MOTOROLA
Semiconductors
BOX 20912 • PHOENIX, ARIZONA 85036

THE RF LINE

1N5139 thru 1N5148

1N5139A thru 1N5148A

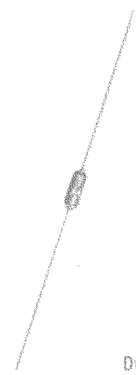
6.8-47 pF EPICAP VOLTAGE-VARIABLE CAPACITANCE DIODES

SILICON EPITAXIAL PASSIVATED

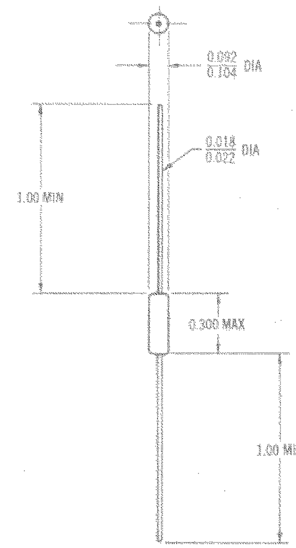
SILICON EPICAP* DIODES

. . . designed for electronic tuning and harmonic-generation applications, and providing solid-state reliability to replace mechanical tuning methods.

- Guaranteed High-Frequency Q
- Guaranteed Wide Tuning Range
- Guaranteed Temperature Coefficient
- Standard 10% Capacitance Tolerance
- Complete Typical Design Curves



DO-7 GLASS



DO-7

MAXIMUM RATINGS (T_C = 25°C unless otherwise noted)

Rating	Symbol	Value	Unit
Reverse Voltage	V_R	60	Volts
Forward Current	I_F	250	mA
RF Power Input†	P_{in}	5	Watts
Device Dissipation @ T_A = 25°C Derate above 25°C	P_D	400 2.67	mW mW/°C
Device Dissipation @ T_C = 25°C Derate above 25°C	P_C	2.0 13.3	Watts mW/°C
Junction Temperature	T_J	+175	°C
Storage Temperature Range	T_{stg}	-65 to +200	°C

† The RF power input rating assumes that an adequate heat sink is provided.

*Trademark of Motorola Inc.

ELECTRICAL CHARACTERISTICS ($T_A = 25°C$ unless otherwise noted)

Characteristic—All Types	Test Conditions	Symbol	Min	Typ	Max	Unit
Reverse Breakdown Voltage	I_R = 10 μAdc	B_{VR}	60	70	—	Vdc
Reverse Voltage Leakage Current	V_R = 55 Vdc, T_A = 25°C V_R = 55 Vdc, T_A = 150°C	I_R	— —	— —	0.02 20	μAdc
Series Inductance	f = 250 MHz, L ≈ 1/16"	L_S	—	5	—	nH
Case Capacitance	f = 1 MHz, L ≈ 1/16"	C_C	—	0.25	—	pF
Diode Capacitance Temperature Coefficient	V_R = 4 Vdc, f = 1 MHz	TC_C	—	200	300	ppm/°C

	C_T, Diode Capacitance V_R = 4 Vdc, f = 1 MHz pF			Q, Figure of Merit V_R = 4 Vdc, f = 50 MHz	α V_R = 4 Vdc, f = 1 MHz		TR, Tuning Ratio C_4/C_{60} f = 1 MHz	
Device	Min	Typ	Max	Min	Min	Typ	Min	Typ
1N5139	6.1	6.8	7.5	350	0.37	0.40	2.7	2.9
1N5139A	6.5	6.8	7.1	350	0.37	0.40	2.7	2.9
1N5140	9.0	10.0	11.0	300	0.38	0.41	2.8	3.0
1N5140A	9.5	10.0	10.5	300	0.38	0.41	2.8	3.0
1N5141	10.8	12.0	13.2	300	0.38	0.41	2.8	3.0
1N5141A	11.4	12.0	12.6	300	0.38	0.41	2.8	3.0
1N5142	13.5	15.0	16.5	250	0.38	0.41	2.8	3.0
1N5142A	14.3	15.0	15.7	250	0.38	0.41	2.8	3.0
1N5143	16.2	18.0	19.8	250	0.38	0.41	2.8	3.0
1N5143A	17.1	18.0	18.9	250	0.38	0.41	2.8	3.0
1N5144	19.8	22.0	24.2	200	0.43	0.45	3.2	3.4
1N5144A	20.9	22.0	23.1	200	0.43	0.45	3.2	3.4
1N5145	24.3	27.0	29.7	200	0.43	0.45	3.2	3.4
1N5145A	25.7	27.0	28.3	200	0.43	0.45	3.2	3.4
1N5146	29.7	33.0	36.3	200	0.43	0.45	3.2	3.4
1N5146A	31.4	33.0	34.6	200	0.43	0.45	3.2	3.4
1N5147	36.1	39.0	42.9	200	0.43	0.45	3.2	3.4
1N5147A	37.1	39.0	40.9	200	0.43	0.45	3.2	3.4
1N5148	42.3	47.0	51.7	200	0.43	0.45	3.2	3.4
1N5148A	44.7	47.0	49.3	200	0.43	0.45	3.2	3.4

PARAMETER TEST METHODS

1. L_S, SERIES INDUCTANCE

L_S is measured on a shorted package at 250 MHz using an impedance bridge (Boonton Radio Model 250A RX Meter). L = lead length.

2. C_C, CASE CAPACITANCE

C_C is measured on an open package at 1 MHz using a capacitance bridge (Boonton Electronics Model 75A or equivalent).

3. C_T, DIODE CAPACITANCE

($C_T = C_C + C_J$). C_T is measured at 1 MHz using a capacitance bridge (Boonton Electronics Model 75A or equivalent).

4. TR, TUNING RATIO

TR is the ratio of C_T measured at 4 Vdc divided by C_T measured at 60 Vdc.

5. Q, FIGURE OF MERIT

Q is calculated by taking the G and C readings of an admittance bridge at the specified frequency and substituting in the following equations:

$$Q = \frac{2\pi fC}{G}$$

(Boonton Electronics Model 33AS8).

6. α, DIODE CAPACITANCE REVERSE VOLTAGE SLOPE

The diode capacitance, C_T (as measured at V_R = 4 Vdc, f = 1 MHz) is compared to C_T (as measured at V_R = 60 Vdc, f = 1 MHz) by the following equation which defines α.

$$\alpha = \frac{\log C_T(4) - \log C_T(60)}{\log 60 - \log 4}$$

Note that a C_T versus V_R law is assumed as shown in the following equation where C_C is included.

$$C_T = \frac{K}{V^{\alpha}}$$

7. TC_C, DIODE CAPACITANCE TEMPERATURE COEFFICIENT

TC_C is guaranteed by comparing C_T at V_R = 4 Vdc, f = 1 MHz, T_A = −65°C with C_T at V_R = 4 Vdc, f = 1 MHz, T_A = +85°C in the following equation which defines TC_C:

$$TC_C = \left| \frac{C_T(+85°C) - C_T(-65°C)}{85 + 65} \right| \cdot \frac{10^6}{C_T(25°C)}$$

FIGURE 1 — DIODE CAPACITANCE versus REVERSE VOLTAGE

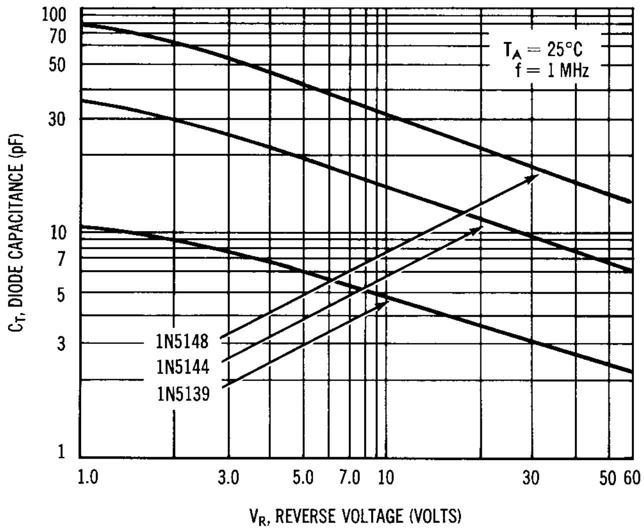


FIGURE 2 — FIGURE OF MERIT versus REVERSE VOLTAGE

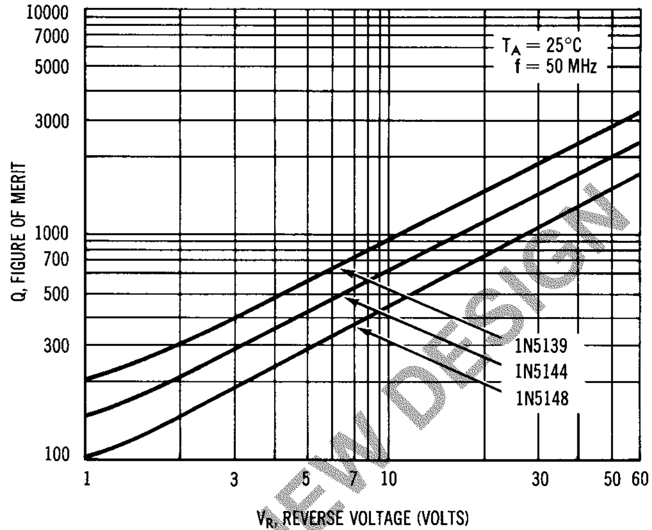


FIGURE 3 — NORMALIZED DIODE CAPACITANCE versus JUNCTION TEMPERATURE

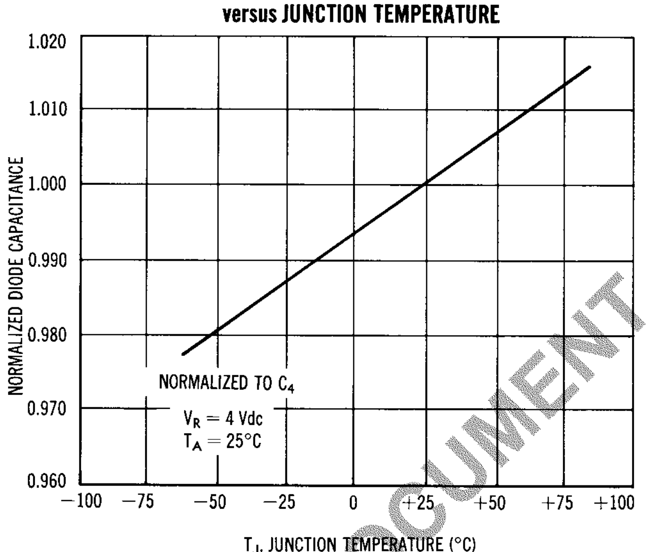


FIGURE 4 — NORMALIZED FIGURE OF MERIT versus JUNCTION TEMPERATURE

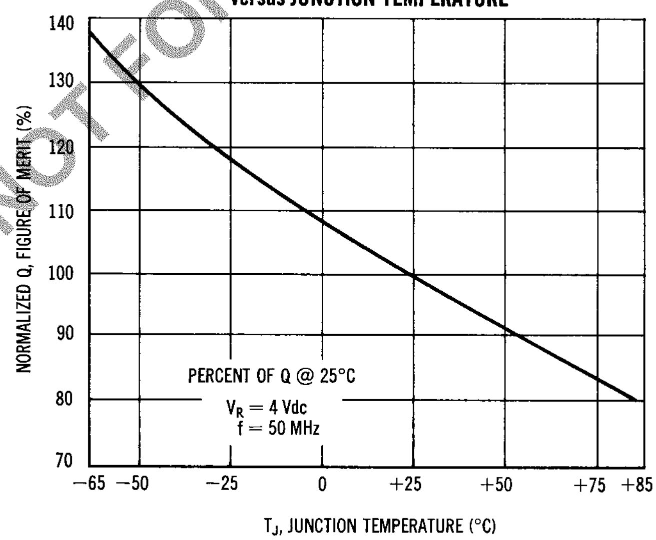


FIGURE 5 — REVERSE CURRENT versus REVERSE BIAS VOLTAGE

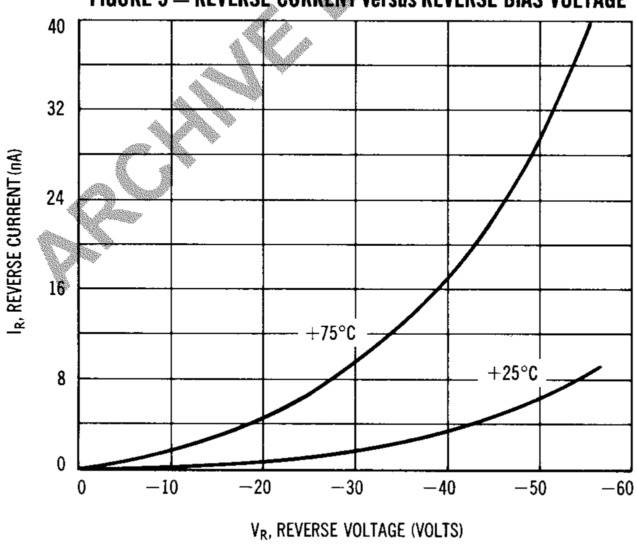
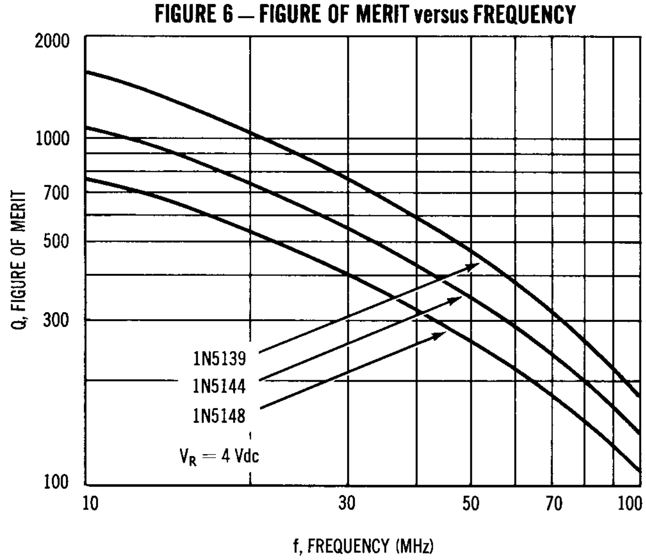


FIGURE 6 — FIGURE OF MERIT versus FREQUENCY

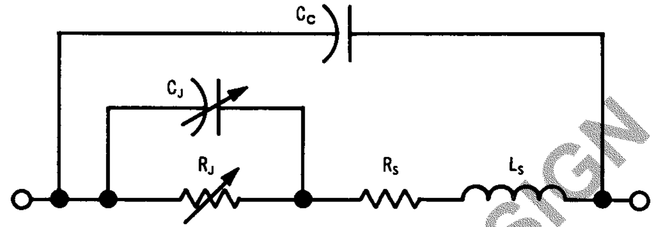


EPICAP VOLTAGE VARIABLE CAPACITANCE DIODE DEVICE CONSIDERATIONS

A. EPICAP NETWORK PRESENTATION

The equivalent circuit in Figure 7 shows the voltage capacitance and parasitic elements of an EPICAP diode. For design purposes at all but very high and very low frequencies, L_S, R_J, and C_C can be neglected. The simplified equivalent circuit of Figure 8 represents the diode under these conditions.

FIGURE 7



Definitions:

- C_J — Voltage Variable Junction Capacitance
- R_S — Series Resistance (semiconductor bulk, contact, and lead resistance)
- C_C — Case Capacitance
- L_S — Series Inductance
- R_J — Voltage Variable Junction Resistance (negligible above 100 kHz)

FIGURE 8

B. EPICAP CAPACITANCE VS REVERSE BIAS VOLTAGE

The most important design characteristic of an EPICAP diode is the C_T versus V_R variation as shown in equations 1 and 2. Since the designer is primarily interested in the slope of C_T versus V_R, the C_C, C_O, ϕ, and γ characteristics have been encompassed by the simplified equation 3. Min/max limits on α (as defined in Note 6) can be guaranteed over a specified V_R range.

$$C_T = C_C + C_J \qquad (1)$$

$$C_T = C_C + \frac{C_o}{\left(1 + \frac{V_R}{\phi}\right)^{\gamma}} \qquad (2)$$

$C_o = C_J$ at $V_R = 0$ — V_R = Reverse Bias

ϕ = Contact Potential, $\phi \approx 0.6$ Volt — $\gamma = C_J$ slope, $\gamma \approx 0.5$

$$C_T = \frac{K}{V_R^{\alpha}} \qquad (3)$$

C. EPICAP CAPACITANCE VS FREQUENCY

Variations in EPICAP effective capacitance, as a function of operating frequency, can be derived from a simplified equivalent circuit similar to that of Figure 7, but neglecting R_S and R_J. The admittance expression for such a circuit is given in equation 4. Examination of equation 4 yields the following information:

At low frequencies, $C_{eq} \approx C_J$; at very high frequencies $(f \approx \infty)$ $C_{eq} \approx C_C$.

As frequency is increased from 1 MHz, C_{eq} increases until it is maximum at $\omega^2 = 1/L_SC_J$; and as ω^2 is increased from $1/L_SC_J$ toward infinity, C_{eq} increases from a very negative capacitance (inductance) toward $C_{eq} = C_C$, a positive capacitance.

Very simple calculations for C_{eq} at higher frequencies indicate the problems encountered when capacity measurements are made above 1 MHz. As ω approaches $\omega_o = 1/\sqrt{L_SC_J}$, small variations in L_S cause extreme variations in measured diode capacitance.

$$Y = j\omega C_{eq} = j\omega C_c + \frac{j\omega C_J}{1 - \omega^2 L_S C_J} \qquad (4)$$

D. EPICAP FIGURE OF MERIT (Q) AND CUTOFF FREQUENCY (f_{co})

The efficiency of EPICAP response to an input frequency is related to the Figure of Merit of the device as defined in equation 5. For very low frequencies, equation 6 applies whereas at high frequencies, where R_J can be neglected, equation 5 may be rewritten into the familiar form of equation 7.

Another useful parameter for EPICAP devices is the cutoff frequency (f_{co}). This is merely that frequency at which Q is equal to 1. Equation 8 gives this relationship.

$$Q = \frac{X_{Seq}}{R_{Seq}} \qquad (5)$$

$$Q_{Lf} = \frac{\omega C_J R_J^2}{R_J + R_S(1 + \omega^2 C_J^2 R_J^2)} \qquad (6)$$

$$Q_{hf} = \frac{1}{\omega R_S C_{eq}} \qquad (7)$$

$$f_{co} = Qf_{max} \approx \frac{1}{2\pi R_S C_{BVR}} \qquad (8)$$

E. HARMONIC GENERATION USING EPICAPS

Efficient harmonic generation is possible with Motorola EPICAPS because of their high cutoff frequency and breakdown voltage. Since EPICAP junction capacitance varies inversely with the square root of the breakdown voltage, harmonic generator performance can be accurately predicted from various idealized models. Equation 9 gives the level of maximum input power for the EPICAP and equation 10 gives the relationships governing EPICAP circuit efficiency. In these equations, adequate heat sinking has been assumed.

$$P_{in(max)} = \frac{M(BV_R + \phi)^2}{R_S} \frac{f_{in}}{f_{co}} \qquad (9)$$

$M(x2) = 0.0285$; $M(x3) = 0.0241$; $M(x4) = 0.196$

$$Eff = 1 - N\frac{f_{out}}{f_{co}} \qquad (10)$$

$N(x2) = 20.8$; $N(x3) = 34.8$; $N(x4) = 62.5$

M and N are Constants

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