

## Choosing the Right Diode For Your AGC Detector

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AGC (Automatic Gain Control) 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.

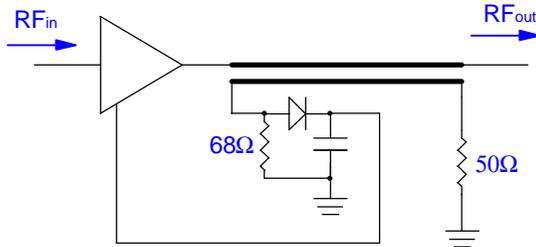


Figure 1 – Typical AGC circuit

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<sup>[1]</sup>. The case of the self-biased detector will be examined first.

The typical self-biased detector (sometimes referred to as

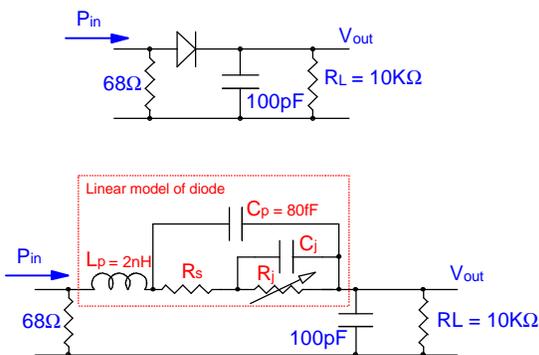


Figure 2 – Self-biased detector

“zero-biased”) is shown in Figure 2. A diode is combined with a capacitor on the DC side of sufficient size as to present a low impedance (compared to that of the diode) and a shunt 68Ω resistor on the RF side. This resistor serves two functions – it provides a good impedance match at the input to the detector circuit and it furnishes a return path for the DC current generated in the diode. The circuit is completed with a DC load resistor of 1KΩ to 10KΩ.

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). It can be seen that as frequency or junction capacitance increase, the junction resistance of the diode will be shorted out and RF energy diverted to  $R_s$ , where it is converted into heat. When this occurs, output voltage will fall.

This analysis is made more complex in that junction resistance in a self-biased detector is a variable. As input power  $P_{in}$  increases,  $V_{out}$  will increase and with it, the magnitude of the current circulating through  $R_L$ . 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<sup>[2]</sup>.

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 small signal detectors ( $P_{in} < -20\text{dBm}$ ). 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 to self-bias. Finally, 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.

		HSMS-282x	HSMS-286x	HSMS-285x
		n-type	n-type	p-type
$C_j$	pF	0.65	0.12	0.13
$R_s$	$\Omega$	7.8	9.0	35
$I_s$	A	1.5E-8	5E-8	3E-6
$V_{br}$	V	26.7	7.0	4.8
n		1.067	1.080	1.100
cost		low	moderate	moderate
consistency		very high	high	moderate

Table 1 – Diode SPICE parameters

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

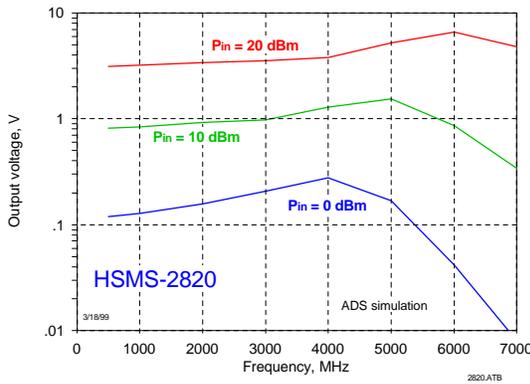


Figure 3 – simulation for HSMS-282x

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.

The HSMS-286x family of microwave detector diodes offers superior performance at frequencies over 4 GHz, as

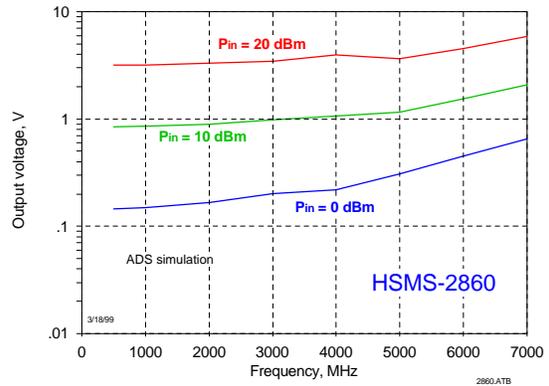


Figure 4 – simulation for HSMS-286x detector

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 gives the results of the simulation for the HSMS-

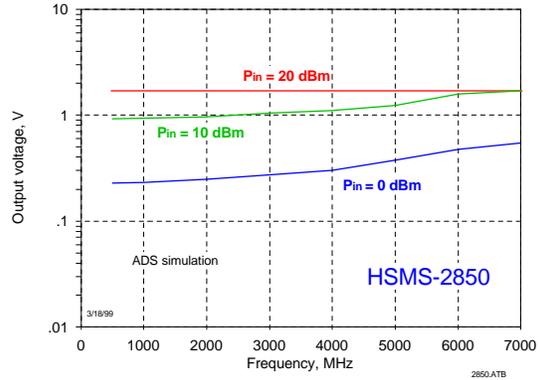


Figure 5 – simulation for HSMS-285x detector

285x family of small signal zero-bias detectors. At first glance, it would appear 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 can be seen 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.

	freq < 1.5 GHz	1.5 GHz < freq < 4 GHz	4 GHz < freq < 12 GHz
$P_{in} > -20$ dBm	<a href="#">HSMS-282x</a>	<a href="#">HSMS-282x</a>	<a href="#">HSMS-286x</a>
$P_{in} < -20$ dBm	<a href="#">HSMS-285x</a>		

Table 2 – Summary of zero bias diode applications

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*, Vol. 2, No. 7, July 1997, pp 42 – 48.
- [2] Advanced Design System<sup>®</sup>, Hewlett-Packard Company.