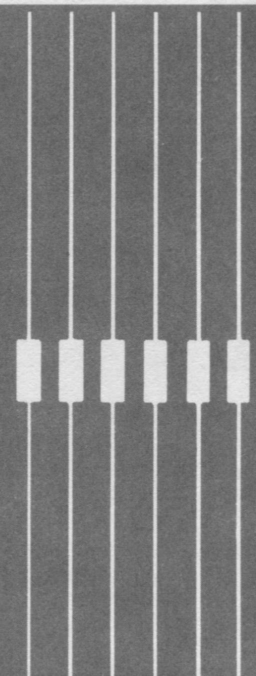
APPLICATION NOTE 936

HIGH PERFORMANCE PIN ATTENUATOR FOR LOW COST AGC APPLICATIONS

HEWLETT hp PACKARD



SUMMARY

PIN diodes offer an economic way of achieving excellent performance in AGC circuits. Significant improvements in crossmodulation and intermodulation distortion performance compared to transistors are obtained.

Other advantages of PIN diodes, such as good low frequency operation, constant impedance levels, and low power consumption will be discussed in this article.

INTRODUCTION

In the short time since its introduction, the PIN diode has found many areas of application. New developments in diode design have allowed the PIN diode to be useful at much lower frequencies than ever before. This article describes its use as an attenuator for automatic gain control and compares its performance to a transistorized AGC system in a television receiver.

The most important feature of the PIN diode is its inherent ability to act as a current controlled resistor a⁺ RF frequencies. Most diodes possess this capability to some degree, but the PIN diode is especially optimized in design to achieve a wide resistance range with consistently good linearity and low distortion. As typically shown in Figure 1, when the control current is varied continuously from 1 μA to 100 mA, the resistance of a PIN diode will change from over ten thousand ohms to about one ohm. This characteristic variation of resistance with current makes the PIN diode ideally suited for application in automatic gain control systems.

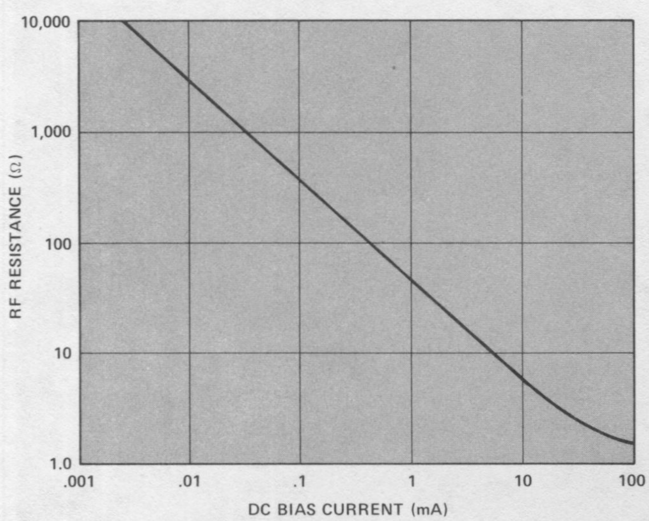


Figure 1. Typical PIN Diode Resistance vs. Control Current.

The PIN diode is similar to ordinary PN junction diodes except for an added intrinsic region (I-layer) sandwiched between the p^+ and n^+ layers. It is in this I-layer that the control of minority carriers is enhanced. The high resistance and large width of the intrinsic layer result in a high breakdown voltage and low capacitance. When forward bias is applied between p^+ and n^+ layers, the injection of minority carriers into the intrinsic region increases the conductivity of the I-layer.

Above a limiting frequency the PIN diode acts as a pure resistance. This RF resistance is controlled by varying the forward bias. Below the limiting frequency, rectification occurs as in an ordinary PN diode. In the vicinity of the limiting frequency there is some rectification with resulting distortion in RF resistance. The amount of distortion is dependent on the bias current, RF power, the frequency, and minority carrier lifetime. Distortion becomes appreciable at a frequency of operation equal to about 10 times the inverse of the minority carrier lifetime. Diodes of the HP 5082-3080 series, especially designed for low frequency operation, have a lifetime in excess of 1 microsecond, and are thus useful below 10 MHz. As an example, these low frequency PIN diodes are suitable for use in the attenuator to be described here for AGC application in television receivers.

AUTOMATIC GAIN CONTROL SYSTEMS

Many receivers today use transistors to accomplish their AGC requirements. For normal operation these transistors are biased for maximum gain. When the signal exceeds a set threshold level, automatic gain control is achieved by an increase in bias current, which results in a gain reduction. The principle of forward AGC is applied.

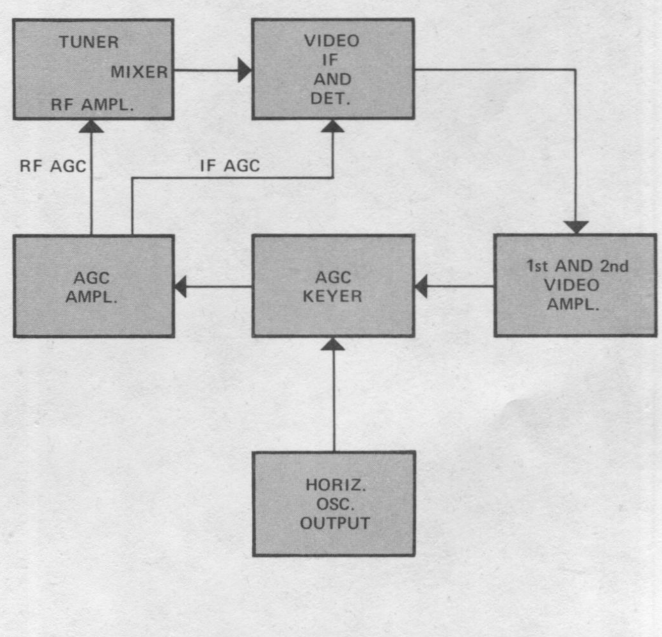


Figure 2. Block Diagram of a Typical AGC System in a TV Receiver.

A block diagram of a typical AGC system in a television receiver is shown in Figure 2. The objective is to keep the output of the video detector constant with increasing RF signal levels. The usual way of determining the signal strength of the incoming signal is to use the height of the horizontal pulses as a reference. A synchronized AGC keyer is used for this purpose. The threshold level required to trigger the keyer is preset. A winding in the flyback transformer supplies the horizontal pulses needed to bias the keyer transistor. When the keyer is off, the AGC amplifier supplies the required voltage to bias the RF and IF amplifiers for maximum gain. When the signal from the video amplifier exceeds the threshold level during the horizontal sync pulse, the keyer turns on and biases the AGC off. This results in an increased AGC voltage to the RF and IF amplifiers and thus a reduction in gain.

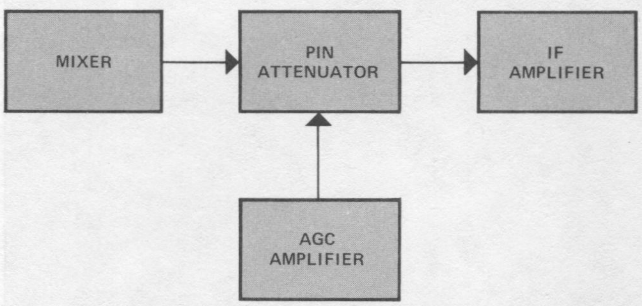


Figure 3. Use of a PIN Diode Attenuator as an Interstage for Providing AGC.

When AGC is applied to a transistor, the optimum operating point is disturbed, and the input and output impedances change drastically. This change will, of course, adversely affect the associated tuned circuit. The use of a PIN diode attenuator as an interstage, as shown in Figure 3, will provide a wide range of gain control without disturbing the optimum operating point of the associated circuit elements. This minimizes changes in impedance levels, phase shift and tuning, while achieving the required change in gain.

When the basic requirements of an attenuator for AGC application in a receiver are considered, the reasons for the superiority of PIN diodes over other PN junction diodes will become obvious. In particular, consider the use of 3 low frequency diodes in a π configuration attenuator as shown in Figure 4. The ratio of on to off resistance of PIN diodes is significantly greater than that of other diodes, so that the insertion loss is lower and the maximum attenuation is greater. In terms of AGC this means larger dynamic range. The linearity of resistance as a function of bias makes the PIN diode less susceptible to modulation distortion. In

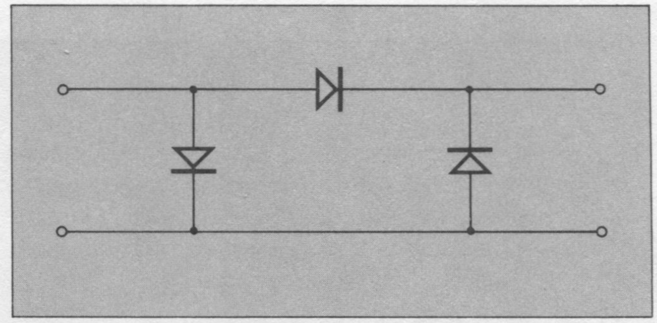


Figure 4. 3 Diode π Attenuator.

the VHF/UHF range distortion from partial rectification cannot be tolerated. The use of low frequency PIN diodes ensures that distortion be minimized at these low frequencies. HP 5082-3080 and 5082-3081 PIN diodes with lifetime, respectively, in excess of 1 and 1.5 microseconds are usable below 10 MHz.

PERFORMANCE CHARACTERISTICS

A transistorized amplifier stage and a low frequency PIN diode attenuator built for AGC performance comparison are shown, respectively, in Figures 5 and 6. In each case there is a fixed supply voltage of 12 volts and a variable voltage for AGC control.

In the transistor circuit the principle of forward AGC is applied. In addition to the fixed 12 volts an AGC voltage of –4.5 volts is required to bias the

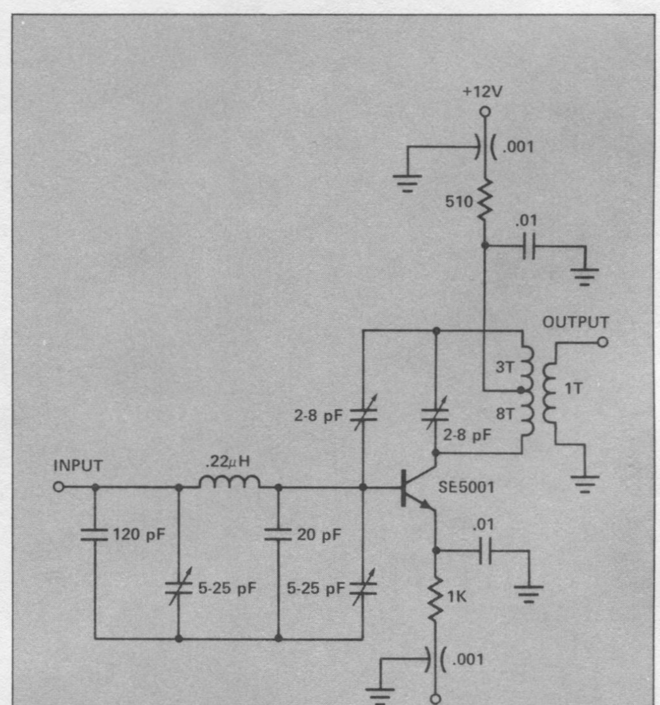


Figure 5. Transistor AGC Circuit.

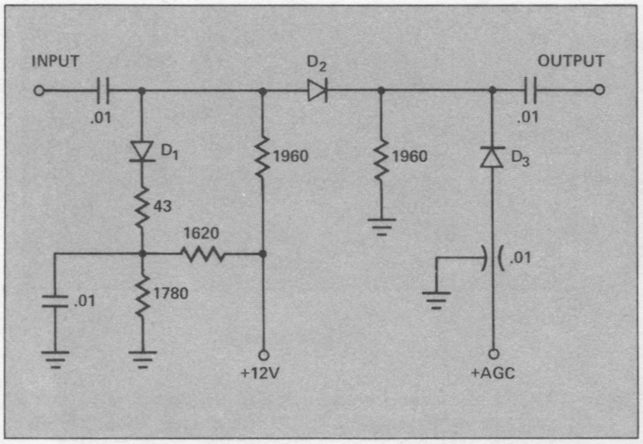


Figure 6. PIN Diode Attenuator AGC Circuit.

transistor for maximum gain. Further increase in AGC voltage results in a larger collector current and a reduction in gain. A curve of Gain Reduction versus AGC voltage at 45 MHz is shown in Figure 7. A maximum gain of approximately 40 dB is obtained at an AGC voltage of −4.5 volts. With more AGC voltage the gain decreases until a gain reduction of 40 dB is achieved at about 11.5 volts of AGC voltage.

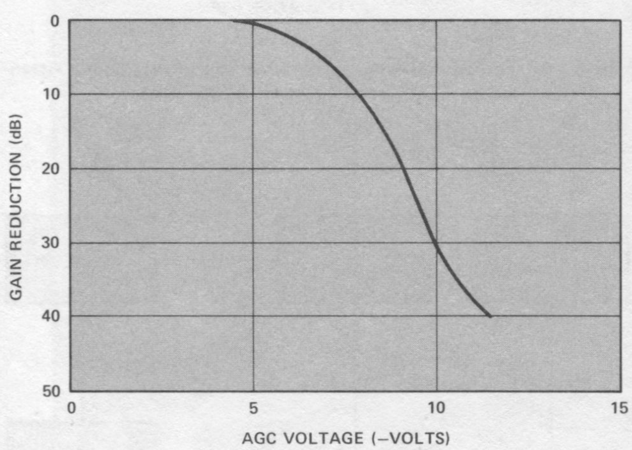


Figure 7. Gain Reduction vs. AGC Voltage in Transistor AGC Circuit at 45 MHz.

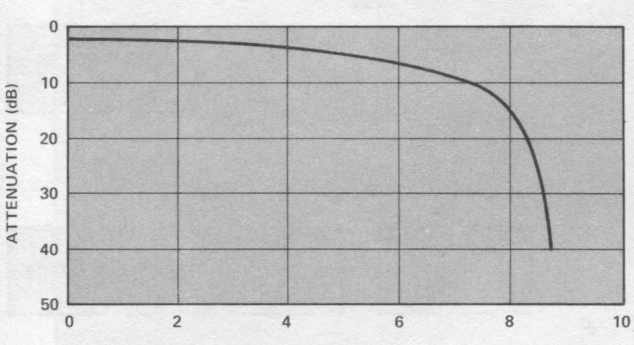


Figure 8. Attenuation vs. AGC Voltage in PIN Diode Attenuator AGC Circuit at 45 MHz.

Attenuation versus AGC voltage for the PIN attenuator circuit is shown in Figure 8. There is minimum attenuation when the AGC voltage is zero. The attenuation increases with AGC voltage until 40 dB of attenuation is obtained with 8.75 volts of AGC voltage. For 40 dB of attenuation the PIN attenuator requires 35 mW of power, while the transistor circuit consumes 120 mW for the same gain reduction.

Intermodulation and crossmodulation characteristics of the transistor and PIN attenuator AGC circuits are illustrated in Figures 9 through 14. A block diagram of the test equipment used for these distortion measurements is shown in Figure 15. The wave analyzer is used only for the crossmodulation tests. The tests are conducted with two equal amplitude input signals, one at 45 MHz and the other at 45.5 MHz. For the crossmodulation measurements one of the input signals is 100% modulated with a 15 KHz signal from the wave analyzer.

Examination of the distortion characteristics will reveal significant differences in performance of the two AGC circuits. Over a 30 dB dynamic range,

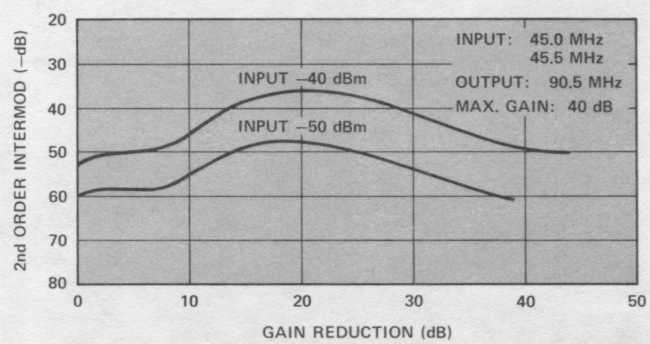


Figure 9. Second Order Intermodulation vs. Gain Reduction in Transistor AGC Circuit.

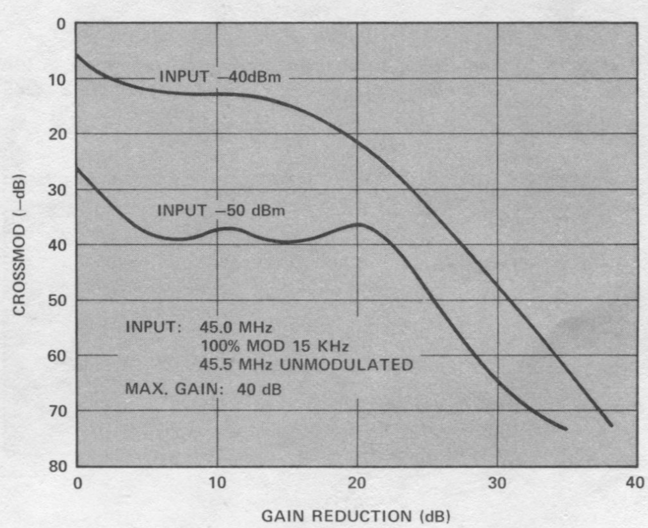


Figure 10. Crossmodulation vs. Gain Reduction in Transistor AGC Circuit.

it is seen that second order intermodulation distortion at the same level of fundamental output is less in the PIN attenuator than in the transistor circuit. The difference at some points in the range is in excess of 10 dB. Longer lifetime HP 5082-3081 PIN diodes definitely show more favorable intermodulation characteristics than the HP 5082-3080 diodes. The superiority of the PIN attenuator as an AGC circuit is even more apparent with comparison of the crossmodulation characteristics. At some power levels, crossmodulation in the transistor circuit is seen to be 50 dB worse. A comparison of Figure 12 and 14 indicates better crossmodulation rejection when using HP 5082-3080 PIN diodes.

A comparison of the PIN and transistor AGC circuit performance is shown in Table 1.

TABLE 1

	PIN Diode		Transistor
	5082-3080	5082-3081	
Power Consumption, mW	35	35	120
2nd Order Intermod, dB (−20 dBm output)	−59	−64	−55
Crossmodulation (−20 dBm output)	−68	−59	−37

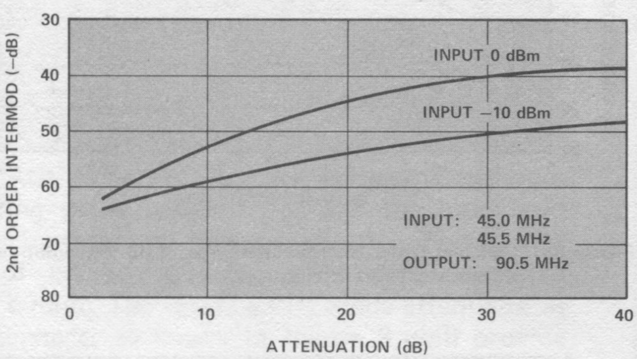


Figure 11. 2nd Order Intermodulation vs. Attenuation in PIN Diode Attenuator AGC Circuit Using HP 5082-3080.

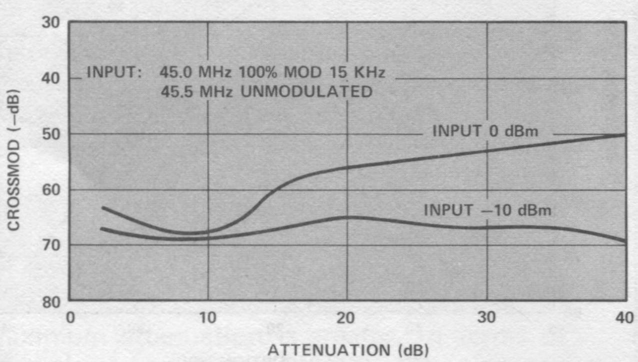


Figure 12. Crossmodulation vs. Attenuation in PIN Diode Attenuator AGC Circuit Using HP 5082-3080.

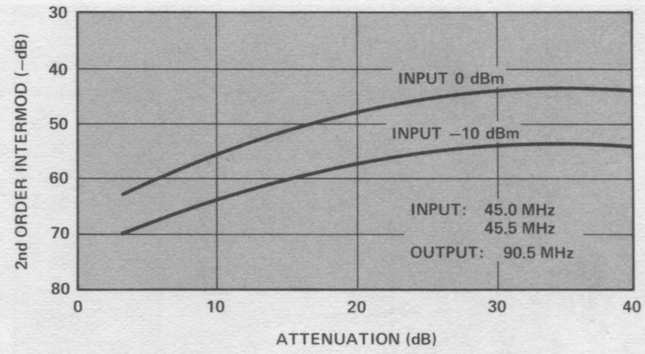


Figure 13. 2nd Order Intermodulation vs. Attenuation in PIN Diode Attenuator AGC Circuit Using HP 5082-3081.

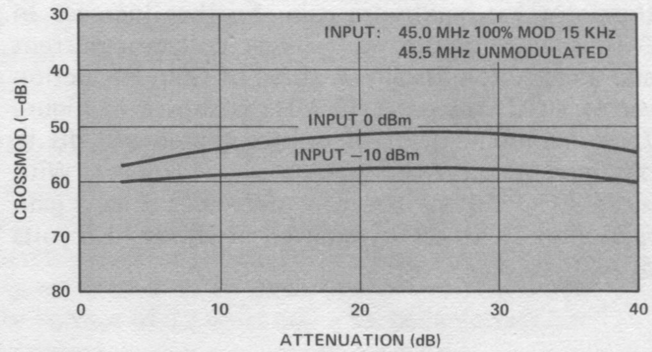


Figure 14. Crossmodulation vs. Attenuation in PIN Diode Attenuator AGC Circuit Using HP 5082-3081.

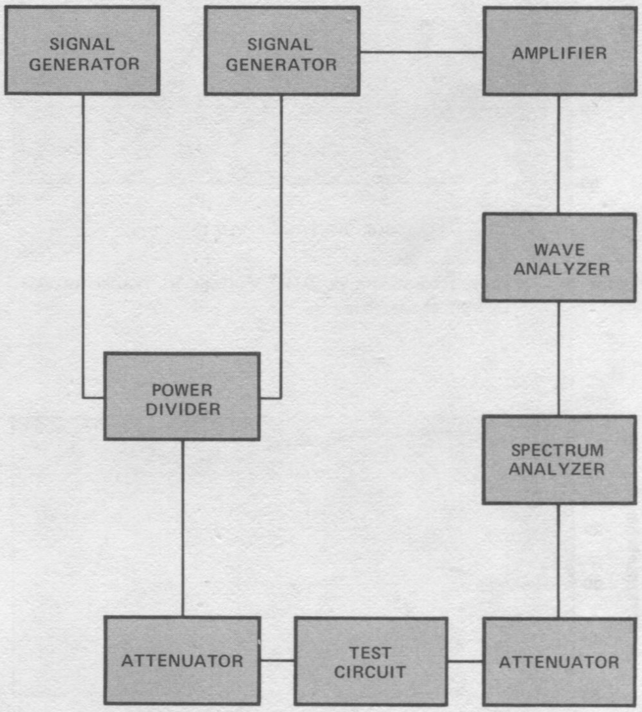


Figure 15. Block Diagram of Test Equipment used for Distortion Measurement.

CONCLUSION

Automatic gain control in a transistorized circuit requires that the optimum operating point of the AGC transistor be shifted. This produces a drastic change in the impedance level, which severely affects the adjoining tuned circuit.

The use of a PIN diode attenuator as the AGC control element will provide the required gain control without the attendant problems of large impedance shift. The result is minimum distortion in the output coupled with low power consumption. The use of long lifetime PIN diodes gives added assurance of usefulness at low frequencies for low cost applications.

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