

AUTOMATIC GAIN CONTROL SYSTEM

5 This invention relates to Automatic Gain Control (AGC) systems for amplifier circuits and more particularly to such systems for adjusting the gain of a telephone amplifier circuit in dependence on the amount of current available on a telephone line.

10 Many telephone sets equipped with loudspeakers obtain the necessary electrical energy for the loudspeaker amplifier from the telephone line. The energy available however, depends on the length of the telephone line and on the current consumption of any other circuits taking their power from it.

15 It is in general not possible to know in advance the current available for the loudspeaker amplifier. Should the amplifier absorb too much current however, it may prevent other circuits from receiving sufficient energy and thereby perturb the whole telephone set. It is therefore necessary to equip the

20 loudspeaker amplifier with an AGC system which will reduce the output signal level and hence the current demand of the amplifier if it is found that insufficient supply current is available.

25 Normally the energy for the loudspeaker amplifier and other circuits, is stored in a reservoir capacitor, in parallel with which is coupled a shunt voltage regulator so as to absorb any current in excess of that which can be used. It may be noted that telephone set specifications usually define the DC characteristics at the telephone terminals and hence

30 require the absorption of certain levels of current. In the past, loudspeaker AGC systems have operated by comparing the voltage on the reservoir capacitor with a reference level, the gain being reduced should the voltage pull below the reference level. This system has several drawbacks:

35 1. The reference level must be set significantly below the regulator level to allow for tolerances and signal voltages on the reservoir capacitor. The telephone circuit

must therefore be able to operate correctly at this lower supply voltage.

5 2. The reservoir capacitor generates a time constant in the AGC loop which may compromise the dynamic performance or even the stability thereof.

 3. In some configurations there may be no reference voltage level available if the shunt regulator itself is
10 inactive because the supply voltage is reduced. A supplementary reference generator would then be required.

 There therefore exists a need for an AGC system which operates in response to the detection of inadequate supply current by means other than the detection of reduced supply
15 voltage.

 Accordingly, the invention provides an AGC system providing a control signal for controlling the gain of an amplifier receiving its power from a power supply regulated by a shunt regulator, the AGC system comprising detecting means
20 for producing a detection signal in response to current flowing in the shunt regulator, and integrating means responsive to the detection signal for providing the control signal representative of the ratio of periods of conduction and non-conduction of the shunt regulator.

25 Preferably, the detecting means comprises sensing means for sensing whether current is flowing in the shunt regulator and producing a sensing signal in response to such current flow, and means responsive to said sensing signal for adjusting the level of an input signal to produce said
30 detection signal. In a preferred embodiment, the means for adjusting the level of an input signal comprises a current mirror having a gain dependent on the sensing signal for mirroring an input current to produce the detection signal. The integrating means preferably comprises an integrating
35 element coupled to a switching means responsive to said detection signal for switching a charging signal between said integrating element and a ground reference potential, the switching means conveniently comprising a comparator having a first input for receiving the detection signal and a second

input for receiving a reference signal whereby the charging signal is switched between the integrating element and the ground reference potential in dependence on a comparison between the detection signal and the reference signal.

One embodiment of an AGC system according to the invention will now be more fully described by way of example with reference to drawings of which:

Figure 1 is a schematic diagram of a loudspeaker telephone power supply arrangement;

Figure 2 shows current waveforms for the currents of Figure 1; and

Figure 3 is a circuit diagram of an AGC system according to the invention for controlling an amplifier of the type shown in Figure 1.

Thus, a power supply arrangement for a telephone loudspeaker amplifier is shown schematically in Figure 1. Although the power is actually taken from the telephone line, for the purposes of this description there is shown a current generator 1 which supplies a current I equal to the difference between the total supply current available from the telephone line and that absorbed by the other circuits (not shown). The power supply is regulated by a shunt regulator, represented by zener diode 3, and the power is supplied to a loudspeaker amplifier 4 powered by voltage generator 5 and driving a loudspeaker 6. A reservoir capacitor 2 across which is developed a supply voltage V is coupled in parallel with the shunt regulator 3.

If a current I_A drawn by the loudspeaker amplifier 4 is always less than the supply current I , then the reservoir capacitor 2 will be charged to a voltage V_R set by the shunt regulator 3. In this condition there is no need to reduce the amplifier gain. For maximum loudspeaker power however, the average current absorbed by the amplifier can be almost equal to the supply current I , the instantaneous value being at some times much larger and at other times smaller than the supply current I . While the amplifier current I_A exceeds the

supply current I the shunt regulator 3 will be non-conducting and the capacitor 2 will be discharging. When the amplifier
5 current falls below the supply current I the capacitor 2 will charge until the regulator 3 enters conduction. Fig. 2 shows the current waveforms which will occur for a Class B type loudspeaker amplifier driven by a sinusoidal signal. It will be noted that the regulator current I_R is reduced to a
10 series of pulses if the peak loudspeaker amplifier current I_A exceeds the supply current I . The duty cycle of the I_R pulse train depends only on the ratio of the speaker amplifier current to the available current and each time a pulse occurs it is known that the full supply voltage has been
15 established. The duty cycles of the I_R pulse train may therefore be used as an input signal for an AGC system.

Fig. 3 shows the essential elements of a preferred embodiment of an AGC system using such an input signal. Capacitor C_1 is the reservoir capacitor and transistor T_1
20 (an npn bipolar transistor in this example) is the current shunt element of the shunt regulator. It is to be understood that substantially all of the current absorbed by the regulator flows through transistor T_1 . Resistor R_1 develops a voltage proportional to the current I_1 flowing
25 through transistor T_1 at low levels, the maximum voltage being limited by diode D_1 coupled in parallel with resistor R_1 so as to prevent transistor T_1 saturating at very high current levels. The voltage developed across resistor R_1 is applied in series with the diode element T_2 of a pnp current
30 mirror T_2, T_4 biased by a current I_3 supplied by an npn current source T_3, R_2 . Current I_3 is made small so that the voltage drop due to current I_3 flowing through resistor R_1 is negligible. The output of the current mirror, the collector of transistor T_4 , is coupled to a current source
35 T_5, R_3 which sinks a current somewhat larger than I_3 e.g. $1.4 I_3$ and to one input of a differential amplifier T_6, T_8 biased by a constant current I_7 supplied by a pnp current mirror T_7, T_{10} which is biased in turn by an npn current source T_{11}, R_5 . The second input of the

differential amplifier, the base of transistor T_8 , is biased in this example at two diode drops below the positive supply rail via transistor T_{10} and diode D_2 . The output of the differential amplifier, the collector of transistor T_8 , is coupled to a current source T_9 , R_4 and an integrating capacitor C_2 . In a complete circuit, means for preventing transistors T_5 and T_9 from entering saturation might be required, e.g. transistors or diodes to clamp the transistors T_5 and T_9 to appropriate voltage levels.. These have been omitted for simplicity.

The operation of the arrangement of Fig. 3 is as follows:

While the shunt regulator element T_1 is nonconducting, the pnp mirror T_2 , T_4 will provide a gain of unity so that the current supplied by transistor T_4 will be below that absorbed by transistor T_5 . The base of transistor T_6 will thus be pulled low and the current I_7 will flow via transistor T_6 to ground reference potential.

When current flows in transistor T_1 , the gain of the mirror T_2 , T_4 is increased due to the voltage developed across resistor R_{12} in series with the emitter of transistor T_2 . When the gain reaches a level such that the current that transistor T_4 would supply exceeds that absorbed by transistor T_5 , then the base of transistor T_6 will be pulled high and the current I will flow via transistor T_8 into capacitor C_2 . It is readily shown that this condition will occur if the current I_1 in transistor T_1 exceeds

$$\frac{KT}{qR_1} \ln \frac{I_5}{I_3}$$

This level can be arbitrarily made very low e.g.

$$R_1 = 10 \text{ } \Omega$$

$$\frac{I_5}{I_3} = 1.4$$

$$\frac{KT}{qR_1} \ln \frac{I_5}{I_3} \approx 1mA$$

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Thus while any significant current flows in transistor T_1 , the current I_7 will be diverted to charge the capacitor C_2 . This capacitor is continually discharged by the current source T_9 , R_4 . The ratio of the currents I_9 and I_7 thus defines the duty cycle required of the current pulses through transistor T_1 to maintain a charge on capacitor C_2 . For example, if current I_9 is one tenth of current I_7 then current pulses of more than 1mA (with the values assumed above) must flow in transistor T_1 for 10% of the time to prevent current I_9 completely discharging capacitor C_2 .

The voltage across capacitor C_2 is then applied to control the gain of the loudspeaker amplifier. While capacitor C_2 remains charged to above a suitable threshold, the gain can be maintained or increased. If capacitor C_2 discharges, then the duty cycle of the shunt regulator current pulses has fallen below the threshold set by the currents I_9 , I_7 and the gain must be reduced.

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CLAIMS

- 5 1. An AGC system providing a control signal for controlling the gain of an amplifier receiving its power from a power supply regulated by a shunt regulator, the AGC system comprising detecting means for producing a detection signal in response to current flowing in the shunt regulator, and
10 integrating means responsive to the detection signal for providing the control signal representative of the ratio of periods of conduction and non-conduction of the shunt regulator.
- 15 2. An AGC system according to Claim 1 wherein said detecting means comprises sensing means for sensing whether current is flowing in the shunt regulator and producing a sensing signal in response to such current flow, and means responsive to said
20 sensing signal for adjusting the level of an input signal to produce said detection signal.
3. An AGC system according to Claim 2 wherein said sensing means comprises a resistor coupled in series with the shunt regulator for producing a voltage when current flows through
25 the shunt regulator.
4. An AGC system according to either Claim 2 or Claim 3 wherein said means for adjusting the level of an input signal comprises a current mirror having a gain dependent on the
30 sensing signal for mirroring an input current to produce the detection signal.
5. An AGC system according to any preceding claim wherein said integrating means comprises an integrating element
35 coupled to a switching means responsive to said detection signal for switching a charging signal between said integrating element and a ground reference potential.



- 8 -

6. An AGC system according to claim 5 wherein said switching means comprises a comparator having a first input
5 for receiving the detection signal and a second input for receiving a reference signal whereby the charging signal is switched between the integrating element and the ground reference potential in dependence on a comparison between the detection signal and the reference signal.

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7. An AGC system according to claim 6 wherein said integrating element is a capacitor which is charged by the charging signal and wherein the integrating means further comprises means for discharging the capacitor such that the
15 charge remaining on the capacitor provides the control signal for controlling the gain of the amplifier.

8. An AGC system substantially as hereinbefore described by way of example with reference to the drawings.
