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DRAWINGS ATTACHED

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(54) WIDE-BAND AMPLIFIER

(71) We RCA CORPORATION, a corporation organized under the laws of the State of Delaware, United States of America, of 30 Rockefeller Plaza, City and State of New York, 10020, United States of America do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:

This invention relates to wide band amplifiers and, more particularly, to one which is especially suited for fabrication using integrated circuit techniques.

A wide-band amplifier incorporating the principles of the present invention is especially useful as the gain controlled stage in the intermediate frequency (IF) channel of a transistorized television receiver. There, tuner manufacturing techniques are such that the delivered output signal at minimum signal strength without application of automatic gain control (maximum sensitivity condition is of the order of tenths of millivolts while the comparable value at maximum signal strength with automatic gain control applied (minimum sensitivity condition) often reaches 100 millivolts.

While the smaller of these two values can easily be handled by a conventional cascode transistor pair in the following gain controlled IF stage, the application of the larger of these values to the transistor pair introduces severe distortion in the amplified output. Attenuating the applied signal to the pair to an acceptable value for high input amplitudes reduces this distortion, but similarly attenuating the signals for the low input amplitudes would decrease the signal-to-noise ratio of the developed output as the major source of noise—that of the common-emitter cascode transistor — would remain substantially unchanged. The result for this condition in prior art circuits is that while the distortion is decreased, the noise in the reproduced television picture, for example, is increased.

As is apparent, however, these disadvantages are significantly reduced by using the wide-band amplifier of the present invention which, as will subsequently become clear, operates to continuously attenuate the signals applied to a transistor once the signal amplitude reaches that level at which distortion would otherwise be introduced, and to provide substantially no attenuation to those signal amplitudes which the transistor pair can easily handle and where attenuation would serve to impair signal-to-noise ratio.

Accordingly, it is an object of the present invention to provide a new and improved wide band amplifier.

With the above object in view, the present invention consists in an electrically gain-controlled amplifier comprising a first transistor having a signal input electrode and a signal output electrode; a source of automatic gain control signals; a source of input signals to be amplified; first means for coupling said input signal and automatic gain control signal sources to said input electrode over at least a first range of input signal levels; second means for sensing input signal amplitude beyond said first range and for stabilizing the bias voltage at said input electrode and the gain of said first transistor in response to sensing of said amplitude; and third means coupling said second means to said first means for varying the level of signals supplied to said input electrode in response to said sensing of said amplitude.

For a better understanding of the wide band amplifier of the present invention, reference is had to the following description taken in connection with the single figure of the drawing showing one of its embodiments.

Referring to the drawing, the wide band amplifier there shown includes a pair of cascode transistors 10 and 12 illustratively incorporated as part of an integrated circuit structure as outlined by the dotted line. The emitter electrode of the transistor 10 is connected to the collector electrode of the transistor 12, while the emitter electrode of transistor 12 is connected to a common reference, e.g. ground, point 35 for the integrated circuit structure, provided by way of a contact area 3.

The base electrode of the transistor 10 is connected to a source of energizing potential $+V_1$ whereas the base electrode of the transistor 12 is coupled to receive signals for amplification in a manner to be described hereinafter. Input signals to be amplified by the wide band circuit are applied to the integrated structure by means of a contact area 5, and output signals developed by the circuit are taken from the collector electrode of the transistor 10 at a contact area 7.

The wide band amplifier also includes three emitter-follower transistors 14, 16, and 18, each having an associated load resistor 20, 22, and 24 respectively. The collector electrodes of these transistors are commonly connected to a source of energizing potential $+V_2$ while their emitter electrodes are coupled to the reference ground point 35 by way of their respective associated load resistors.

The emitter electrode of the transistor 16 is also connected to the base electrode of the transistor 18. The emitter electrode of transistor 18 is additionally connected to the base electrode of the transistor 12, and the base electrode of the transistor 14 is connected to the input signal contact area 5.

The wide band amplifier of the drawing additionally includes a network for coupling signals between the emitter electrode of the transistor 14 and the base electrode of the transistor 16. More particularly, the network includes a pair of transistors 26 and 28 and a pair of resistors 30 and 32. The collector electrode of the transistor 26 is connected to the $+V_3$ energizing source, while the collector electrode of the transistor 28 is connected to the base electrode of the transistor 26. The collector electrode of transistor 28 is also connected to a contact area 9, at which point control currents are applied to the integrated chip for a purpose to be described below.

The resistor 30 is connected between the emitter electrodes of the transistors 14 and 26, and the resistor 32 is connected between the base electrodes of the transistors 12 and 28. Lastly, the emitter electrode of the transistor 26 is directly connected to the base electrode of the transistor 16 and the emitter electrode of the transistor 28 is connected directly to the reference point 35.

When employed as the gain controlled first IF amplifier stage in a color television receiver, the input signal contact area 5 is coupled by means of a capacitor 51 to the output of the tuner, represented by the terminal 53. The output signal contact area 7 is coupled to the input of a second IF amplifier stage (the terminal 55) and, also, to a source of operating potential $+V_3$ for the cascode transistors 10 and 12 by means of a resonant circuit 57 tuned to 50 MHz (for United States Standards) and a resistor 59.

Bias voltages for the transistor 14 are supplied by a divider network including resistors 59, 61, 63 and 65 serially connected in the order named between the source $+V_3$ and ground potential. The contact area 5 is connected between the junction of resistors 63 and 65.

Automatic gain control (AGC) voltage signals supplied from a terminal 67 to the junction of resistors 61 and 63 serve to vary the bias voltage for the transistor 14, and one of a pair of bypass capacitors 69 and 71 is included respectively at each end of resistor 61. An additional source of control potential $+V_4$ is coupled via a resistor 75 from a terminal 73 to the contact area 9, with a capacitor 77 added to bypass the contact area 9 to ground. This potential $+V_4$ and resistor 75 — both external to the integrated circuit construction—comprise the current source previously mentioned to set the threshold of attenuator action.

In such an environment, the amplitude of signals supplied by the tuner to the terminal 53 characteristically range from a few tenths of a millivolt to one hundred millivolts or so. Signals having amplitude values near the upper end of this range overload the cascode amplifier stage 10-12, and are distorted thereby. The wide band amplifier of the present invention, however, avoids this difficulty.

In the operation of the amplifier and in the absence of supplied signals to the terminal 53, the voltage at the base electrode of transistor 16 with respect to the reference point 35 is approximately 2.1 volts positive — the sum of the 0.7 base-emitter voltage drop of each of the transistors 12, 16 and 18. The energizing source $+V_4$ and the resistors 32 and 75 are selected so that the resulting current flow through resistor 32 in this quiescent condition places transistor 28 in a saturated state, with its collector electrode voltage in turn maintaining transistor 26 in non-conductive condition.

As input signals of increasing amplitude are supplied, a level will be reached at which AGC signals will be developed (in any known manner) and applied to the ter-

minal 67 to stabilize the signal excursion at the amplifier output terminal 55. These control signals are translated by the divider network 63, 65, the transistors 14, 16 and 18, and the resistor 30 from the terminal 67 to the transistor 12 to lower the transconductance of that transistor by decreasing (i.e. making more negative) its base electrode bias voltage.

At the same time, the supplied input signals will be coupled to the transistor 12 by transistor 14, resistor 30, transistor 16 and transistor 18 in that order. Thereafter, while one result of increasing input signal strength would be to further decrease the gain of the transistor 12 in order to produce the desired output signal stabilization, a second result would be that transistor 28 would remain in saturation until the translated gain control signals caused a predetermined bias voltage to be reached at the transistor 12. Once that level is reached, however, the following will be seen to happen.

First, the transistor 28 will come out of saturation, increasing its collector electrode output voltage and the base electrode bias voltage of transistor 26. When the increase is such as to operate transistor 26 into its conductive condition, the reduction in impedance level to ground through the voltage supply $+V_2$ that would result at that transistor's emitter electrode would serve to attenuate slightly — due to voltage divider action in conjunction with the resistor 30 — the signal applied to transistor 16, and consequently, the signal applied to the base electrode of transistor 12.

In this respect, it will be understood that the emitter follower transistors 16 and 18 operate to increase the impedance presented to the signals translated from transistor 14 by resistor 30. The resistor 30 is selected to be small enough compared to the effective input impedance between the base electrode of transistor 16 and ground so that there will be little attenuation of the AGC voltage when transistor 26 is nonconducting.

Second, the increase in voltage at the collector electrode of transistor 28 serves to lower the impedance of the transistor 26 so that the total AGC voltage is divided down in a manner to stabilize the direct voltage at the base of transistor 12 at a relatively fixed value.

As the supplied input signal continues to increase in amplitude, the supplied AGC signal continues to increase (more negative) as well. The negative feedback loop including transistors 16, 18, 26 and 28 and resistor 32 serves, however, to stabilize the direct voltage at the base electrode of transistor 26 and, consequently, serves to oppose any change that AGC signal increase would otherwise tend to cause in the transistor 12 base electrode bias. This situation of maintaining constant the bias on transistor 12 prevails after the input signal amplitude and AGC voltage increases sufficiently to bring the transistor 28 out of saturation.

As the supplied input signal continues to increase in amplitude, at the same time, the increasing AGC voltage coupled to transistor 14 causes the voltage at that transistor's emitter electrode to become less positive. This, in turn, causes an increase in current flow through resistor 30—rendering transistor 26 more conductive — and causes a corresponding decrease in impedance at the emitter electrode of transistor 26. The signal developed at the emitter electrode of transistor 14 is thereby attenuated prior to its translation to the base electrode of transistor 16 by an amount equal to that reduced impedance to the resistance of resistor 30, with the amount of attenuation being directly proportional to the amplitude of the supplied input signal. The result is to effectively stabilize the signal excursions at the base electrodes of the transistors 16 and 18 and, more importantly, at the base electrode of the transistor 12.

Once an input signal amplitude is reached at which transistor 28 comes out of saturation, therefore, it will be seen that the control over the signal amplitude developed at output terminal 55 will be governed by the operation of the attenuator transistor 26 in conjunction with the resistor 30. Stated another way, for a first amplitude range of supplied input signals, control is provided in the described amplifier by virtue of the supplied AGC signals reducing the gain of the transistor 12 stage while, beyond that range, the control is provided by attenuator action reducing the amplitude of signals applied to transistor 12 for amplification.

As will be readily apparent, the demarcation from the first type of control to the second type is primarily and precisely established by the selection of the energizing source $+V_4$ and the resistor 75, which together determine, or "delay", the threshold point at which transistor 28 will come out of saturation. As will also be apparent, the emitter follower transistor 14 serves to isolate the resulting impedance changes due to the attenuator action from the signal supply circuitry connected to the input terminal 53.

This operation is particular useful in the intermediate frequency amplifier of a television receiver. There, input signals having amplitudes ranging from approximately tenths of millivolts to 100 millivolts are supplied by the tuner. To prevent distortion from being introduced in the output signal of a cascode amplifier (such as includes

transistors 10 and 12), it has been found that the maximum signal swing at the base electrode of the common emitter transistor of the pair (e.g. transistor 12) should be of the order of 10 millivolts. Using the amplifier of the invention, it is but a simple matter to delay the attenuator action until the amplitude of signal applied to transistor 12 reaches this 10 millivolt level, by the selection of potential for the source $+V_1$ and resistance for the resistor 75.

For increases of corresponding input signal amplitude such as would exceed this 10 millivolt translated level, the attenuator would effectively maintain the amplitude of applied signal to the transistor 12, and would prevent the introduction of distortion into the developed output. For corresponding input signals below this amplitude level, no attenuation would be provided, and no consequent deterioration in output signal-to-noise ratio would therefore result.

WHAT WE CLAIM IS:—

1. An electrically gain-controlled amplifier comprising a first transistor having a signal input electrode and a signal output electrode; a source of automatic gain control signals; a source of input signals to be amplified; first means for coupling said input signal and automatic gain control signal sources to said input electrode over at least a first range of input signal levels; second means for sensing input signal amplitude beyond said first range and for stabilizing the bias voltage at said input electrode and the gain of said first transistor in response to sensing of said amplitude; and third means coupling said second means to said first means for varying the level of signals supplied to said input electrode in response to said sensing of said amplitude.

2. An amplifier according to Claim 1 wherein said second means comprises negative feedback means coupled to said input electrode for maintaining said bias voltage and said gain of said first transistor substantially fixed for input signals beyond said first range.

3. An amplifier according to claim 1 or 2 wherein said first means comprises a voltage divider including a substantially fixed resistance and the emitter-collector conduction path of a second transistor for coupling said input signals to said input electrode substantially without attenuation over a first range of input signal amplitudes and further coupling said input signals to said input electrode with controlled attenuation for input signal amplitudes beyond said range to effectively limit signal excursions at said input electrode to a level corresponding to the upper end of said first signal amplitude range.

4. An amplifier according to claim 3 wherein the a third transistor is coupled to sense the current flow in said first transistor and is biased into saturation for applied signals having a first range of amplitude excursions; and comprising said second transistor having an input electrode coupled to an output electrode of said third transistor and biased into non-conduction when said third transistor is in saturation; and an impedance coupling said signals to said first transistor substantially without attenuation over said first range of signal amplitude excursions and forming an attenuator network with said second transistor for signal amplitudes beyond said range effective in bringing said third transistor out of saturation and rendering said second transistor conducting.

5. An amplifier as defined in Claim 4 comprising means for coupling said control signals to said input of said first transistor to vary the direct voltage bias level thereat over said first range of signal amplitudes and to stabilize said direct voltage bias level for signal amplitudes beyond said range.

6. An amplifier as defined in Claim 5 wherein said signal source coupling means additionally includes a fourth transistor arranged in an emitter follower configuration interposed between said signal source and said attenuator impedance.

7. An amplifier as defined in Claim 6 wherein a further transistor arranged in an emitter follower configuration is interposed between said attenuator impedance and the input electrode of said first transistor.

8. An amplifier as defined in Claim 5, 6 or 7 wherein said coupling means includes a negative feedback loop including said second and third transistors coupled between said input of said first transistor and said source of gain control signals.

9. An amplifier according to any of claims 1-8 comprising a pair of transistors arranged in cascode configuration as the output stage.

10. An amplifier according to claim 9 when appendent to claim 3 comprising means for setting the threshold of signal detection for causing said attenuator network to be substantially inoperative over a first range of input signal amplitudes, wherein the amplitude of signals developed at said output terminal is primarily governed by said automatic gain control signals, and for causing said attenuator network to be substantially operative beyond said range, wherein the amplitude of signals developed at said output terminal is primarily governed by the resulting attenuation of said input signals.

11. An amplifier according to Claim 10 wherein said cascode connected transistors, said first and second means, said attenuator network, and said signal threshold detector are included in a negative feedback loop

transistors 10 and 12), it has been found that the maximum signal swing at the base electrode of the common emitter transistor of the pair (e.g. transistor 12) should be of the order of 10 millivolts. Using the amplifier of the invention, it is but a simple matter to delay the attenuator action until the amplitude of signal applied to transistor 12 reaches this 10 millivolt level, by the selection of potential for the source $+V_t$ and resistance for the resistor 75.

For increases of corresponding input signal amplitude such as would exceed this 10 millivolt translated level, the attenuator would effectively maintain the amplitude of applied signal to the transistor 12, and would prevent the introduction of distortion into the developed output. For corresponding input signals below this amplitude level, no attenuation would be provided, and no consequent deterioration in output signal-to-noise ratio would therefore result.

WHAT WE CLAIM IS:—

1. An electrically gain-controlled amplifier comprising a first transistor having a signal input electrode and a signal output electrode; a source of automatic gain control signals; a source of input signals to be amplified; first means for coupling said input signal and automatic gain control signal sources to said input electrode over at least a first range of input signal levels; second means for sensing input signal amplitude beyond said first range and for stabilizing the bias voltage at said input electrode and the gain of said first transistor in response to sensing of said amplitude; and third means coupling said second means to said first means for varying the level of signals supplied to said input electrode in response to said sensing of said amplitude.

2. An amplifier according to Claim 1 wherein said second means comprises negative feedback means coupled to said input electrode for maintaining said bias voltage and said gain of said first transistor substantially fixed for input signals beyond said first range.

3. An amplifier according to claim 1 or 2 wherein said first means comprises a voltage divider including a substantially fixed resistance and the emitter-collector conduction path of a second transistor for coupling said input signals to said input electrode substantially without attenuation over a first range of input signal amplitudes and further coupling said input signals to said input electrode with controlled attenuation for input signal amplitudes beyond said range to effectively limit signal excursions at said input electrode to a level corresponding to the upper end of said first signal amplitude range.

4. An amplifier according to claim 3 wherein the a third transistor is coupled to sense the current flow in said first transistor and is biased into saturation for applied signals having a first range of amplitude excursions; and comprising said second transistor having an input electrode coupled to an output electrode of said third transistor and biased into non-conduction when said third transistor is in saturation; and an impedance coupling said signals to said first transistor substantially without attenuation over said first range of signal amplitude excursions and forming an attenuator network with said second transistor for signal amplitudes beyond said range effective in bringing said third transistor out of saturation and rendering said second transistor conducting.

5. An amplifier as defined in Claim 4 comprising means for coupling said control signals to said input of said first transistor to vary the direct voltage bias level thereat over said first range of signal amplitudes and to stabilize said direct voltage bias level for signal amplitudes beyond said range.

6. An amplifier as defined in Claim 5 wherein said signal source coupling means additionally includes a fourth transistor arranged in an emitter follower configuration interposed between said signal source and said attenuator impedance.

7. An amplifier as defined in Claim 6 wherein a further transistor arranged in an emitter follower configuration is interposed between said attenuator impedance and the input electrode of said first transistor.

8. An amplifier as defined in Claim 5, 6 or 7 wherein said coupling means includes a negative feedback loop including said second and third transistors coupled between said input of said first transistor and said source of gain control signals.

9. An amplifier according to any of claims 1-8 comprising a pair of transistors arranged in cascode configuration as the output stage.

10. An amplifier according to claim 9 when appendent to claim 3 comprising means for setting the threshold of signal detection for causing said attenuator network to be substantially inoperative over a first range of input signal amplitudes, wherein the amplitude of signals developed at said output terminal is primarily governed by said automatic gain control signals, and for causing said attenuator network to be substantially operative beyond said range, wherein the amplitude of signals developed at said output terminal is primarily governed by the resulting attenuation of said input signals.

11. An amplifier according to Claim 10 wherein said cascode connected transistors, said first and second means, said attenuator network, and said signal threshold detector are included in a negative feedback loop

to stabilize the bias voltage at said signal input electrode for input signal amplitudes beyond said first range.

12. An amplifier according to any preceding claim wherein all the transistors and their intercoupling are integral.

13. An electrically gain-controlled amplifier substantially as hereinbefore described in conjunction with the drawing.

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