A Schottky Diode Optimized for Consistency

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In a cellular or PCS CDMA handset, power monitoring and gain control are provided by a Schottky detector diode in the transmit side of the unit. This detector diode must exhibit very good stability or consistency over a wide range of temperatures.

Consistency in a Schottky diode can be defined in two ways:

1. Lot-to-lot consistency in key parameters, and

2. Diode-to-diode parameter match, over a wide temperature range, when two or more diodes are put into a single plastic package.

Lot-to-lot consistency is important in order to insure good yields in the manufacture of certain high volume products such as cellular handsets. For example, variation in the junction capacitance or detection sensitivity of the diode used in the handset's AGC circuit can result in handsets being out of spec when diodes from certain lots are used.

Parameter match between two or four diodes in a single package is necessary in many applications. For example, port-port isolation and distortion performance in a double balanced mixer is related to the degree to which the four ring quad diodes are matched. Another example is the differential detector, illustrated in Figure 1.

This circuit is used in DC biased detectors to differentiate between the voltage on the detector diode due to DC bias (V_f) and that due to rectification of the RF signal (V_o). The same DC bias is applied to the detector and a second (reference) diode, and a differential amplifier is used to cancel V_f. This circuit will only work if the two diodes are matched, having the same value of V_f at the chosen value of bias current and over the range of operating temperatures.

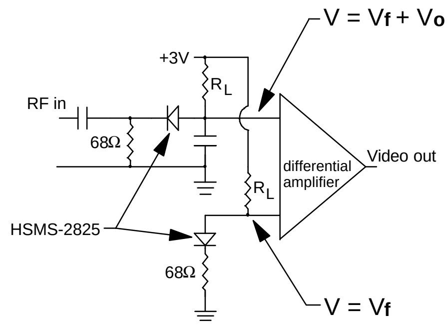

Figure 1: DC differential detector

Traditionally, manufacturers of Schottky diodes have ignored the issue of lot-to-lot consistency. For parameter match, they have often offered matched pairs or quads of Schottky diodes, or have offered batch-matching, where "match" has been usually defined as a certain ΔV_f (difference in forward voltage) at 1 mA of forward current. This has left the circuit designer in the dark, since it is impossible to relate ΔV_f to mixer distortion or detector performance.

Hewlett-Packard has undertaken three initiatives with their HSMS-282x family. The first has been to redesign the wafer fab process to insure the highest possible consistency from lot-to-lot. The second has been to optimize parameter match by putting Schottky dice from adjacent sites on a wafer into multiple diode packages, insuring the highest possible degree of match. See Figure 2. Third, lot-to-lot and diode-diode parameter variations are soon to be tracked in terms which can be understood by the circuit designer; by their SPICE parameters.

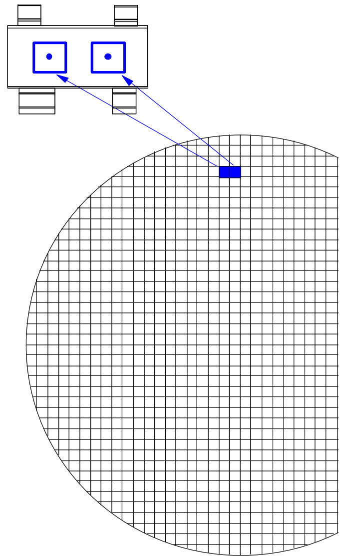

Figure 2: Dice from adjacent sites

All Hewlett-Packard plastic packaged Schottky diodes are 100% tested. To avoid additional manufacturing costs associated with additional testing for SPICE parameters, five key parameters (rather than the usual set of ten) are being monitored. They are n (ideality factor), I_s (saturation current), R_s (parasitic series resistance), C_{j0} (junction capacitance at zero bias) and BV (breakdown voltage). These parameters can be used, for example, to predict the performance of a AGC circuit detector in a cellular handset[1].

Twenty samples from each lot of diodes are measured and the five key SPICE parameters are extracted. Mean and standard deviation are computed for the twenty parts. These data are stored, and a summary will be published quarterly as a Surface Mount Diode Statistical Data sheet (available from your Hewlett-Packard Component Sales Engineer). He or she can also furnish you with the Mathcad© worksheet which is used to extract SPICE parameters from raw data.

As an example of lot-to-lot consistency of the HSMS-282x diode, consider the data obtained from seven lots (each consisting of several wafers) manufactured in November and December, 1996. A summary of their data is given in Table 1.

	mean	σ (std. dev.)	σ, %
n	1.067	0.008	0.7%
I_S	1.48E-8	3.84E-9	26%
R_S	7.8	0.79	10%
C_{j0}	0.649	0.04	6.1%
BV	26.7	1.02	3.8%

Table 1: Data summary, 7 lots of HSMS-282x

The first column specifies the SPICE parameter. The second is the "mean of the means," the average of the mean values of the seven lots. The third column is the standard deviation (σ) of the seven mean values. The fourth column is that standard deviation expressed as a percent of the mean value.

The parameter with the largest variation is saturation current. However, the nominal value is 15 namoamps, too small to be significant in detector or mixer applications where DC bias or self bias provide the dominant current. In all other parameters, σ is less than or equal to 10%, illustrating the excellent lot-to-lot consistency of this product.

Next, the degree of parameter match for two or more diodes in a single package was examined. Twenty HSMS-2825 Schottky diode pairs were measured and their SPICE parameters extracted, with the results as shown in Table 2.

	mean	mean Δ	Δ as %
n	1.079	0.0084	0.39%
I_S	2.42E-8	1.79E-9	3.7%
R_S	7.6	0.04	0.30%
C_{j0}	0.74	0.018	1.2%
BV	26.6	0.13	0.24%

Table 2: Data summary, HSMS-2825 pairs

The first column is the mean value for that lot (slightly different from the value given in Table 1). The second column is the average delta or difference between the two diodes within a single SOT-143 package. The third column is the delta expressed as a percent of the mean value.

Aside from I_s (previously discussed), the parameter with the largest variation is C_{j0}, junction capacitance. However, most of this apparent variation is introduced by the fact that modern test equipment cannot accurately resolve capacitance to the nearest femtofarad. The actual C_{jo} match is better than the 1.2% shown.

In addition to these room temperature measurements, three key SPICE parameters were monitored for five HSMS-2825 diode pairs over the temperature range of -55° to +85°C.

First, the variation in n (ideality factor) and Δn is shown in Figure 3.

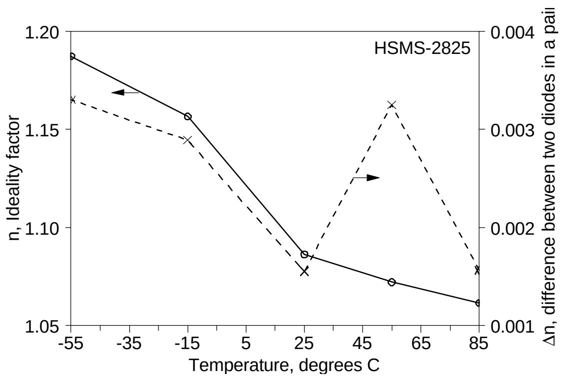

Figure 3: n and Δn vs. temperature

The diode's ideality factor (left hand scale) can be seen to drop slightly with temperature while the delta (difference between the two diodes in the HSMS-2825 pair, right hand scale) is on the order 0.3% of the nominal value over the entire temperature range.

The variation of I_s (saturation current) and ΔI_s with temperature can be seen in Figure 4.

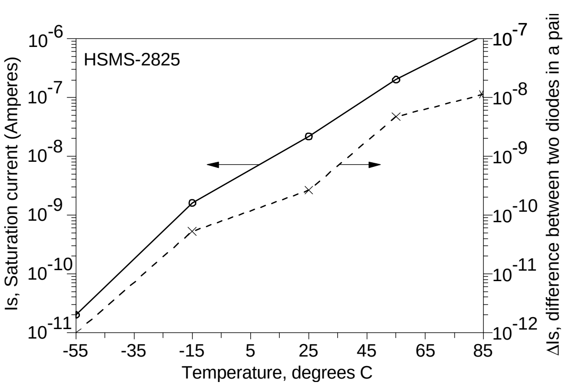

Figure 4: I_s and ΔI_s vs. temperature

Saturation current is a strong function of temperature[2], as can be seen in the plot. ΔI_s tracks I_s, increasing with temperature and remaining virtually constant at 3% to 5% of the nominal value.

Finally, the variation of R_s (series resistance) and ΔR_s is shown in Figure 5.

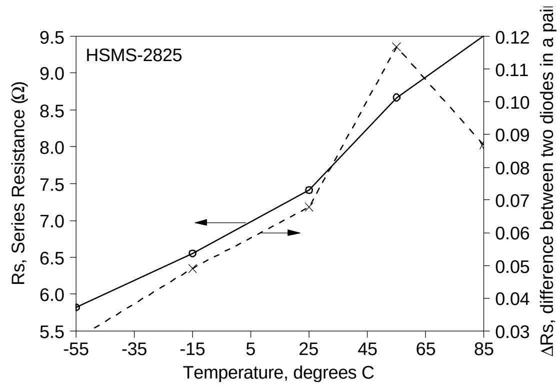

Figure 5: R_s and ΔR_s vs. temperature

Series resistance increases with temperature, and delta R_s tracks fairly well, maintaining a value of 1% ± 0.4% of the nominal value.

This performance can be compared to that for the HSMS-2865 diode pair. The HSMS-286x family is a high frequency detector diode using conventional wafer processing.

In Figure 6, the variation of Δn for the two diodes is compared.

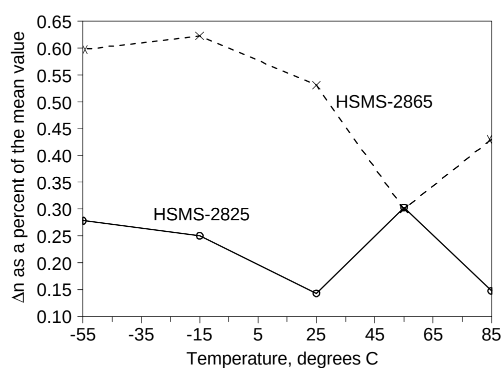

Figure 6: Δn vs. temperature, two diode types

It can be seen that the improved wafer fab process of the HSMS-282x family results in a Δn which is typically half that of the conventional HSMS-286x diodes.

Figure 7 shows the variation in ΔI_s for those same two different diodes.

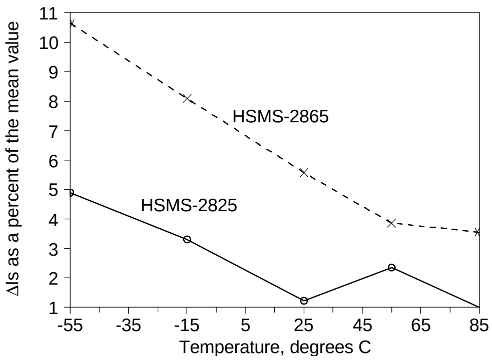

Figure 7: ΔIs vs. temperature, two diode types

Once again, the value of ΔIs for the improved-process diode is half that for the conventional device.

Figure 8 compares the value of ΔR_s for the two diode types.

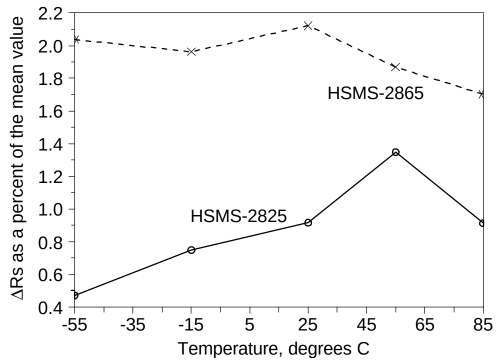

Figure 8: ΔR_s vs. temperature, two diode types

Here the results of the new fabrication process are most evident, producing a value of relative ΔR_s which is typically a third of that for the conventional diode.

In summary, where lot-to-lot consistency or diode match in pairs or quads is important in a design, the Hewlett-Packard HSMS-282x family is the choice for best performance over temperature. These parts are available as matched pairs, trios or quads in the SOT-23 and SOT-363 three-lead packages, the SOT-143 four-lead package and the SOT-363 six-lead package.

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] Raymond W. Waugh and Rolando R. Buted, "The Zero Bias Schottky Diode Detector at Temperature Extremes - Problems and Solutions," Proceedings of the WIRELESS Symposium, 1996, pp 175 - 183.