Temperature Dependence of Schottky Detector Voltage Sensitivity

Application Note 956-6

Although Schottky barrier diodes are less sensitive to temperature changes than are point-contact diodes[1], the effect on detector voltage sensitivity may be significant. Performance improves at lower temperatures in a predictable manner. In fact, a second diode can be used in a compensating circuit[2] to cancel out the temperature effects.

Typical behavior of voltage sensitivity vs. temperature is shown in Figure 1. This spread of values (approximately 1 dB) was obtained from 10 Agilent Technologies 5082-2750 Schottky detector diodes chosen at random from 2 different lots.
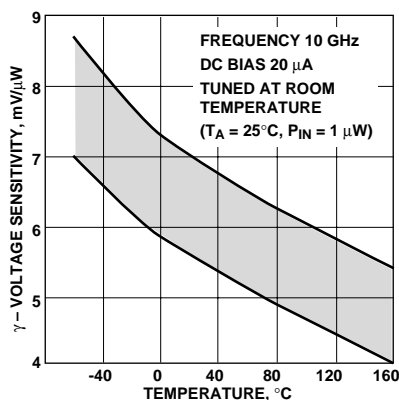
The temperature dependence of current sensitivity was studied by Cowley and Sorensen[3], but the analysis was not extended to voltage sensitivity. For the ideal diode with infinite cutoff frequency (zero series resistance and/or zero junction capacitance) there is no temperature effect on voltage sensitivity. The inverse temperature behavior of current sensitivity is balanced by the direct temperature variation of the diode barrier resistance. That is, for current sensitivity:

$$\beta = \frac{q}{2\ nkT} = \frac{5400}{T} \tag{1}$$

and for diode junction resistance:

$$R_j = \frac{nkT}{qI} = \frac{T}{11\ I} \tag{2}$$

In these equations, T is temperature in degrees Kelvin, I is bias current in milliamperes and n, q, and k are constants[3]. When the load resistance is much greater than diode resistance, the voltage sensitivity, γ_0, is the product of current sensitivity and junction resistance and is independent of temperature:

$$\gamma_0 = \beta\ R_j = \frac{490}{I} \tag{3}$$

In practical cases, however, the voltage sensitivity is reduced by the presence of both junction capacitance and series resistance, i.e.:

$$\gamma = \frac{\gamma_0}{1 + 4\pi^2\ f^2\ C_j^2\ R_S\ R_j} \tag{4}$$

The temperature dependence shows up in the R_j term (equation 2). Using typical values of I = .02 mA, R_S = 25 ohms, C_j = 0.1 pF, and f = 10 GHz, the effect of temperature on voltage sensitivity is:

$$\gamma = \frac{\gamma_0}{1 + .0045T} \tag{5}$$

For a typical voltage sensitivity of 6.5 mV/μW at T = 293°K, γ_0 = 15.1 mV/μW. Figure 2 shows this theoretical curve in excellent agreement with experimental data from a typical diode.

However, when f = 1 GHz, equation (4) predicts a response nearly independent of temperature:

$$\gamma = \frac{\gamma_0}{1 + 4.5T \times 10^{-5}} \tag{6}$$

FREQUENCY 10 GHz
DC BIAS 20 μA
TUNED AT ROOM TEMPERATURE
(T_A = 25°C, P_{IN} = 1 μW)

γ – VOLTAGE SENSITIVITY, mV/μW

TEMPERATURE, °C

Figure 1. Typical Voltage Sensitivity vs. Temperature.

$$\gamma = \frac{15.1}{1 + .0045T}$$
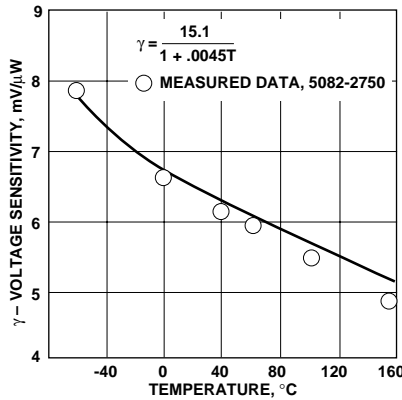
○ MEASURED DATA, 5082-2750

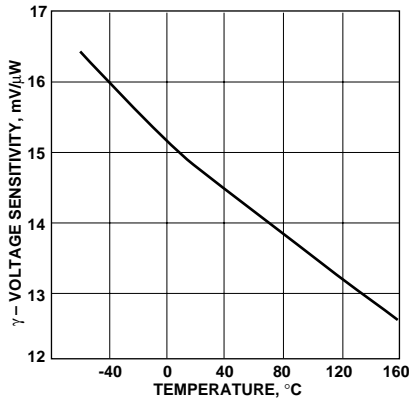**Figure 2. Voltage Sensitivity vs. Temperature at 10 GHz.**

Figure 3. Voltage Sensitivity vs. Temperature at 1 GHz.

Measurements at this frequency are not in good agreement with this prediction. Figure 3 shows considerable improvement in performance over temperature, but there is still a 25% variation.

A theoretical model of the temperature behavior of a Schottky detector is in excellent agreement with 10 GHz measurements. Further refinement of the theory is necessary to extend the model to lower frequencies.

References

1. R. Bayliss, et.al., "Why a Schottky-Barrier? Why a Point Contact?", Microwaves, pp. 34-45, March 1968.

2. R. J. Turner, "Schottky Diode Pair Makes an rf Detector Stable", Electronics, pp. 94-95, May 2, 1974.

3. A. M. Cowley and H. O. Sorensen, "Quantitative Comparison of Solid-State Microwave Detectors", IEEE Trans. on MTT, Vol. MTT-14, No. 12, pp. 588-602, December 1966.