HEWLETT® PACKARD

Surface Mount Microwave Schottky Detector Diodes in SOT-323 (SC-70)

Technical Data

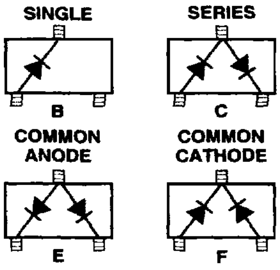
HSMS-285A Series
HSMS-286A Series

Features

- **Surface Mount SOT-323 Package**
- **High Detection Sensitivity:** Up to 50 mV/µW at 915 MHz Up to 35 mV/µW at 2.45 GHz Up to 25 mV/µW at 5.80 GHz
- **Low Flicker Noise:** -162 dBV/Hz at 100 Hz
- **Low FIT (Failure in Time) Rate***
- **Tape and Reel Options Available**

* For more information see the Surface Mount Schottky Reliability Data Sheet.

Package Lead Code Identification (Top View)



Description

Hewlett-Packard's HSMS-285A family of zero bias Schottky detector diodes and the HSMS-286A family of DC biased detector diodes have been designed and optimized for use from 915 MHz to 5.8 GHz. They are ideal for RF/ID and RF Tag, cellular and other consumer applications requiring small and large signal detection, modulation, RF to DC conversion or voltage doubling.

Available in various package configurations, these two families of detector diodes provide low cost solutions to a wide variety of design problems. Hewlett-Packard's manufacturing techniques assure that when two diodes are mounted into a single SOT-323 package, they are taken from adjacent sites on the wafer, assuring the highest possible degree of match.

DC Electrical Specifications, $T_C = +25°C$, Single Diode

Part Number HSMS-	Package Marking Code[1]	Lead Code	Configuration	Maximum Forward Voltage V_F (mV)		Typical Capacitance C_T (pF)
285B	P0	B	Single[2]	150	250	0.30
285C	P2	C	Series Pair[2,3]			
286B	T0	B	Single[4]	250	350	0.25
286C	T2	C	Series Pair[2,3]			
286E	T3	E	Common Anode[2,3]			
286F	T4	F	Common Cathode[2,3]			
Test Conditions				$I_F = 0.1$ mA	$I_F = 1.0$ mA	$V_R = 0.5$V to -1.0V f = 1 MHz

Notes:

1. Package marking code is laser marked.
2. ΔV_F for diodes in pairs is 15.0 mV maximum at 1.0 mA.
3. ΔC_T for diodes in pairs is 0.05 pF maximum at -0.5 V.

RF Electrical Parameters, T_C = +25°C, Single Diode

Part Number HSMS-	**Typical Tangential Sensitivity TSS (dBm) @ f =**			**Typical Voltage Sensitivity γ (mV/μW) @ f =**			**Typical Video Resistance R_V (KΩ)**
	915 MHz	**2.45 GHz**	**5.8 GHz**	**915 MHz**	**2.45 GHz**	**5.8 GHz**	
285B 285C	-57	-56	-55	40	30	22	8.0
Test Conditions	Video Bandwidth = 2 MHz Zero Bias			Power in = 40 dBm R_L = 100 LW, Zero Bias			
286B 286C 286E 286F	-57	-56	-55	50	35	25	5.0
Test Conditions	Video Bandwidth = 2 MHz I_b = 5 μA			Power in = −40 dBm R_L = 100 KΩ, I_b = 5 μA			

Absolute Maximum Ratings, T_C = 25°C, Single Diode

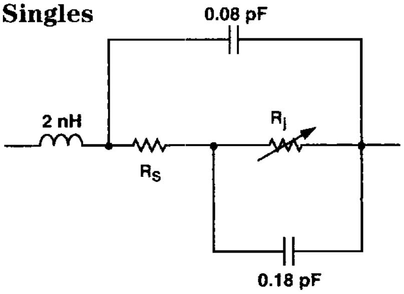
Symbol	**Parameter**	**Unit**	**Absolute Maximum**[1]
P_{IV}	Peak Inverse Voltage	V	2.0
T_J	Junction Temperature	°C	150
T_{STG}	Storage Temperature	°C	-65 to 150
T_{OP}	Operating Temperature	°C	-65 to 150
θ_{jc}	Thermal Resistance[2]	°C/W	350[2]

Notes:

1. Operation in excess of any one of these conditions may result in permanent damage to the device.
2. T_C = +25°C, where T_C is defined to be the temperature at the package pins where contact is made to the circuit board.

***ESD WARNING:* Handling Precautions Should Be Taken To Avoid Static Discharge.**

Equivalent Circuit Model HSMS-285B, HSMS-286B Singles



R_S = series resistance (see Table of SPICE parameters)

$$R_j = \frac{8.33 \text{ X } 10^{-5}\, nT}{I_b + I_s}$$

where

I_b = externally applied bias current in amps

I_s = saturation current (see table of SPICE parameters)

T = temperature, °K

n = identity factor (see table of SPICE parameters)

SPICE Parameters

Parameter	Units	HSMS-285A	HSMS-286A
B_V	V	3.8	7.0
C_{JO}	pF	0.18	0.18
E_G	eV	0.69	0.69
I_{BV}	A	3 x 10E-4	10E-5
I_S	A	3 x 10E-6	5 x 10E-8
N		1.06	1.08
R_S	Ω	25	5.0
P_B (V_J)	V	0.35	0.65
P_T (XTI)		2	2
M		0.5	0.5

Typical Parameters, Single Diode

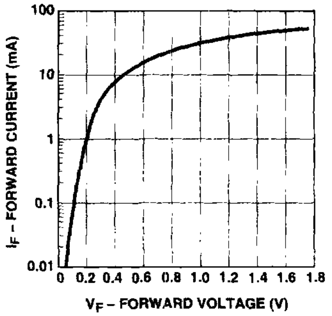


Figure 1. +25°C Forward Current vs. Forward Voltage, HSMS-285A Series.

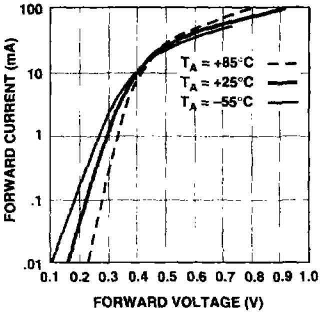


Figure 2. Forward Current vs. Forward Voltage at Temperature, HSMS-286A Series.

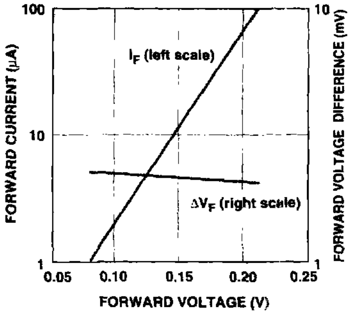


Figure 3. Forward Voltage Match, HSMS-286C, E and F Pairs.

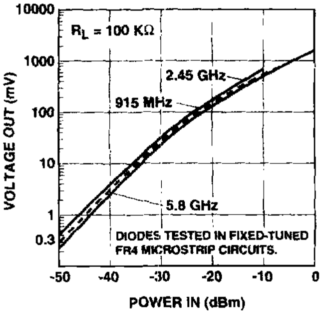


Figure 4. +25°C Output Voltage vs. Input Power, HSMS-285A Series at Zero Bias, HSMS-286A Series at 3 µA Bias.

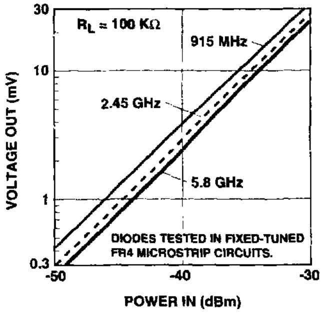


Figure 5. +25°C Expanded Output Voltage vs. Input Power. See Figure 4.

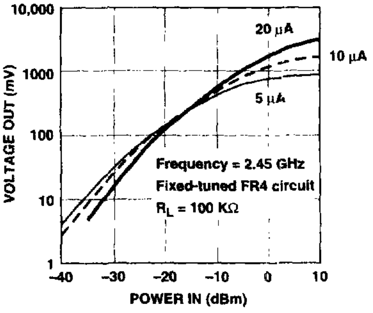


Figure 6. Dynamic Transfer Characteristic as a Function of DC Bias, HSMS-286A.

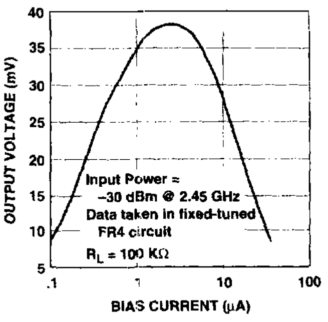


Figure 7. Voltage Sensitivity as a Function of DC Bias Current, HSMS-286A.

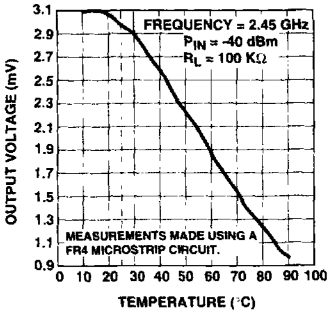


Figure 8. Output Voltage vs. Temperature, HSMS-285A Series.

Applications Information

Introduction

Hewlett-Packard's family of HSMS-285A zero bias Schottky diodes have been developed specifically for low cost, high volume detector applications where bias current is not available. The HSMS-286A family of DC Schottky diodes have been developed for low cost, high volume detector applications where stability over temperature is an important design consideration.

Schottky Barrier Diode Characteristics

Stripped of its package, a Schottky barrier diode chip consists of a metal-semiconductor barrier formed by deposition of a metal layer on a semiconductor. The most common of several different types, the passivated diode, is shown in Figure 9, along with its equivalent circuit.

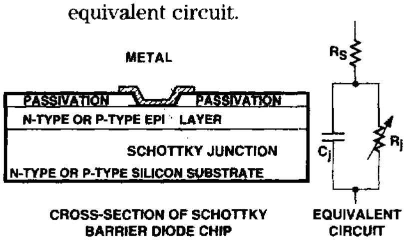


Figure 9. Schottky Diode Chip.

R_S is the parasitic series resistance of the diode, the sum of the bondwire and leadframe resistance, the resistance of the bulk layer of silicon, etc. RF energy coupled into R_S is lost as heat—it does not contribute to the rectified output of the diode. C_J is parasitic junction capacitance of the diode, controlled by the thickness of the epitaxial layer and the diameter of the Schottky contact. R_j is the junction resistance of the diode, a function of the total current flowing through it.

$$R_j = \frac{8.33 \text{ X } 10^{-5}\, n\, T}{I_S + I_b} = R_V - R_s$$

$$= \frac{0.026}{I_S + I_b} \text{ at } 25°\text{C}$$

where

n = ideality factor (see table of SPICE parameters)

T = temperature in °K

I_S = saturation current (see table of SPICE parameters)

I_b = externally applied bias current in amps

I_S is a function of diode barrier height, and can range from picoamps for high barrier diodes to as much as 5 µA for very low barrier diodes.

The Height of the Schottky Barrier

The current-voltage characteristic of a Schottky barrier diode at room temperature is described by the following equation:

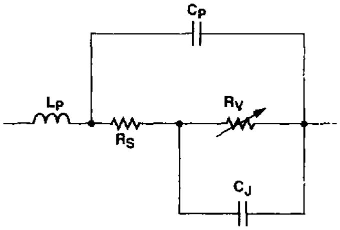
$$I = I_S \left(\exp\left(\frac{V - IR_S}{0.026}\right) - 1\right)$$

On a semi-log plot (as shown in the HP catalog) the current graph will be a straight line with inverse slope 2.3 X 0.026 = 0.060 volts per cycle (until the effect of R_S is seen in a curve that droops at high current). All Schottky diode curves have the same slope, but not necessarily the same value of current for a given voltage. This is determined by the saturation current, I_S, and is related to the barrier height of the diode.

Through the choice of p-type or n-type silicon, and the selection of metal, one can tailor the characteristics of a Schottky diode. Barrier height will be altered, and at the same time C_J and R_S will be changed. In general, very low barrier height diodes (with high values of I_S, suitable for zero bias applications) are realized on p-type silicon. Such diodes suffer from higher values of R_S than do the n-type. Thus, p-type diodes are generally reserved for detector applications (where very high values of R_V swamp out high R_S) and n-type diodes are used for mixer applications (where high L.O. drive levels keep R_V low).

Measuring Diode Parameters

The measurement of the five elements which make up the equivalent circuit for a packaged Schottky diode (see Figure 10) is a complex task. Various techniques are used for each element. The task begins with the elements of the diode chip itself.



FOR THE HSMS-285A or HSMS-286A SERIES
C_P = 0.08 pF
L_P = 2 nH
C_J = 0.18 pF
R_S = 25 Ω
R_V = 9 KΩ

Figure 10. Equivalent Circuit of a Schottky Diode.

R_S is perhaps the easiest to measure accurately. The V-I curve is measured for the diode under forward bias, and the slope of the curve is taken at some relatively high value of current (such as 5 mA). This slope is converted into a resistance R_d.

$$R_S = R_d - \frac{0.026}{I_f}$$

R_V and C_J are very difficult to measure. Consider the impedance of C_J = 0.16 pF when measured at 1 MHz — it is approximately 1 MΩ.

For a well designed zero bias Schottky, R_V is in the range of 5 to 25 KΩ, and it shorts out the junction capacitance. Moving up to a higher frequency enables the measurement of the capacitance, but it then shorts out the video resistance. The best measurement technique is to mount the diode in series in a 50 Ω microstrip test circuit and measure its insertion loss at low power levels (around -20 dBm) using an HP8753C network analyzer. The resulting display will appear as shown in Figure 11.

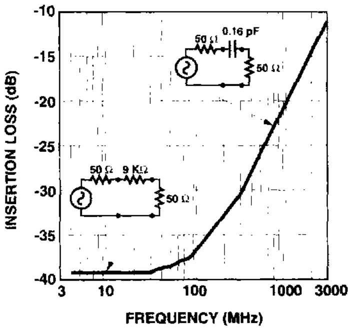


Figure 11. Measuring C_J and R_V.

At frequencies below 10 MHz, the video resistance dominates the loss and can easily be calculated from it. At frequencies above 300 MHz, the junction capacitance sets the loss, which plots out as a straight line when frequency is plotted on a log scale. Again, calculation is straightforward.

L_P and C_P are best measured on the HP8753C, with the diode terminating a 50 Ω line on the input port. The resulting tabulation of S_{11} can be put into a microwave linear analysis program having the five element equivalent circuit with R_V, C_J and R_S fixed. The optimizer can then adjust the values of L_P and C_P until the calculated S_{11} matches the measured values. Note that extreme care must be taken to de-embed the parasitics of the 50 Ω test fixture.

Detector Circuits

When DC bias is available, Schottky diode detector circuits can be used to create low cost RF and microwave receivers with a sensitivity of -55 dBm to -57 dBm.[1] Moreover, since external DC bias sets the video impedance of such circuits, they display classic square law response over a wide range of input power levels[2,3]. These circuits can take a variety of forms, but in the most simple case they appear as shown in Figure 12. This is the basic detector circuit used with the HSMS-286A family of diodes.

Where DC bias is not available, a zero bias Schottky diode is used to replace the conventional Schottky in these circuits, and bias choke L_1 is eliminated. The circuit then is reduced to a diode, an RF impedance matching network and (if required) a DC return choke and a capacitor. This is the basic detector circuit used with the HSMS-285A family of diodes.

In the design of such detector circuits, the starting point is the equivalent circuit of the diode, as shown in Figure 10.

Of interest in the design of the video portion of the circuit is the diode's video impedance—the other four elements of the equivalent circuit disappear at all reasonable video frequencies. In general, the lower the diode's video impedance, the better the design.

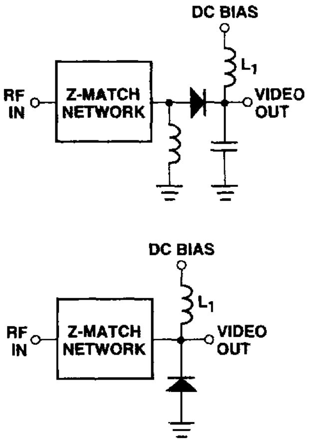


Figure 12. Basic Detector Circuits.

The situation is somewhat more complicated in the design of the RF impedance matching network, which includes the package inductance and capacitance (which can be tuned out), the series resistance, the junction capacitance and the video resistance. Of these five elements of the diode's equivalent circuit, the four parasitics are constants and the video resistance is a function of the current flowing through the diode.

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[1] Hewlett-Packard Application Note 923, *Schottky Barrier Diode Video Detectors.*

[2] Hewlett-Packard Application Note 986, *Square Law and Linear Detection.*

[3] Hewlett-Packard Application Note 956-5, *Dynamic Range Extension of Schottky Detectors.*

$$R_V \approx \frac{26{,}000}{I_S + I_b}$$

where
I_S = diode saturation current in µA
I_b = bias current in µA

Saturation current is a function of the diode's design,[4] and it is a constant at a given temperature. For the HSMS-285A series, it is typically 3 to 5 µA at 25°C. For the medium barrier HSMS-2860 family, saturation current at room temperature is on the order of 50 nA.

Together, saturation and (if used) bias current set the detection sensitivity, video resistance and input RF impedance of the Schottky detector diode. Since no external bias is used with the HSMS-285A series, a single transfer curve at any given frequency is obtained, as shown in Figure 4. Where bias current is used, some tradeoff in sensitivity and square law dynamic range is seen, as shown in Figure 6 and described in reference [3].

The most difficult part of the design of a detector circuit is the input impedance matching network. For very broadband detectors, a shunt 60 Ω resistor will give good input match, but at the expense of detection sensitivity.

When maximum sensitivity is required over a narrow band of frequencies, a reactive matching network is optimum. Such networks can be realized in either lumped or distributed elements, depending upon frequency, size constraints and cost limitations, but certain general design principals exist for all types.[5] Design work begins with the RF impedance of the HSMS-285A series, which is given in Figure 13. Note that the impedance of the HSMS-286A series is very similar when bias current is set to 3 µA.

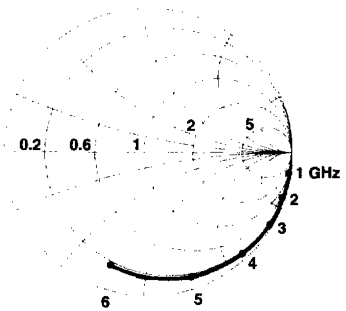

Figure 13. RF Impedance of the HSMS-285A Series at -40 dBm.

915 MHz Detector Circuit

Figure 14 illustrates a simple impedance matching network for a 915 MHz detector.

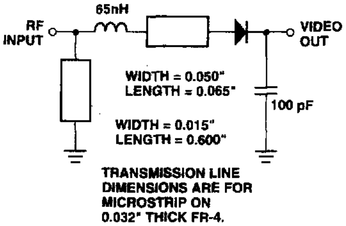

Figure 14. 915 MHz Matching Network for the HSMS-285A Series at Zero Bias or the HSMS-286A Series at 3 µA Bias.

A 65 nH inductor rotates the impedance of the diode to a point on the Smith Chart where a shunt inductor can pull it up to the center. The short length of 0.065" wide microstrip line is used to mount the lead of the diode's SOT-323 package. A shorted shunt stub of length <λ/4 provides the necessary shunt inductance and simultaneously provides the return circuit for the current generated in the diode. The impedance of this circuit is given in Figure 15.

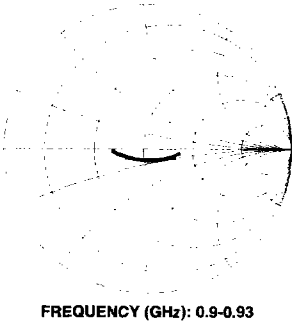

Figure 15. Input Impedance.

The input match, expressed in terms of return loss, is given in Figure 16.

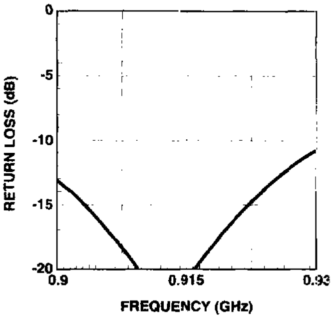

Figure 16. Input Return Loss.

As can be seen, the band over which a good match is achieved is more than adequate for 915 MHz RFID applications.

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[4] Hewlett-Packard Application Note 969, *An Optimum Zero Bias Schottky Detector Diode.*

[5] Hewlett-Packard Application Note 963, *Impedance Matching Techniques for Mixers and Detectors.*

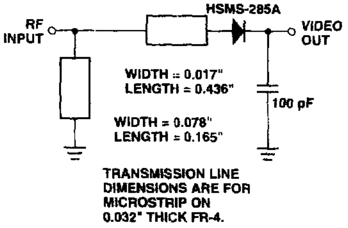

Figure 17. 2.45 GHz Matching Network for the HSMS-285A Series.

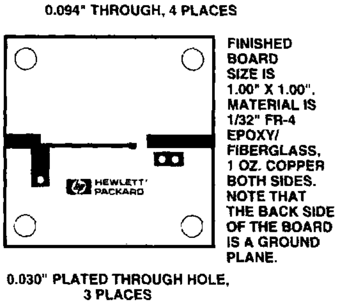

Figure 18. Physical Realization.

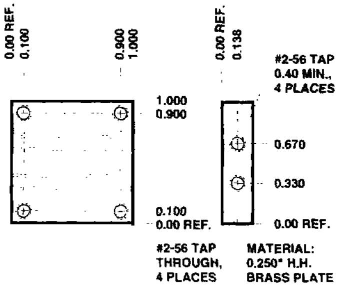

Figure 19. Mounting Plate.

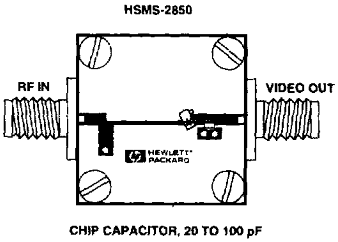

Figure 20. Test Detector.

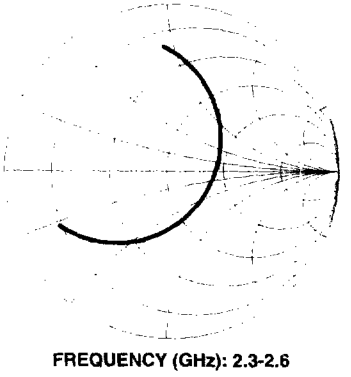

Figure 21. Input Impedance.

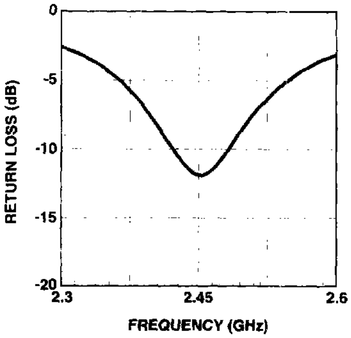

Figure 22. Input Return Loss.

2.45 GHz Detector Circuit

At 2.45 GHz, the RF impedance of the HSMS-285A series is closer to the line of constant susceptance which passes through the center of the chart, resulting in a design which is realized entirely in distributed elements — see Figure 17.

In order to save cost (at the expense of having a larger circuit), an open circuit shunt stub could be substituted for the chip capacitor. On the other hand, if space is at a premium, the long series transmission line at the input to the diode can be replaced with a lumped inductor.

A possible physical realization of such a network is shown in Figure 18.

This board is mounted on the brass or aluminum mounting plate shown in Figure 19.

Two SMA connectors (E.F. Johnson 142-0701-631 or equivalent), a high-Q capacitor (ATC 100A101MCA50 or equivalent), miscellaneous hardware and an HSMS-285B are added to create the test circuit shown in Figure 20.

The calculated input impedance for this network is shown in Figure 21.

The corresponding input match is shown in Figure 22. As was the case with the lower frequency design, bandwidth is more than adequate for the intended RFID application. Note that this same design applies to the HSMS-286A series when it is used with 3 to 5 µA of external bias.

A word of caution to the designer is in order. A glance at Figure 21 will reveal the fact that the circuit does not provide the optimum impedance to the diode at 2.45 GHz. The temptation will be to adjust the circuit elements to achieve an ideal single frequency match, as illustrated in Figure 23.

This does indeed result in a very good match at midband, as shown in Figure 24.

However, bandwidth is narrower and the designer runs the risk of a shift in the midband frequency of his circuit if there is any small deviation in circuit board or diode characteristics due to lot-to-lot variation or change in temperature. The matching technique illustrated in Figure 21 is much less sensitive to changes in diode and circuit board processing.

5.8 GHz Detector Circuit

A possible design for a 5.8 GHz detector is given in Figure 25.

As was the case at 2.45 GHz, the circuit is entirely distributed element, both low cost and compact. Input impedance for this network is given in Figure 26.

Input return loss, shown in Figure 27, exhibits wideband match.

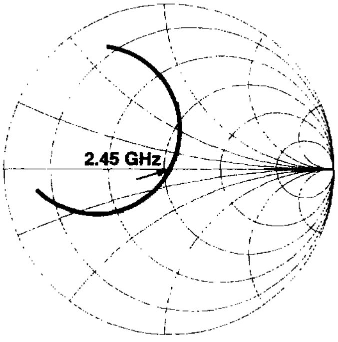

Figure 23. Input Impedance. Modified 2.45 GHz Circuit.

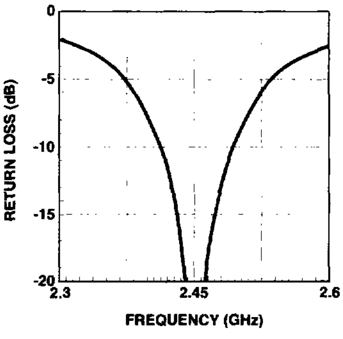

Figure 24. Input Return Loss. Modified 2.45 GHz Circuit.

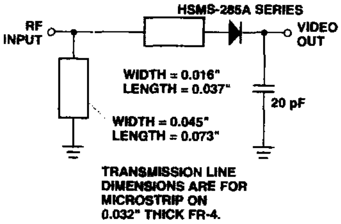

Figure 25. 5.8 GHz Matching Network for the HSMS-285A Series at Zero Bias or the HSMS-286A Series at 3 μA Bias.

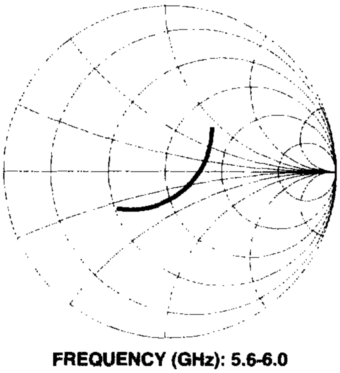

Figure 26. Input Impedance.

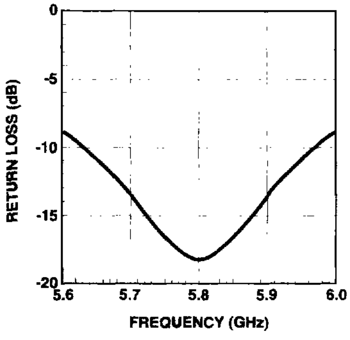

Figure 27. Input Return Loss.

Voltage Doublers

To this point, we have restricted our discussion to single diode detectors. A glance at Figure 12, however, will lead to the suggestion that the two types of single diode detectors be combined into a two diode voltage doubler[6] (known also as a full wave rectifier). Such a detector is shown in Figure 28.

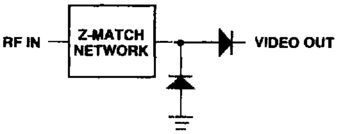

Figure 28. Voltage Doubler Circuit.

Such a circuit offers several advantages. First the voltage outputs of two diodes are added in series, increasing the overall value of voltage sensitivity for the network (compared to a single diode detector). Second, the RF impedances of the two diodes are added in parallel, making the job of reactive matching a bit easier. Such a circuit can easily be realized using the two series diodes in the HSMS-285C or the HSMS-286C.

The "Virtual Battery"

The voltage doubler can be used as a virtual battery, to provide power for the operation of an I.C. or a transistor oscillator in a tag. Illuminated by the CW signal from a reader or interrogator, the Schottky circuit will produce power sufficient to operate an I.C. or to charge up a capacitor for a burst transmission from an oscillator. Where such virtual batteries are employed, the bulk, cost, and limited lifetime of a battery are eliminated.

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[6] Hewlett-Packard Application Note 956-4, *Schottky Diode Voltage Doubler.*

Flicker Noise

Reference to Figure 5 will show that there is a junction of metal, silicon, and passivation around the rim of the Schottky contact. It is in this three-way junction that flicker noise[7] is generated. This noise can severely reduce the sensitivity of a crystal video receiver utilizing a Schottky detector circuit if the video frequency is below the noise corner. Flicker noise can be substantially reduced by the elimination of passivation, but such diodes cannot be mounted in non-hermetic packages. p-type silicon Schottky diodes have the least flicker noise at a given value of external bias (compared to n-type silicon or GaAs). At zero bias, such diodes can have extremely low values of flicker noise. For the HSMS-285A series, the noise temperature ratio is given in Figure 29.

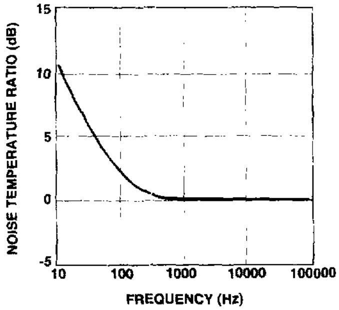

Figure 29. Typical Noise Temperature Ratio.

Noise temperature ratio is the quotient of the diode's noise power (expressed in dBV/Hz) divided by the noise power of an ideal resistor of resistance $R = R_V$.

For an ideal resistor R, at 300°K, the noise voltage can be computed from

$$v = 1.287 \times 10^{-10} \sqrt{R} \text{ volts/Hz}$$

which can be expressed as

$$20 \log_{10} v \quad \text{dBV/Hz}$$

Thus, for a diode with $R_V = 9\ K\Omega$, the noise voltage is 12.2 nV/Hz or -158 dBV/Hz. On the graph of Figure 26, -158 dBV/Hz would replace the zero on the vertical scale to convert the chart to one of absolute noise voltage vs. frequency.

Temperature Compensation

The compression of the detector's transfer curve is beyond the scope of this data sheet, but some general comments can be made. As was given earlier, the diode's video resistance is given by

$$R_V = \frac{8.33 \times 10^{-5}\ nT}{I_S + I_b}$$

where T is the diode's temperature in °K.

As can be seen, temperature has a strong effect upon R_V, and this will in turn affect video bandwidth and input RF impedance. A glance at Figure 7 suggests that the proper choice of bias current in the HSMS-286A series can minimize variation over temperature.

The detector circuits described earlier were tested over temperature. The 915 MHz voltage doubler using the HSMS-286C series pair produced the output voltages as shown in Figure 30. The use of 3 μA of bias resulted in the highest voltage sensitivity, but at the cost of a wide variation over temperature. Dropping the bias to 1 μA produced a detector with much less temperature variation.

A similar experiment was conducted with the HSMS-286B in the 5.8 GHz detector. Once again, reducing the bias to some level under 3 μA stabilized the output of the detector over a wide temperature range.

It should be noted that curves such as those given in Figures 30 and 31 are highly dependent upon the exact design of the input impedance matching network. The designer will have to experiment with bias current using his specific design.

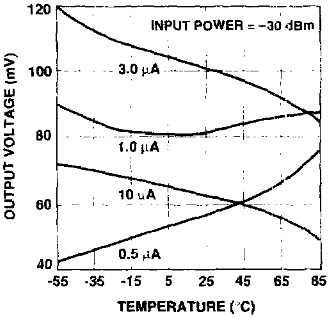

Figure 30. Output Voltage vs. Temperature and Bias Current in the 915 MHz Voltage Doubler using the HSMS-286C.

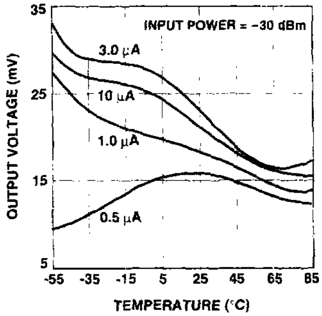

Figure 31. Output Voltage vs. Temperature and Bias Current in the 5.80 GHz Voltage Detector using the HSMS-286B Schottky.

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[7] Hewlett-Packard Application Note 965-3, *Flicker Noise in Schottky Diodes*.

Diode Burnout

Any Schottky junction, be it an RF diode or the gate of a MESFET, is relatively delicate and can be burned out with excessive RF power. Many crystal video receivers used in RFID (tag) applications find themselves in poorly controlled environments where high power sources may be present. Examples are the areas around airport and FAA radars, nearby ham radio operators, the vicinity of a broadcast band transmitter, etc. In such environments, the Schottky diodes of the receiver can be protected by a device known as a limiter diode.[8] Formerly available only in radar warning receivers and other high cost electronic warfare applications, these diodes have been adapted to commercial and consumer circuits.

Hewlett-Packard offers a complete line of surface mountable PIN limiter diodes. Most notably, our HSMP-4820 (SOT-23) can act as a very fast (nanosecond) power-sensitive switch when placed between the antenna and the Schottky diode, shorting out the RF circuit temporarily and reflecting the excessive RF energy back out the antenna.

Assembly Instructions

SOT-323 PCB Footprint

A recommended PCB pad layout for the miniature SOT-323 (SC-70) package is shown in Figure 32 (dimensions are in inches). This layout provides ample allowance for package placement by automated assembly equipment without adding parasitics that could impair the performance.

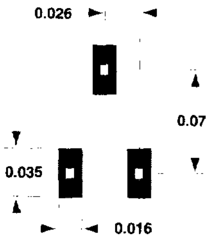

Figure 32. PCB Pad Layout (dimensions in inches).

SMT Assembly

Reliable assembly of surface mount components is a complex process that involves many material, process, and equipment factors, including: method of heating (e.g., IR or vapor phase reflow, wave soldering, etc.) circuit board material, conductor thickness and pattern, type of solder alloy, and the thermal conductivity and thermal mass of components. Components with a low mass, such as the SOT-323 package, will reach solder reflow temperatures faster than those with a greater mass.

HP's SOT-323 diodes have been qualified to the time-temperature profile shown in Figure 33. This profile is representative of an IR reflow type of surface mount assembly process.

After ramping up from room temperature, the circuit board with components attached to it (held in place with solder paste) passes through one or more preheat zones. The preheat zones increase the temperature of the board and components to prevent thermal shock and begin evaporating solvents from the solder paste. The reflow zone briefly elevates the temperature sufficiently to produce a reflow of the solder.

The rates of change of temperature for the ramp-up and cool-down zones are chosen to be low enough to not cause deformation of the board or damage to components due to thermal shock. The maximum temperature in the reflow zone (T_{MAX}) should not exceed 235 °C.

These parameters are typical for a surface mount assembly process for HP SOT-323 diodes. As a general guideline, the circuit board and components should be exposed only to the minimum temperatures and times necessary to achieve a uniform reflow of solder.

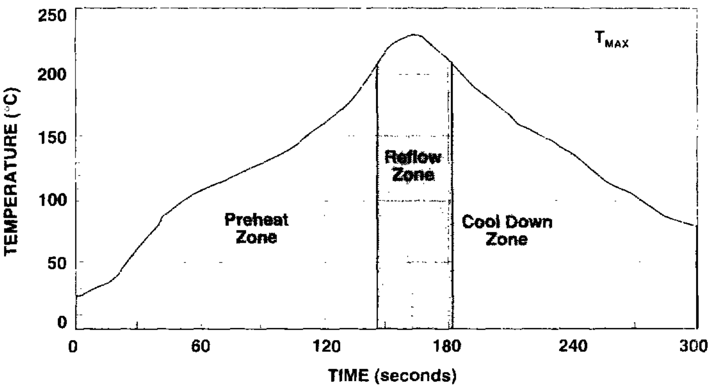

Figure 33. Surface Mount Assembly Profile.

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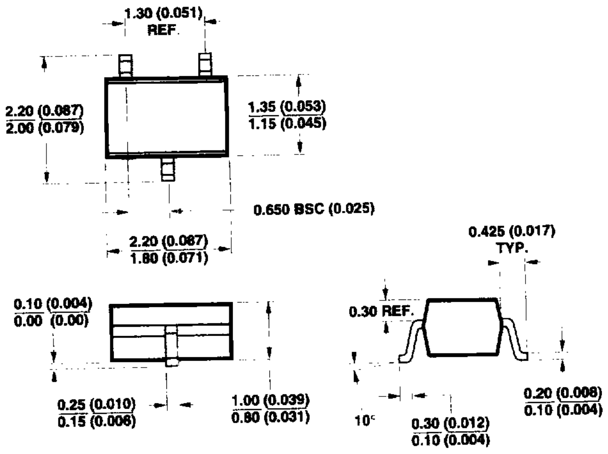
[8] Hewlett-Packard Application Note 1050, *Low Cost, Surface Mount Power Limiters.*

Package Dimensions

Outline SOT-323 (SC-70, 3 Lead)



DIMENSIONS ARE IN MILLIMETERS (INCHES)

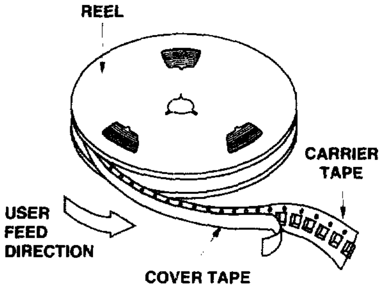
Part Number Ordering Information

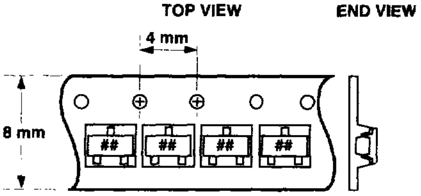
Part Number	No. of Devices	Container
HSMS-285A-TR1[1]	3000	7" Reel
HSMS-285A-BLK[1]	100	antistatic bag
HSMS-286A-TR1[2]	3000	7" Reel
HSMS-286A-BLK	100	antistatic bag

Notes:

1. "A" = B or C only
2. "A" = B, C, E or F

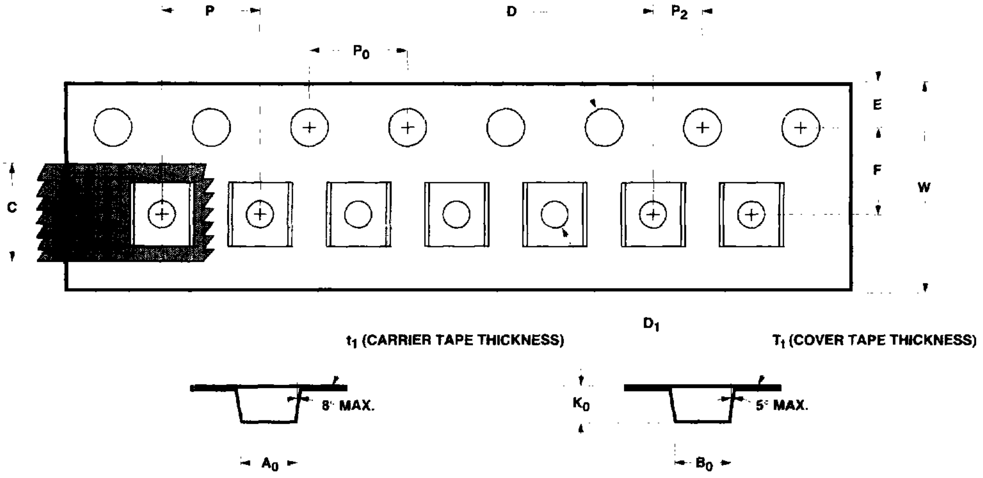
Device Orientation





Note: "##" represents Package Marking Code.

Tape Dimensions and Product Orientation
For Outline SOT-323 (SC-70 3 Lead)



DESCRIPTION		SYMBOL	SIZE (mm)	SIZE (INCHES)
CAVITY	LENGTH	A_0	2.24 ± 0.10	0.088 ± 0.004
	WIDTH	B_0	2.34 ± 0.10	0.092 ± 0.004
	DEPTH	K_0	1.22 ± 0.10	0.048 ± 0.004
	PITCH	P	4.00 ± 0.10	0.157 ± 0.004
	BOTTOM HOLE DIAMETER	D_1	1.00 + 0.25	0.039 + 0.010
PERFORATION	DIAMETER	D	1.55 ± 0.05	0.061 ± 0.002
	PITCH	P_0	4.00 ± 0.10	0.157 ± 0.004
	POSITION	E	1.75 ± 0.10	0.069 ± 0.004
CARRIER TAPE	WIDTH	W	8.00 ± 0.30	0.315 ± 0.012
	THICKNESS	t_1	0.255 ± 0.013	0.010 ± 0.0005
COVER TAPE	WIDTH	C	5.4 ± 0.10	0.205 ± 0.004
	TAPE THICKNESS	T_t	0.062 ± 0.001	0.0025 ± 0.00004
DISTANCE	CAVITY TO PERFORATION (WIDTH DIRECTION)	F	3.50 ± 0.05	0.138 ± 0.002
	CAVITY TO PERFORATION (LENGTH DIRECTION)	P_2	2.00 ± 0.05	0.079 ± 0.002