Choosing the Right Diode for your AGC Detector

Here are the performance characteristics you should know for detector design

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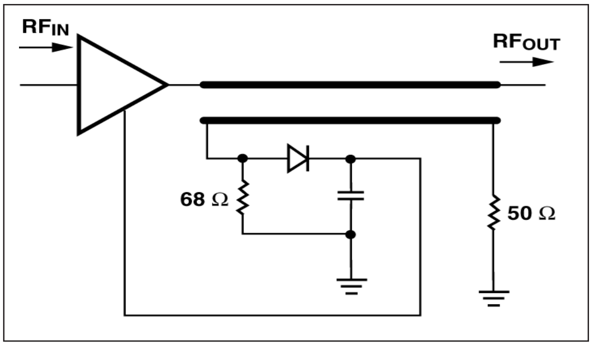
Automatic Gain Control (AGC) loops are used to control the gain or output power of amplifiers in a wide variety of applications. A typical circuit is shown in Figure 1.

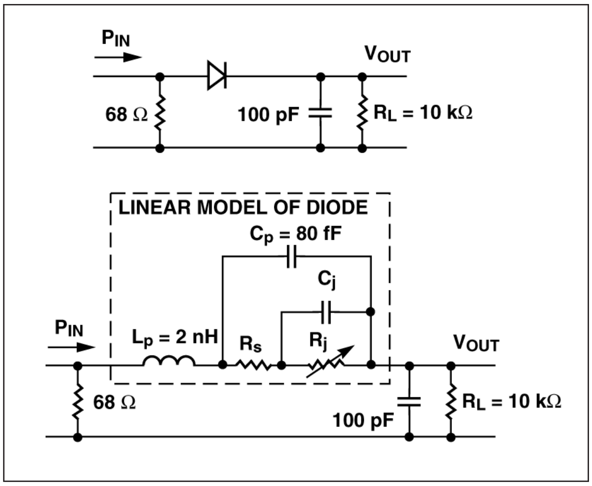
In this circuit, a coupler (distributed transmission line as shown, or lumped element) couples off a small amount of power from the amplifier and feeds it to a Schottky diode detector.. The detector produces a DC voltage proportional to the output power, which is then fed back to the amplifier's gain control circuit. Diode detectors of this type can be externally biased or self biased [1]. Let us first examine the self-biased detector.

The typical self-biased detector (sometimes referred to as "zero-biased") is shown in Figure 2. A diode is combined with a capacitor of sufficient size on the DC side to present a low impedance (compared to that of the diode), and a shunt 68 ohm resistor is placed on the RF side. This resistor serves two functions — it provides a good impedance match at the input to the detector circuit and furnishes a return path for the DC current generated in the diode. The circuit is completed with a DC load resistor of 1 kohm to 10 kohms.

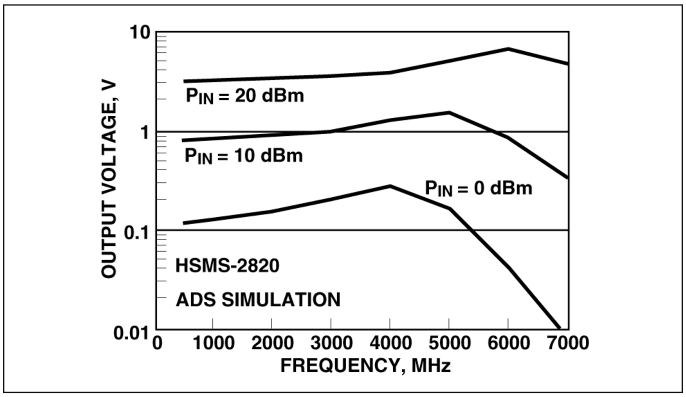
In the lower half of Figure 2, the diode is replaced with its linear equivalent circuit, which can provide insight into the performance of the detector diode. L_p and C_p are package parasitics — little can be done to change their values. The diode chip itself can be represented by a three-element equivalent circuit, including R_s (parasitic series resistance), C_j (parasitic junction capacitance) and R_j (the junction resistance of the diode, where RF energy is converted to DC voltage). As frequency or junction capacitance increases, the junction resistance of the diode will be shorted out and RF energy will be diverted to R_s where it is converted into heat. When this occurs, output voltage will fail.



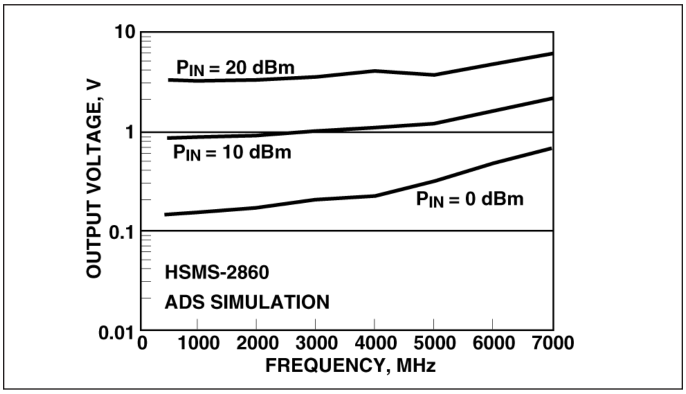
▲ **Figure 1. A typical AGC circuit using a Schottky diode detector.**



▲ **Figure 2. A typical self-biased or "zero biased" detector. Below the schematic is the linear equivalent circuit.**



▲ **Figure 3. Simulation of the HSMS-282x diode family showing the effect of the relatively large junction capacitance in high-frequency rolloff.**



▲ **Figure 4. Simulation of the HSMS-286x diode family showing improved performance above 4 GHz.**

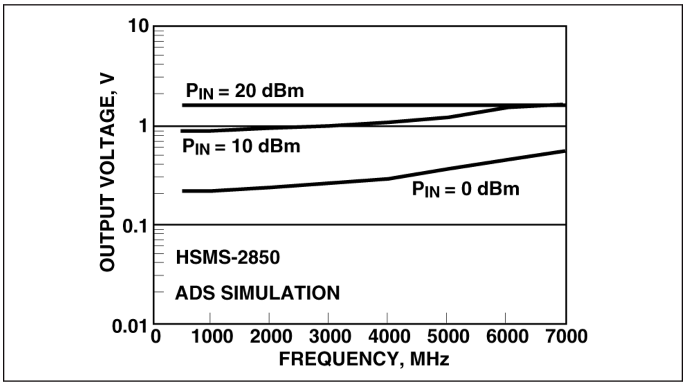
This analysis becomes more complex because junction resistance in a self-biased detector is a variable. As input P_{in} increases, V_{out} will increase, and thus the magnitude of the current circulating through R_L will increase. As this current rises, the value of R_j will fall, diminishing the effect of junction capacitance. The best way in which to conduct the analysis is with a harmonic balance CAD program such as ADS [2].

Schottky diodes are available with a variety of characteristics, based upon the way in which they are fabricated. Diodes based upon p-type silicon feature very low barrier height, making excellent self-biased signal detectors (P_{in}<–20dBm). However, such devices have very low breakdown voltage, severely limiting the maximum value of P_{in}, and very high values of R_s. Diodes based upon n-type silicon offer lower values of series resistance, but their higher barrier height requires a higher value of P_{in} before they begin self-bias. Junction capacitance of the diode can be lowered by reducing the diameter of the Schottky junction, but this comes at the expense of lower yields, lower lot-to-lot consistency and higher cost.

A typical selection of Schottky detector diodes is shown in Table 1. This table provides the key SPICE parameters for the diodes. In addition to C_j and R_s (already defined), they are I_s (saturation current, an indicator of diode barrier height), V_{br} (breakdown voltage) and n (ideality factor). Also shown are ratings of diode cost and lot-to-lot consistency.

Simulations of AGC detectors of the type illustrated in Figure 2 were conducted on ADS, for values of input power (P_{in}) of 0, 10 and 20 dBm and frequencies from 500 MHz to 7 GHz. The results of these analyses are shown in Figures 3, 4 and 5.

In Figure 3, the effect of the relatively large junction capacitance of the HSMS-282x family of diodes is seen in the rolloff of output voltage at high frequencies, particularly at lower values of input power where junction resistance is higher. This low cost and consistent diode makes an excellent AGC detector at frequencies below 4 GHz, but ought not to be used at higher frequencies.



▲ **Figure 5. Simulation of the HSMS-285x diode family of small-signal zero-bias detectors. Such p-type low-barrier diodes are characterized by series resistance and low breakdown voltage, causing the diode to saturate.**

The HSMS-286x family of microwave detector diodes offers superior performance at frequencies over 4 GHz, as can be seen in Figure 4. However, the higher cost and lot-to-lot variation of this part makes it a poor choice for frequencies below 4 GHz.

Figure 5 presents the results of the simulation for the HSMS-285x family of small signal zero-bias detectors. At first glance, it appears that its performance in an AGC circuit matches that of the n-type HSMS-286x family. However, p-type low-barrier diodes are characterized by high series resistance and low breakdown voltage. While these characteristics cause no problems in the performance of a small signal detector, they lead to severe performance limitations in large-signal AGC detectors. As shown in Figure 5, low breakdown voltage causes the diode output to saturate, especially at frequencies above 4 GHz. P-type diodes such as the HSMS-285x family should never be used for AGC detector applications (see Table 2).

Device	HSMS-282x	HSMS-286x	HSMS-285x
material	n-type	n-type	p-type
Cj, pF	0.65	0.12	0.13
Rs, Ω	7.8	9.0	35.0
Is, A	1.5E-8	5E-8	3E-6
Vbr, V	26.7	7.0	4.8
n	1.067	1.080	1.100
cost	low	moderate	moderate
consistancy	very high	high	low

▲ **Table 1. Key diode SPICE parameters and indication of relative cost and degree of lot-to-lot consistency.**

In summary, low-cost diodes such as the HSMS-282x family make excellent self-biased AGC detectors at frequencies below 4 GHz, while the HSMS-286x family of microwave detector diodes would be a better choice at frequencies above that limit. P-type low-barrier diodes are never used in applications where the input power is higher than –20 dBm. ■

References

1. Raymond W. Waugh, "Designing Large-Signal Detectors for Handsets and Base Stations," *Wireless Systems Design,* Volume 2, Number 7, July 1997.

2. *Advanced Design System*, Hewlett-Packard Company.

Author information

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