charge to govern the gain of the amplifier. Preferably the alternating E. M. F. derived from the amplifier, which may be called the output E. M. F. since it represents or depends upon the output strength, is derived from the demodulated output of a radio frequency amplifier and detector or demodulator and has a value depending on the amplified modulation and in the fullest embodiment of the invention is superimposed on a direct and preferably adjustable control E. M. F., and the resulting algebraic sum of the alternating and direct E. M. F.'s is applied to a rectifier. The negative of the control E. M. F. is connected to the anode of the rectifier and the positive to the cathode, so that ordinarily no current flows through the rectifier from the direct current source. When the peak value of the alternating or output E. M. F. exceeds the value of the direct or control E. M. F., at the moments when the peaks are positive the algebraic sum of the direct and alternating E. M. F.'s will be positive and a current will flow through the rectifier. This rectified current is used to charge a flotation condenser which constitutes the governor element, whose charge builds up until it reaches a point where its E. M. F. is equal to the excess of the positive peaks over the fixed negative control E. M. F. When the floating charge reaches this point rectification ceases. The amount of the floating charge depends upon the peak value of the alternating or output E. M. F. which in turn depends upon or is proportional to the output or sound volume. The use of a flotation condenser as the governor element has the effect of steadying the governing action by keeping the governing E. M. F. and hence the gain of the amplifier substantially constant over a considerable time, thus permitting transitory changes in the output level and giving a true rendition of speech or music, while maintaining a definite limiting level.

The floating charge in the governor element is used to control the gain of the amplifying system which supplies the output in such manner that the gain is reduced as the floating charge increases. This may be accomplished by regulating the supply of space current to the amplifier or a part thereof. The result may be accomplished in various ways. For example, in one arrangement the governing E. M. F. of the floating

charge is used to control the effective impedance of a ballast or regulator tube inserted in the plate supply of one or more of the amplifier tubes, so cutting down the current and voltage supplied to the amplifier and thus controlling its gain. In another arrangement the governing E. M. F. is used to supply a floating bias for the amplifier tubes, this bias being increased with increasing signal strength to such an extent that the gain of the amplifier is diminished. In a third arrangement the governing E. M. F. is used to control the output of a rectifier which supplies the anode current of one or more of the amplifier tubes, in such manner that the rectified voltage or current is cut down as the signal strength increases and the gain of the amplifier is correspondingly reduced. These arrangements which are chosen for illustration are typical of the various possible embodiments of the invention which will be readily understood.

It is desirable to combine the various novel features of the invention in a single apparatus, including the feature of deriving the governing E. M. F. from the demodulated output, the use of a floating charge obtained by rectification to perform the governing function, the use of a regulator tube to control the gain of the amplifier, and the devices employed to secure quick response and slow recovery in the operation of the governor, but certain advantages of the invention may be obtained by employing some of these features without the others.

In each case, when a strong signal or input is applied to the system the amplified output, if it exceeds the predetermined limiting level, causes a rectified current to flow which builds up a floating charge in the governor element or condenser, thus reducing the gain of the amplifier and tending to reduce the output E. M. F. and so limit the accumulation of the floating charge. After a brief interval a condition of equilibrium is reached in which the floating charge of the governor condenser becomes constant, and this floating charge has an E. M. F. which is added to the control E. M. F. and raises the limit at which rectification can occur. This E. M. F. also operates to reduce the gain of the amplifying system to a point which produces the desired output or sound volume, and this output or sound volume is represented by an alternating or output E. M. F. insufficient to produce further rectification except as this may be required to replenish the charge in the flotation condenser or governor element.

It will be understood that the stronger the input signals, the larger the floating charge in the governor element will become and hence the smaller the gain of the amplifier. When the parts of the system are suitably proportioned, as hereinafter explained, the governing action may be made very sensitive, so that signals of widely varying input strength will be reduced to a substantially constant output level.

The invention will be described with reference to the accompanying drawings in which it is illustrated and in which:

Figure 1 represents a typical embodiment of the invention in schematic form.

Figure 2 is a diagram illustrating the relation of the various E. M. F.'s in the system.

Figure 3 represents different application of the invention in which the governing E. M. F. operates on the grids of the amplifier tubes.

Figure 4 shows another application of the invention in which the governing E. M. F. oper-

ates to control the output of the anode supply rectifier.

Figure 1 shows schematically a self contained governor G which is capable of use with amplifiers of widely varying form, and illustrates the application of the governor in governing the output of an amplifier A. The mode of employing the governor to regulate the gain of the amplifier here shown is to control the current or E. M. F. supplied to the anodes of the amplifier by a ballast or regulator element B in the anode supply circuit, whose effective impedance is varied by the governing E. M. F. The regulator element here shown is a three-electrode tube B, of the heater type whose control electrode is operated by the governing E. M. F. This type of tube is desirable since it permits variation in the D. C. potential of the cathode.

In the drawings the amplifier is shown as comprising a radio frequency portion including two stages, RF—1 and RF—2, a detector D and an audio frequency portion including a first stage AF—1 and a power stage P. The governor is shown as operating to control the gain of the radio frequency portion, RF—1 and RF—2, this arrangement being desirable since it leaves the detector and audio frequency amplifier operating always at normal load so that they may be designed to meet the most favorable conditions of distortionless operation. Governing the radio frequency amplifier is desirable also because a very wide range of signal strengths can be thus controlled without distortion. The range of permissible signal strengths that can be effectively handled may be increased to any desired degree by increasing the number of radio frequency stages controlled by the governor.

It will be understood that the apparatus thus shown is merely typical and illustrative, the invention not being limited to any particular arrangement of the amplifier proper.

Associated with the amplifier and preferably in its output circuit, is a suitable means for taking off an alternating E. M. F. depending on the output level, which is here shown as a transformer T_1 whose primary coil is shunted across the output circuit and whose secondary coil supplies the output E. M. F. which operates the governing system. The transformer T_1 may have a step-up or step-down ratio, depending on the value of the output E. M. F. required to give the governor system the desired sensitivity, as explained later.

The governing system includes a rectifier R, preferably of the well known type including an anode and a thermionic cathode.

The secondary of the transformer T_1 is connected across the terminals of the rectifier R through a flotation condenser or governor element C and a source of direct or control E. M. F., E_0 . This control E. M. F. is preferably adjustable, for example by means of a battery and potentiometer as shown. The negative terminal of the control E. M. F., E_0 , is connected to the anode of the rectifier and the positive terminal to the cathode as shown. The alternating or output E. M. F. of the transformer T_1 is thus superimposed on the direct or control E. M. F., E_0 , and the resulting E. M. F. is applied to the rectifier through the flotation condenser or governor element C.

The terminals of the condenser C are connected through suitable choke coils L, L to the cathode and the control electrode respectively of the regulator or ballast tube B, as shown, in such manner that any floating charge accumulating in the

condenser C will be communicated to the control electrode of the regulator tube. It is usually desirable to employ the choke coils L, L to exclude any alternating component or sudden changes in the governing E. M. F. from the regulator and amplifier and permit the passage of the relatively steady floating or governing E. M. F. only. It is also desirable to employ a second condenser C' further to steady the governing E. M. F. It shares with the condenser C the functions of the flotation or governor element. The choke coils L, L, and either of the condensers C, C', as a separate element, may be omitted, though the use of both condensers and the choke coils as shown gives a steadier governing E. M. F.

The operation of the apparatus is as follows:

Any signal impulses applied to the radio frequency amplifying system RF-1 and RF-2 through the input terminals I are amplified and then applied to the detector or demodulator D, where they are demodulated or converted into audio frequency currents. These audio frequency currents are amplified by the audio frequency amplifier AF whose gain and power capacity are so chosen as to deliver the desired output to or produce the desired sound volume in a loud speaker or other translating device located in the output circuit.

The transformer T₁ derives from the amplifier an alternating output E. M. F. proportional to the output of the system and depending on the amplified modulation and impresses it on the rectifier tube R in series with the direct or control E. M. F., E₀. The positive excess of the output E. M. F., E_A, over the negative control E. M. F., E₀, is rectified in the rectifier tube R and builds up a floating charge in the governor element C, C' whose E. M. F. depends upon the positive excess of E_A over E₀.

The relations of the different E. M. F.'s is shown in the theoretical diagram Fig. 2. Here E_A represents the alternating or output E. M. F. depending upon and preferably proportional to the output, and E₀ represents the direct or control E. M. F. on which it is superimposed. If the peak value E₁ of the alternating E. M. F., E_A is less than E₀ then no positive E. M. F. will be impressed on the rectifier tube R and no rectification will occur. If however the peak value of E_A exceeds E₀, as shown, then the excess of the positive peak E₁ over the steady negative E. M. F., E₀, will be represented by the difference E_D, which impresses a positive E. M. F. on the anode of the rectifier tube. A rectified current will then flow through the tube and a charge will accumulate in the condensers constituting the governor element C, C' and this rectification and accumulation will continue until the floating E. M. F., which builds up in the condensers equals the differential E. M. F., E_D. Rectification will then cease, and becomes a substantially steady governing E. M. F.

The governing E. M. F. is communicated to the regulator tube B through the choke coils L, L, builds up a floating negative potential on the grid and thus increases the effective impedance of the tube, cutting down the flow of space current through the regulator tube and the amplifier, thus reducing the gain of the amplifier and limiting the strength of the output.

It will be seen that any excess in the output or sound volume beyond the point which makes the peak value of the output E. M. F., E_A, equal to the control E. M. F., E₀, results in building up a charge in the governor element, whose E. M. F.

cuts down the gain of the amplifier to a degree depending on the amount of excess of E_A over E₀.

The actual values of E_A and E₀ are chosen according to the value of the governing E. M. F. required to give the desired range of regulation of the amplifier gain, and according to the desired sensitivity of the governing function.

The level of the output limit is readily altered at will by suitably choosing or adjusting the control E. M. F., E₀, as by the potentiometer shown. If E₀ is made small the flotation begins and the gain is reduced when the output is relatively small. If E₀ is made larger the limit of the output level is raised. Thus by adjusting the control E. M. F., E₀, the output limit may be set at will at any desired point. When so determined the output cannot exceed the limit level except by the small amount determined by the sensitivity of the governor, and this amount may be made as small as desired, as will now be explained.

The degree of sensitivity of the governing function may be determined at will by choosing the relation of the output E. M. F., E_A, to the particular means employed to regulate the gain of the amplifier. If the system is so designed that the output E. M. F., E_A, is normally large compared to the governing E. M. F., E₀, required to regulate the gain of the amplifier, then a slight proportional increase of the output E. M. F. above that which over-flows the level of the control E. M. F., E₀, will produce a large actual increase in the governing E. M. F., and this will be sufficient to reduce the gain of the amplifier to a point which produces the desired output. The governing effect then becomes very sensitive and only a slight increase in the output level above the desired limit will be permitted. Any desired sensitivity, or permissible increase of the output above the normal, may be obtained by suitably choosing the parts, particularly the relation of the output E. M. F. and the control E. M. F. to the required governing E. M. F.

If desired, the condensers C and C' and associated parts may be made with high insulation, so that a floating charge, once accumulated in the governor element, will remain for a long time. The system will then reproduce variations in the tone values or relative strength of the input in their true relative proportions, while preventing the output from exceeding the desired limiting level. This is desirable particularly in the case of reproduction of music, to preserve the proper dynamic proportions of the composition. It is desirable however to provide means for restoring the sensitivity of the apparatus when changing to a weaker signal or input. This restoration may be accomplished automatically by shunting a high resistance leak R₁ across the governor element as shown. When the input strength decreases the floating charge will be slowly dissipated through this leak and the sensitivity of the system is thus restored. If the resistance R₁ and the capacity C+C' are made large enough the leak circuit will have a high time constant, so that the system is not sensitive to temporary variations in the input strength, which are truly reproduced in the output, but when the input strength falls permanently below a given level the sensitivity is restored after a length of time that may be determined at will by choice of the values of C+C' and R₁. The quick response and slow recovery thus secured are desirable characteristics of the invention especially when the governing function is dependent on the amplified modulation, as in the arrangement shown. This

results in maintaining the output level at a value that is independent of the degree of modulation of the carrier wave, but which reproduces, nevertheless, all the shadings or variations in dynamic of music or speech.

In some cases it is desirable to employ a key K, with or without the leak resistance R₁, so that the gain of the system, once determined by the floating E. M. F. resulting from a given signal strength, will remain constant and not subject to further fluctuation until the sensitivity of the system is restored by closing the key K and discharging the condensers C+C'.

In the arrangement shown in Figure 1 the governing function is applied to the radio frequency amplifier only. This is usually desirable for reasons already explained. The invention is not limited however to the regulation of a radio frequency amplifier, but may be applied in any desired way to control the gain of the system or otherwise govern its output.

Another mode of applying the governing function to an amplifier is shown in Figure 3. In this case a separate regulator tube is not employed, and the governing E. M. F. is applied directly to the grids of the amplifier tubes. The governor proper shown in this figure is similar to that shown in Figure 1, and the corresponding parts are indicated by the same reference characters. In Figure 3 however the mode of applying the governing E. M. F. built up in the condensers C, C' to control the gain of the amplifier is different. The terminals of the governor condensers C, C' are connected respectively to the cathodes and grids of the amplifier tubes RF—1 and RF—2, and the floating negative charge thus acquired by the grids becomes sufficiently great to choke off the anode current of these tubes, thus reducing the gain of the amplifier to the required degree.

It will thus be seen that any slight increase in the output above the predetermined limit will increase the governing E. M. F. and so reduce the gain of the amplifier that a further increase in the output is prevented. The output is thus fixed at a substantially constant value, irrespective of the input signal strength.

The type of radio frequency amplifier here shown is aperiodic and it is shown associated with a band selector of the type set forth in my United States Patent 1,725,433, August 20, 1929, but the invention may be applied with equal effect to amplifiers of other types, including selective or band amplifiers, for example those shown in my U. S. Patents No. 1,666,518, April 17, 1928, and No. 1,682,874, September 4, 1928.

Another means of regulating the gain of the system is shown in Figure 4. In this arrangement the governing E. M. F. set up in the governor element C, C' is used to regulate the output of a rectifier tube B¹ which supplies the anode current of the amplifier, and so controls its gain. The rectifier tube B¹ differs from those ordinarily employed in having a control electrode to which the governing E. M. F. is applied, thus increasing the effective impedance of the rectifier and reducing the effective anode voltage or current or both applied to the amplifier and correspondingly reducing its gain.

Various other modifications and applications of the invention will readily suggest themselves, now that the principle of the invention has been explained, and it will be understood that the invention is not limited to the particular embodiments

shown and described, except as pointed out in the accompanying claims.

I claim as my invention:

1. The method of governing the output of an electrical amplifying system for modulated signal waves which consists in amplifying and demodulating the signal wave, deriving from the demodulated output a floating electromotive force whose value depends upon its maximum amplitude, employing this electromotive force to regulate the gain of the amplifying system, and slowly dissipating the floating electromotive force when the amplitude of the demodulated output decreases and thereby restoring the gain of the amplifier.

2. The method of governing the output of an electrical amplifying system for modulated signal waves which consists in amplifying and demodulating the signal wave, deriving a floating electromotive force from the demodulated output by rectifying the excess of the demodulated output above the floating electromotive force and employing the floating electromotive force to regulate the gain of the amplifying system.

3. The method of governing the output of an electrical amplifying system which consists in deriving from the amplifying system an alternating electromotive force proportional to the output of the system, combining this alternating electromotive force with a direct electromotive force, deriving from the combination a governing electromotive force depending on the excess of the alternating electromotive force over the direct electromotive force, and using the governing electromotive force to regulate the gain of the amplifying system.

4. The method of governing the output of an electrical amplifying system which consists in deriving from the amplifying system an alternating electromotive force proportional to the output of the system, combining this alternating electromotive force with a direct control electromotive force of controllable value, deriving from this combination a governing electromotive force depending on the excess of the alternating electromotive force over the control electromotive force, using the governing electromotive force to regulate the gain of the amplifying system and adjusting the control electromotive force and thereby determining the output level of the system.

5. The method of governing the output of an electrical amplifying system which consists in deriving from the system an alternating electromotive force proportional to the output, superimposing this alternating electromotive force on a direct electromotive force, deriving by rectification a floating charge depending on the excess of the alternating electromotive force over the direct electromotive force and utilizing this floating charge to regulate the gain of the amplifying system.

6. The combination with an electrical amplifier of means for deriving from the amplifier an electromotive force dependent on the output of the amplifier, means for combining this electromotive force with a direct electromotive force, means for receiving the combined electromotive force, a condenser in which a floating charge is thus excited, and means whereby this floating charge regulates the gain of the amplifier.

7. In an electrical amplifying system a radio frequency amplifier, means for converting the amplified radio frequency energy into audio frequency energy, means for deriving from the audio

frequency energy a floating charge depending on the amount of this energy and means for regulating by this floating charge the gain of the radio frequency amplifier.

ing from the amplifier an alternating electromotive force whose value depends on the output of the amplifier, a rectifier, a source of direct electromotive force, a capacity connected in series relation with the two electromotive forces and the rectifier whereby the capacity acquires a floating charge by rectification of the resultant electromotive force, and means for utilizing the floating charge to control the gain of the amplifier.

15. An automatic governor for electrical amplifiers wherein are combined means for deriving from the amplifier an alternating electromotive force depending upon the output, means for superimposing this output electromotive force on a direct electromotive force, means for rectifying the excess of the output electromotive force over the direct electromotive force, a governor element in which a floating electromotive force is set up by such rectification, and a regulator element operated by such floating electromotive force whereby the gain of the amplifier is regulated.

16. An automatic governor for electrical amplifiers wherein are combined means for deriving from the amplifier an alternating electromotive force depending upon the output, means for superimposing the output electromotive force on a direct electromotive force, means for rectifying the excess of the output electromotive force over the direct electromotive force, a governor element in which a floating charge is set up by such rectification, a regulator element regulating the supply of space current to the amplifier, and means for operating the regulator element by the floating electromotive force.

17. An automatic governor for electrical amplifiers wherein are combined a rectifier, a condenser, means for deriving from the amplifier an alternating electromotive force whose value depends upon the output, means for impressing said electromotive force on the rectifier, means for exciting a floating charge in the condenser by rectification of the excess of said electromotive force above the floating charge, and means controlled by the floating charge for regulating the gain of the amplifier.

18. An automatic governor for electrical amplifiers wherein are combined a rectifier, a condenser, means for deriving from the amplifier an alternating electromotive force whose value depends upon the output, means for impressing said electromotive force on the rectifier, means for exciting a floating charge in the condenser by rectification of the excess of said electromotive force above the floating charge, means controlled by the floating charge for regulating the gain of the amplifier, and means whereby the floating charge is slowly dissipated when the output electromotive force decreases, thereby restoring the gain of the amplifier.

FREDERICK K. VREELAND.

DISCLAIMER

1,926,129.—*Frederick K. Vreeland*, Montclair, N. J. GOVERNING THE OUTPUT OF ELECTRICAL AMPLIFIERS. Patent dated September 12, 1933. Disclaimer filed November 14, 1936, by the assignee, *Vreeland Corporation*.

Hereby enters this disclaimer to claims 3, 4, 5, 6, 12, 13, 14, 15, 17, and 18 in said patent.

[Official Gazette December 3, 1936.]

CERTIFICATE OF CORRECTION.

Patent No. 1,926,129.

September 12. 1933.

FREDERICK K. VREELAND.

It is hereby certified that error appears in the printed specification of the above numbered patent requiring correction as follows: Page 4, line 143, claim 6, for "receiving" read rectifying; and that the said Letters Patent should be read with this correction therein that the same may conform to the record of the case in the Patent Office.

Signed and sealed this 7th day of January, A. D. 1936.

Leslie Frazer

Acting Commissioner of Patents.

(Seal)