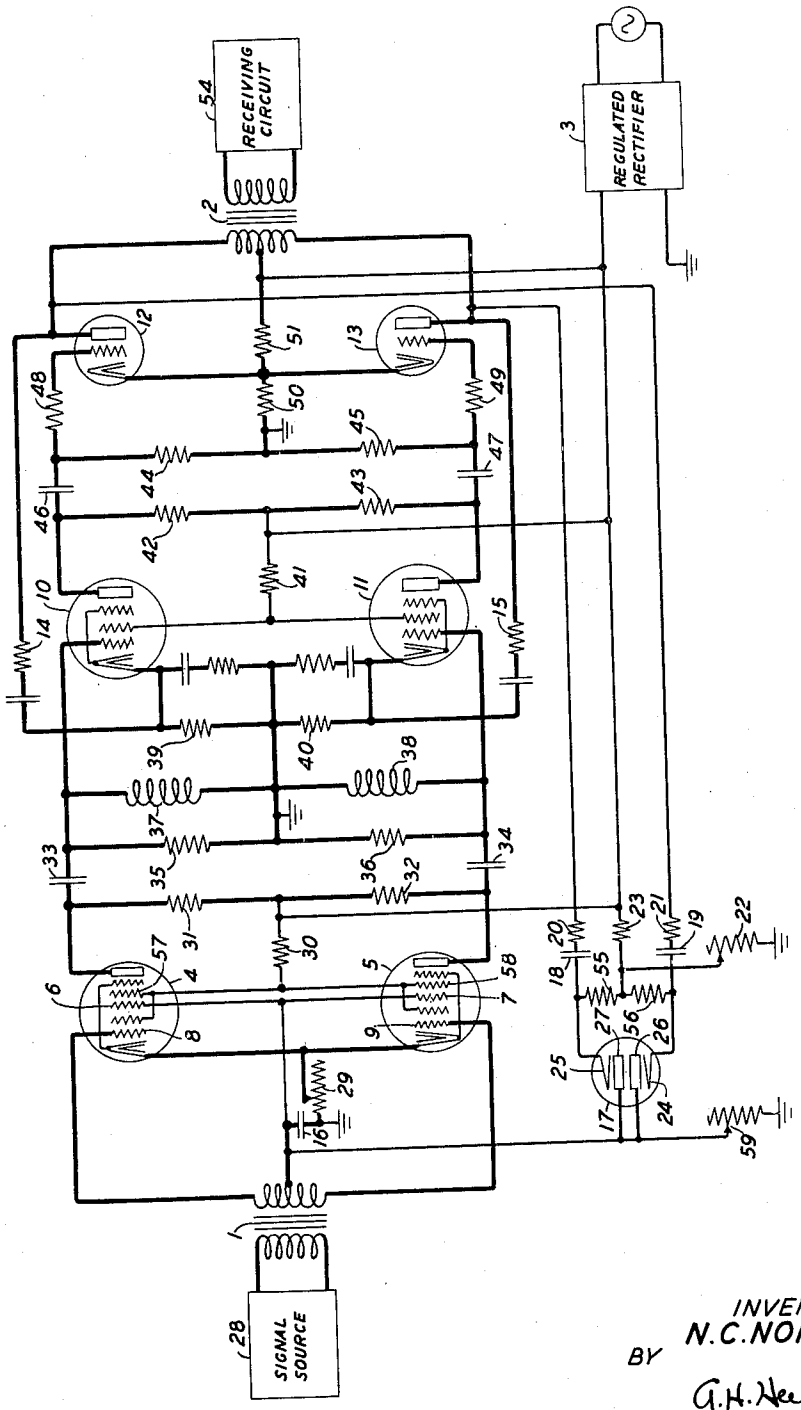
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AMPLIFYING SYSTEM

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AMPLIFYING SYSTEM

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This invention relates to amplifying systems and particularly to the automatic control of the output level of such systems.

For many applications it is highly desirable that an amplifying system be capable of being operated at a high average output level without exceeding a predetermined maximum. This is particularly true of speech input systems for radio broadcasting where, from the standpoint of maximum radiated power, it is necessary to operate close to 100 per cent modulation of the carrier but where any over-modulation, even momentarily, results in extra band radiation or "splash" which seriously interferes with other radio channels.

Various automatic volume control schemes have, of course, been suggested heretofore but these prior circuits have not been entirely satisfactory usually due either to a lag in operation upon a sudden large increase in signal level or to distortion produced by the limiting circuit.

The object of this invention is an amplifying system capable of operating at a high average output level without exceeding the allowable maximum and without introducing appreciable distortion.

According to the general features of the invention, the amplifier operates in the normal manner for signals of average intensity but as the level approaches the maximum, the transconductance is decreased by means of a very fast operating backward acting control circuit and even very sudden large increases in input level are effectively prevented from producing excessive levels in the output by this circuit in combination with an instantaneously operating peak limiter or "chopper" which is preferably operative only during the short interval required for the control circuit to become effective.

According to an important feature of the invention, one or more of the amplifier stages consist of push-pull tubes with screen grids connected to the power supply through a common unbypassed resistor. This type of screen circuit improves the dynamic balance of the amplifier for signal currents and reduces its transconductance for power supply noise and control circuit pulses thereby making it possible to eliminate the usual interstage and control circuit filters and correspondingly reduce the attack time of the control circuit.

These and other features of the invention will be more clearly understood from the following detailed description and the accompanying drawing, the single figure of which shows an amplifying system according to the invention.

The amplifier shown comprises three resistance-capacity coupled push-pull vacuum tube stages with input and output transformers 1 and 2, respectively, and a rectifier 3 for energizing the system from an alternating current circuit. The input and limiting stage comprises two pentagrid mixer tubes 4 and 5 having injector grids 6 and 7 and control grids 8 and 9. These tubes have a high sensitivity to changes in grid bias. The second stage comprises two sharp cut-off pentodes 10 and 11 and the output tubes 12 and 13 may be of the triode type as shown. Conventional negative feedback paths 14 and 15 extend from the plates of the output tubes to the cathodes of the second stage and these two stages together constitute the instantaneous peak chopper.

Variable bias voltage for the control and injector grids of the limiter tubes is impressed on the condenser 16 by the double diode 17 which is bridged across the plate circuits of the output stage through blocking condensers 18 and 19 and resistors 20 and 21 which prevent the diode from producing an excessive shunting effect on the output circuit. The signal level at which the diode 17 becomes conductive is determined by the setting of the variable resistor 22 which is connected in series with resistor 23 across the output of the power supply rectifier 3 and determines the blocking bias of the cathodes 24, 25 with respect to the plates 26, 27 of the diode 17.

Signals from the microphone or other source 28 are impressed on the input transformer 1 and are amplified in the usual manner by the tubes 4 and 5 which are self-biased by the drop in potential in resistor 29 and supplied with proper screen potential through the common resistor 30. The amplified signal voltages across the plate resistors 31, 32 are impressed through the coupling condensers 33 and 34 across the grid resistors 35, 36 of the second stage and also across the coils 37, 38 the function of which will be described below.

The tubes 10 and 11 are self-biased by the individual cathode resistors 39, 40 and provided with screen grid potential through the resistor 41 which is common to the tubes. The amplified signal potentials across the plate resistors 42 and 43 are impressed on the grid resistors 44, 45 of the output stage through the condensers 46, 47 and on the grid circuits of the tubes 12 and 13 through the series grid resistors 48, 49. These output tubes are biased by the potential

drop in resistor 50 which is connected in series with resistor 51 across the plate supply. The output of these tubes is applied through the transformer 2 to radio transmitter or other work circuit 54.

Signals of low level from the source 28 will be amplified and transmitted to the work circuit 54 in the ordinary manner. As the signal level increases the alternating components of the currents in the output stage flowing through the resistors 55 and 56 are correspondingly increased until the potentials developed across these resistors exceed the positive bias on the rectifier 17 due to the resistor 22. When excess potential is developed across resistor 55, the upper diode of tube 17 is conductive and forms with condenser 16 and resistor 59 a shunt across resistors 22 and 55 in the signal current path. Similarly when excess potential is developed across resistor 56 the lower diode of tube 17 is conductive and forms with condenser 16 and resistor 59 a conductive shunt across resistors 22 and 56. The condenser 16 is therefore charged to a potential proportional to the signal strength. This charge is applied to the control and injector grids of the tubes 4 and 5 as a variable negative bias which decreases the transconductance of the tubes and limits their output in the same general manner as in the limiter of Patent 2,199,080, granted to me April 30, 1940.

If the signal level from the source 28 increases very suddenly from a value less than that required to make the limiter operative to a very high value, the limiter may not be able to reduce the gain fast enough to prevent the output from exceeding momentarily the maximum permissible value. While the limiter of this invention is very fast acting so that these excess peaks will rarely occur and in any case will be of very short duration, they are very objectionable in radio transmitter applications and the possibility that such peaks may occur would ordinarily make it necessary to operate at a somewhat lower average output level.

In this circuit, however, the bias on the cathodes of tubes 12 and 13 is such that when the input to these tubes approaches the level which would result in an excessive output, the grids are driven positive and current flows in the grid circuits. The resistors 48 and 49 are of a high value such as 1 megohm and as soon as grid current begins to flow through them, potentials are built up across them which reduce the signal potentials at the grids almost instantaneously and prevent the output from rising beyond the desired maximum. At such times the distortion content of the output will, of course, be increased but this distortion is kept down to a moderate value by means of the negative feedback circuits 14 and 15 and it will be remembered that for high quality applications the circuit constants may be so adjusted that this peak chopping action occurs only for a very short interval since the limiting circuit quickly reduces the gain of the input tubes to the point where tubes 12 and 13 are again operating with proper negative bias.

It will be noted that the resistors 30 and 41 in the first and second stages are common to the two push-pull tubes in each case and that the condensers usually used to by-pass the resistor in the screen grid lead have been omitted. Signal voltages from the source 28 will be impressed in opposite phases on the grids 8 and 9 of the push-pull tubes 4 and 5 and the screen grids 57 and 58 of these tubes acting as anodes will develop corresponding voltages each of which is 180 degrees out of phase with the grid voltage which produced it. If the applied signals, or the tubes 4 and 5 are unbalanced, the voltages developed by the screen grids will be unequal and the changes in the screen currents will not exactly compensate each other. The net change in the total screen current will, however, produce a change in the potential drop across the common screen resistor 30 which is 180 degrees out of phase with the tube developing the higher screen voltage so that the screen grids act on the electron streams to oppose any inequalities in the voltages developed in the plate circuits due to the action of the control grids.

In other words, the varying potentials developed across the resistor 30 tend to balance the signal voltages and this effect will be cumulative in the second stage due to the similar action of resistor 41.

Any ripple voltage in the power supply or any alternating components in the volume control voltage are applied to the two tubes of each stage in the same phase. The two sides of the push-pull circuit are therefore effectively in parallel for these voltages and the changes they produce in the potential drop across the screen regulating resistors are additive with the result that the transconductance of the amplifier for these undesired variations is much less than for the signals. When, for example, the extraneous pulsations are positive at the grids 8 and 9, the plate and screen currents of the tubes 4 and 5 tend to increase but the increasing screen currents both increase the potential drop in the resistor 30 and the resulting decrease in screen grid voltage tends to reduce the plate currents. Similarly, when the applied pulsations are negative, the plate currents tend to decrease but the decrease in potential drop in resistor 30 increases the screen voltages and tends to maintain the plate currents. The use of these common unbypassed screen resistors in any push-pull amplifier simplifies the design and reduces the cost in that less filtering is required in the power supply circuit for given output noise level, more impedance in the portion of the power supply circuit which is common to the several stages can be tolerated without danger of instability, no decoupling circuits are required between the low level stages for amplifiers of even moderately large gains and more variations in tube constants and resistance values can be tolerated without producing excessive unbalance.

In the case of push-pull amplifiers with backward acting control circuits, the fact that these resistors make it possible to eliminate the usual control circuit and interstage filtering is of great advantage in decreasing the attack time of the control circuit since such filters necessarily retard the building up of the control potential across the condenser 16.

Since the levels at which the limiting and peak chopping actions begin are determined by the biases on rectifier 17 and on the tubes 12 and 13, it is necessary for a proper functioning of the circuit that these biases be held to close limits. When, as in the usual case, the power supply voltage is not constant, the rectified voltage must be closely regulated by suitable means such, for example, as the regulated rectifier disclosed in the application of J. E. Tarr, Serial No. 361,983, filed October 19, 1940.

When the impedance of the tubes 4 and 5 is suddenly increased by the action of the limiter,

there is a corresponding sudden increase in the potentials of the plates of these tubes above ground with a result that a longitudinal wave is transmitted through the condensers **33** and **34** to the grids of the tubes **10** and **11**. If this wave is of sufficient amplitude to drive the grids positive, it produces an undesirable disturbance in the output and in such cases retard coils **37** and **38** may be connected across the inputs of the tubes **10** and **11** as shown to reduce this effect to any necessary extent.

While this system has been described as one in which the limiter functions to control the output for all inputs except very sudden large peaks, it will be understood that the levels at which the limiting and peak chopping actions begin may be varied to meet the requirements of the particular case. Moreover, by making the condensers **18** and **19** and the resistor **59** associated with the rectifier of as large values as practicable and the capacity of the condenser **16** of as small value as practicable, the attack time of the limiter may be made so short that in some cases the peak chopper may not be necessary.

What is claimed is:

1. In a vacuum tube amplifying system, a vacuum tube of high sensitivity to changes in grid bias, means for automatically limiting the output of the system to a predetermined maximum level without producing appreciable distortion comprising a backward-acting volume control circuit limiting the output of the tube in accordance with the average output level of the system over a very short time interval, a second tube and means associated therewith for instantaneously limiting signal peaks in the output of the system to the predetermined maximum level, means for reducing the distortion produced by the instantaneous peak limiter, and means for fixing the operating levels of the backward-acting control and the instantaneous limiting means whereby said instantaneous limiting means is effective only over the interval during which the backward-acting control averages the output level.

2. In an amplifying system, a plurality of push-pull vacuum tube stages connected in tandem, a backward-acting control circuit extending from the output of the last stage to the input of the first stage for reducing the gain of the system when the output exceeds a predetermined level, means associated with the output stage for effecting instantaneous limiting of the signal peaks which would produce an excessive output signal level and a negative feedback path around the output stage and an intermediate stage for reducing distortion produced by the instantaneous peak limiting means.

3. A system according to the preceding claim in which the two tubes of at least one of the stages have screen grids connected to a source of current through a common unbypassed resistor.

4. A system according to claim 1 in which the input circuits of the tubes of the intermediate stage are shunted by inductances for limiting the effect of longitudinal currents produced when the gain of the system is changed by the backward-acting control circuit.

5. A system according to claim 2, in combination with a source of variable voltage for the system, means for deriving from the source biasing potentials for fixing the initial operating levels of the gain reducing and peak limiting means and means for closely regulating the biasing voltage to maintain the operating characteristics of the system substantially constant and independent of variations in the voltage of the source.

6. In an amplifier having input and output circuits and at least one stage of amplification comprising two push-pull tubes having control and screen grids, means for rectifying a portion of the output energy to produce a potential varying with the average value of the output over a predetermined very short time interval, a backward-acting circuit for applying said potential to the control grids to vary the gain of the amplifier, a source of power and a single unbypassed resistor connecting the source to the screen grids of the push-pull tubes for balancing and stabilizing the amplifier.

7. An amplifier comprising a plurality of push-pull stages connected in tandem to an output circuit, a source of power therefore having noise components, vacuum tubes in said stages having screen grids and plates connected to the source of power without interstage filtering elements and a single unbypassd resistor interposed between the source and the grids of each stage for stabilizing and balancing the amplifier and reducing the noise level in the output circuit.

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