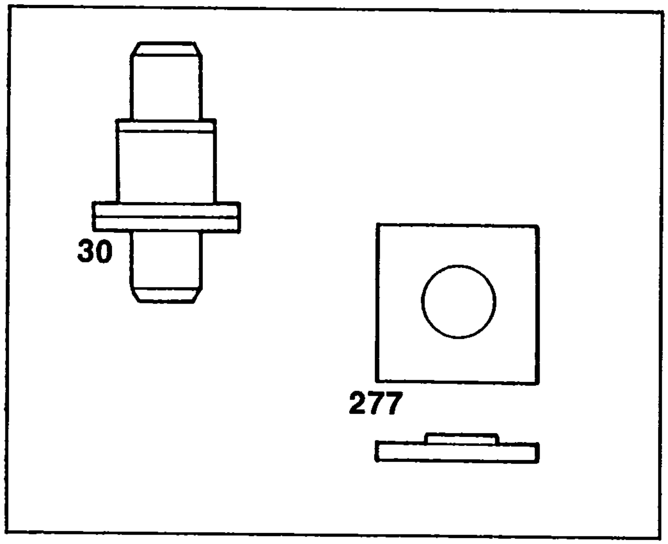
M/A-COM

MA46450 through MA46480 Series — 1.00 and 1.25 Gamma

GaAs Hyperabrupt Tuning Varactors



Features

- CONSTANT GAMMA = 1.0 OR 1.25
- HIGH Q (UP TO 4000 AT −4 VOLTS)
- LARGE CAPACITANCE CHANGE WITH VOLTAGE
- MORE LINEAR FREQUENCY TUNING
- HIGH AND NEARLY CONSTANT MODULATION SENSITIVITY

Description

The MA46450 series and the MA46470 series of tuning varactors are hyperabrupt junction Gallium Arsenide devices featuring constant gamma of 1.0 (MA46450 series) and 1.25 (MA46470 series). These series offer high "Q" (up to 4000) that permit excellent tuning performance from VHF through Ka-band. Each device in these series exhibits the large capacitance change with voltage of hyperabrupt tuning varactors. Standard capacitance matching is ±10%, with closer matching available on request. All diode types are available in a wide selection of ceramic packages and in chip form.

Applications

The constant gamma value of 1.0 or 1.25 available from these diodes permits significant circuit performance improvements for the circuit designer. Constant gamma tuning varactors permits more linear VCO frequency tuning with bias voltage than conventional varactors. These varactors are also useful for tunable filters and can improve the frequency tuning linearity of these circuits. These diodes are an excellent choice for modulator applications where excellent linearity and constant modulation sensitivity is desired.

Specifications @ T_A = 25°C

MA46450 Series
GaAs Constant Gamma Hyperabrupt Tuning Varactors
Gamma = 1.0

Breakdown Voltage = 22 Volts Minimum
Gamma Constant = 1.0 ± 10% 2 – 20 volts
Capacitance Tolerance[3] = ± 10%

Model[1] Number	Case Style	Total[9, 2, 5] Capacitance @ −4 Volts (±10%) (pF)	Capacitance[3, 9] Ratio (2/20) Min./Max.	Q at[6] −4 Volts Minimum
MA46450	30	0.5	2.0/2.7	4000
MA46451	30	0.7	2.9/4.1	4000
MA46452	30	1.0	3.6/5.2	3000
MA46453	30	1.2	3.6/5.2	3000
MA46454	30	1.5	3.8/5.5	3000
MA46455	30	1.8	4.1/6.1	3000
MA46456	30	2.0	4.1/6.1	3000
MA46457	30	2.2	4.1/6.1	3000
MA46458	30	2.7	4.5/6.7	2000
MA46459	30	3.3	4.5/6.7	2000
MA46460	30	3.7	4.7/7.1	2000
MA46461	30	4.7	4.8/7.2	1500
MA46462	30	5.6	4.9/7.4	1500
MA46463	30	6.8	4.9/7.4	1500
MA46464	30	8.2	5.0/7.6	1500
MA46465	30	10.0	5.0/7.6	1500

MA46470 Series
GaAs Constant Gamma Hyperabrupt Tuning Varactors
Gamma = 1.25

Breakdown Voltage = 22 Volts Minimum
Gamma Constant = 1.25 ± 10% 2 – 20 Volts Minimum
Capacitance Tolerance[3] = ± 10%

Model[1] Number	Case Style	Total[9, 2, 5] Capacitance @ −4 Volts (±10%) (pF)	Capacitance[3, 9] Ratio (2/20) Min./Max.	Q at[6] −4 Volts 50 MHz
MA46470	30	0.5	2.2/3.2	4000
MA46471	30	0.7	3.6/5.3	4000
MA46472	30	1.0	4.8/7.1	3000
MA46473	30	1.2	4.8/7.1	3000
MA46474	30	1.5	5.0/7.4	3000
MA46475	30	1.8	6.6/8.7	3000
MA46476	30	2.0	6.6/8.7	3000
MA46477	30	2.2	6.6/8.7	3000
MA46478	30	2.7	6.4/10.0	2000
MA46479	30	3.3	6.4/10.0	2000
MA46480	30	3.7	6.8/11.0	2000
MA46481	30	4.7	6.9/11.1	1500
MA46482	30	5.6	7.2/11.5	1500
MA46483	30	6.8	7.2/11.5	1500
MA46484	30	8.2	7.2/11.5	1500
MA46485	30	10.0	7.5/12.0	1500

NOTES:

1. All GaAs tuning varactors are available upon special request in chip form as well as any other case style and the standard ODS – 30 package. When ordering, specify the desired case by adding the case designation as a suffix to the type number.
2. Case parasitics (C_p and L_S) are given for most case styles along with case outlines in this bulletin. The C_p values listed typically have tolerances of ±0.02 pF.
3. The nominal tolerance at −4 volts is ±10%. Closer tolerances are available upon request. By adding the suffix A to the part number, a tolerance of ± 5% can be obtained.
4. Gamma is within the limits of 0.90 < γ < 1.10 over the voltage range of 2 – 20 volts for the MA46450 series. Gamma is within the limits of 1.13 < γ < 1.40, over the range of 2 – 20 volts for the MA46470 series. Total capacitance of the packaged diodes will deviate from constant gamma characteristics due to differences in case capacitance (C_p). Figures 1 and 4 illustrate typical total capacitance versus applied voltage for these series when case style 30 is selected. Figure 3 illustrates the typical range of γ versus voltage when case style 30 is selected. Figures 2 and 5 illustrate typical capacitance ratios versus applied voltage in case style 30.
5. Capacitance is measured at 1 MHz using a shielded test holder.
6. Diode Q is measured by the DeLoach technique at −4 volts and extrapolated to 50 MHz.
7. Parasitic inductance (L_S) has been determined at X band using the DeLoach method measurement.
8. Breakdown voltage (V_b) is measured at 10 microamps.
9. The total capacitance and capacitance ratios shown are for devices housed in case style 30. Other case styles will result in different values.

Electrical Characteristics (at 25°C)

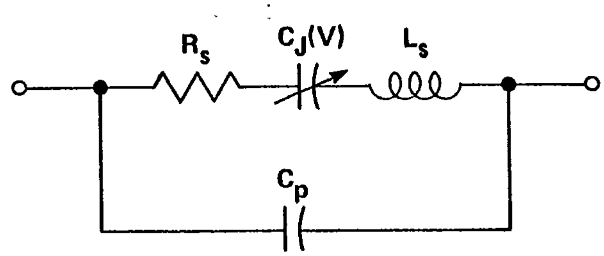
MAXIMUM RATINGS

Operating Temperature	−65°C to +200°C
Storage Temperature	−65°C to +200°C
Reverse Voltage	Breakdown Voltage

ENVIRONMENTAL RATINGS PER MIL-STD-750

	MIL Method	Level
Storage Temperature	1031	See maximum ratings
Operating Temperature		See maximum ratings
Temperature Cycle	1051	10 cycles, −65°C to +175°C
Shock	2016	500 g's
Vibration	2056	15 g's
Constant Acceleration	2006	20,000 g's
Humidity	1021	10 days

TUNING VARACTOR EQUIVALENT CIRCUIT



Typical Performance Curves

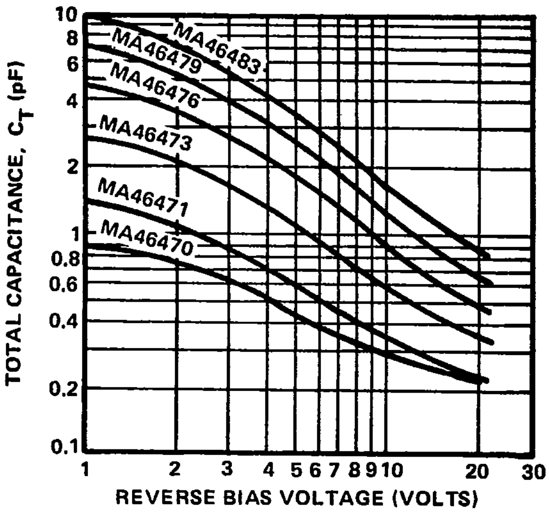


FIGURE 1. Total Capacitance vs. Reverse Bias Voltage (Case Style 30)

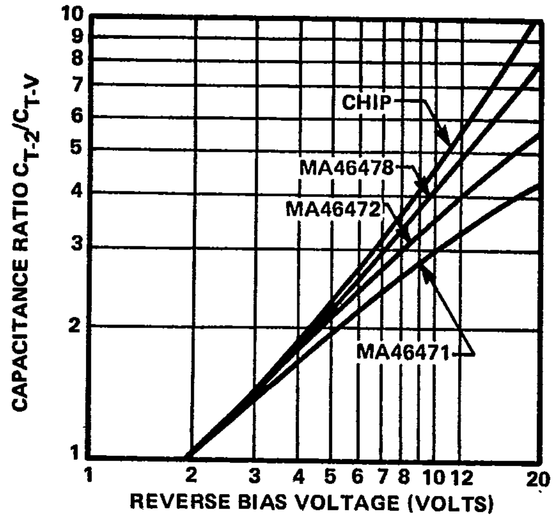


FIGURE 2. Capacitance Ratio vs. Reverse Bias Voltage (Case Style 30)

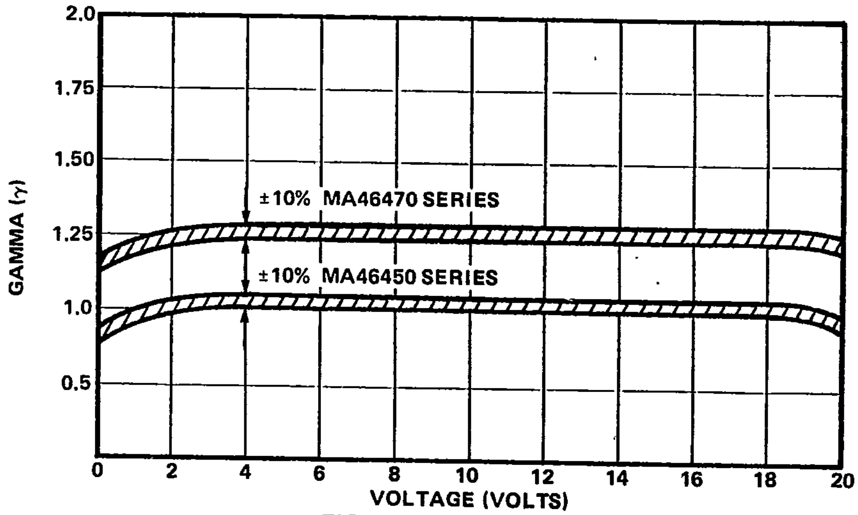


FIGURE 3. Gamma vs. Voltage

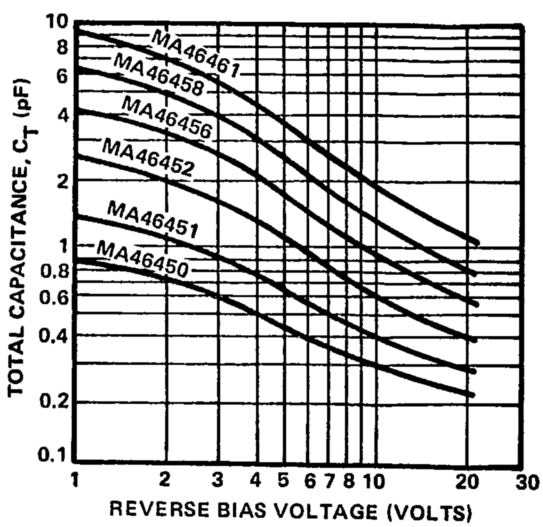


FIGURE 4. Total Capacitance vs. Reverse Bias Voltage (Case Style 30)

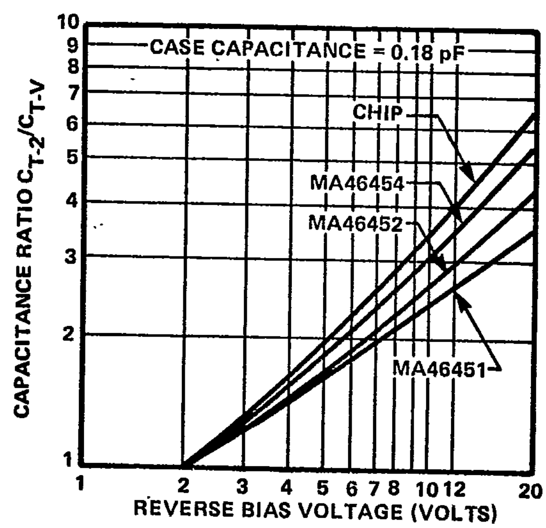


FIGURE 5. Capacitance Ratio vs. Reverse Bias Voltage (Case Style 30)

Application Notes

SELECTION OF CONSTANT GAMMA HYPERABRUPT TUNING VARACTORS

For varactors, the dependence of junction capacitance, C_j, on applied voltage, V, is given by:

$$C_j = \frac{C_o}{\left(1 + \frac{V_R}{\theta}\right)^{\gamma}} \qquad (1)$$

Φ = the built in potential ($\phi = 1.3$ volts for GaAs)

C_o = a constant (mathematically extrapolated to junction capacitance at V = 0)

γ = the capacitance-voltage slope exponent (gamma)

For simple abrupt junction varactors, gamma is constant and nominally equal to 0.5. The junction is referred to as hyperabrupt when gamma is >0.5 and for most varactors, the value of gamma varies widely with applied voltage.

From Equation (1), we observe that gamma is graphically determined as the slope of junction capacitance, C_j, as a function of total voltage (applied voltage plus built-in potential) plotted on log-log paper. A typical plot of the constant gamma hyperabrupt tuning varactor C-V characteristics is illustrated in Figure A, where the slope of the curve is a constant gamma = 1.25 over the applied voltage range of 2-20 volts. Notice that constant gamma is not maintained at low applied voltages, so C_o = 6.6 pF is a mathematical value determined by extending the constant slope to V=0 or (V + Φ = 1.3). The capacitance versus applied voltage, Curve 2, is also shown in Figure A for the chip, and Curve 3 illustrates the C-V curve when the chip is mounted in a style 30 package having a package capacitance of ~0.18 pF.

The primary purpose of the constant gamma hyperabrupt varactors is to permit the designer to approach linear frequency tuning without the use of a linearizer. For a simple resonant circuit comprised of an inductance, L, and a varactor with junction capacitance C_j (V), the frequency-voltage relationship is given by:

$$fr(V) = \frac{1}{2\pi\sqrt{LC_j(V)_1}} = \frac{1}{2\pi\sqrt{LC_o}}\left(1 + \frac{V_R}{\theta}\right)^{\gamma/2}$$

and the desired gamma value for linear tuning is 2.0.

In all microwave oscillator circuits, the varactor is not the only capacitor in the resonant circuit. Instead, this capacitance makes up only a portion of the total resonant capacitive element. An analysis has been performed of the simple series circuit illustrated in Figure B where a fixed capacitor, C_S, is in series with the varactor junction. The results of this analysis provides guidance to the selection of a suitable gamma. The total capacitance, C_t of the resonant circuit can be expressed in terms of a coupling factor, K_S, as:

$$\frac{1}{C_t(V)} = \frac{1}{C_{to}}\left[1 - K_S + K_S\left(1 + \frac{V}{\theta}\right)^{\gamma}\right]$$

where:

$K_S = C_{to}$ = total capacitance of resonator at V = 0
C_o = varactor junction capacitance at V = 0

when K_S = 1, the varactor is fully coupled and the value of gamma for linear tuning is 2.0.

As K_S approaches 0, the varactor becomes decoupled and the optimum gamma for linear tuning approaches 1.0. An optimum value of gamma for linear frequency tuning is predictable and the result is illustrated in Figure C. In this illustration, the optimum gamma value is plotted versus the frequency f_{max}/f_{min}, the coupling factor, Ks, as a parameter. Notice that linear tuning can be achieved for constant gamma within the limits $1.0 < \gamma < 2.0$ depending on the coupling factor.

A circuit designer can use this simplified analysis for selection of constant gamma hyperabrupt varactors. For example, suppose a circuit requirement is for a tuning ratio of 2:1. The designer could select γ = 2 and fully couple the varactor with $C_{max}/C_{min} < 4$. Alternatively, if the circuit is decoupled to K_S = 0.6 where γ = 1.6 and $C_{max}/C_{min} > 6$. The further decoupling can also be considered with correspondingly lower optimum γ. The decoupling limit occurs when the C_{max}/C_{min} is not available in the varactor. It has been empirically found that to obtain the best noise and bandwidth characteristics, most moderate bandwidth voltage controlled oscillators will have varactor coupling factors (K_S) of 0.2-0.4. Most moderate power C and X band bipolar or FET oscillator transistors will have a C_C of approximately 0.25 pF. 50-100 mW Gunn diodes have similar capacitances. (For further discussion on varactor coupling refer to M/A-COM SPO's article "Tuning Varactor Diode Selection Guide", 1986). These broadband tuning requirements are optimized in circuits with $1.2 < \gamma < 1.4$, while circuits with narrow tuning bandwidth need to utilize a value of gamma approaching 1.0. Linearity improvement with these varactors is frequently a factor of 10 or more in comparison to conventional abrupt junction varactors.

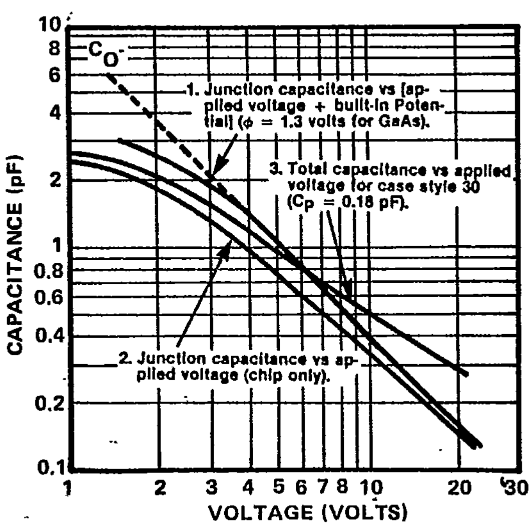


FIGURE A. Typical GaAs Hyperabrupt C-V Characteristics

Application Notes (Cont'd)

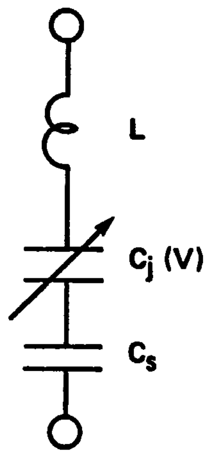


FIGURE B. Resonant Circuit With Decoupled Tuning Varactor

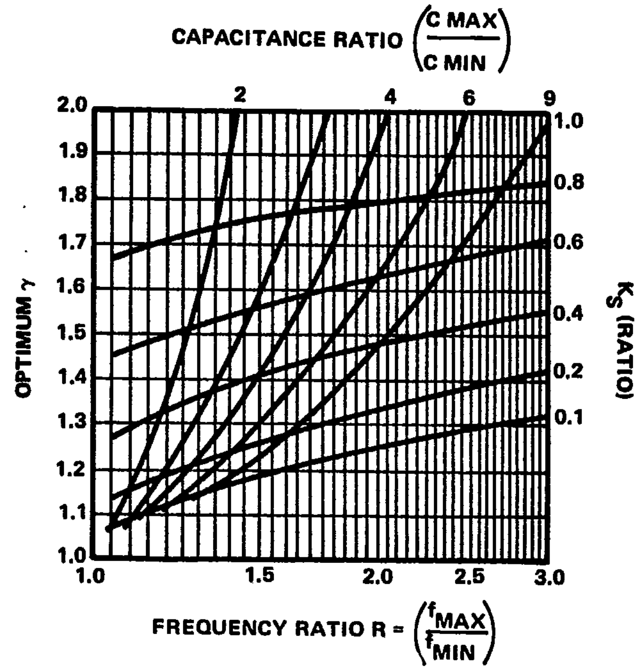
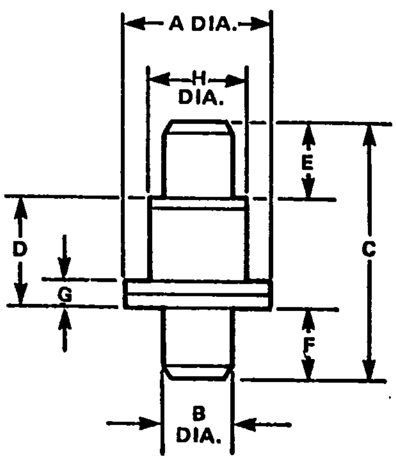


FIGURE C. Optimum γ Selection for Linear Tuning

Case Styles

30

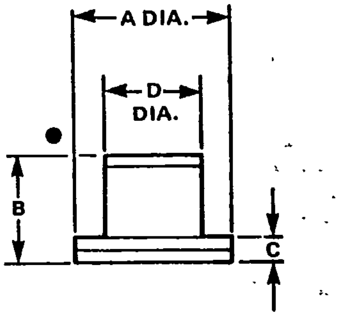


DIM.	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.119	0.127	3,02	3,22
B	0.060	0.064	1,52	1,63
C	0.205	0.225	5,21	5,72
D	0.085	0.097	2,16	2,46
E	0.060	0.064	1,52	1,63
F	0.060	0.064	1,52	1,63
G	0.016	0.024	0,41	0,61
H	0.079	0.083	2,01	2,11

C_P = 0.18 pF Typical
L_S = 0.40 nH Typical

Case Styles (Cont'd)

31



DIM.	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.119	0.127	3,02	3,23
B	0.085	0.097	2,16	2,46
C	0.016	0.024	0,41	0,61
D	0.077	0.083	1,96	2,11

C_P = 0.18 pF Typical
L_S = 0.40 nH Typical

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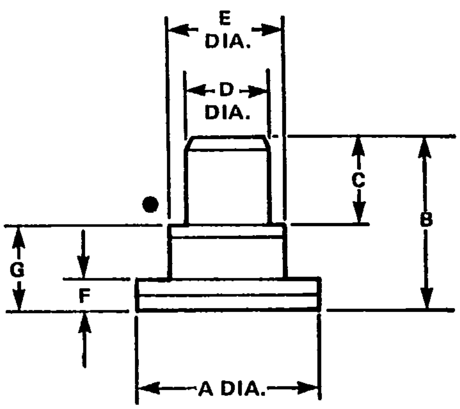
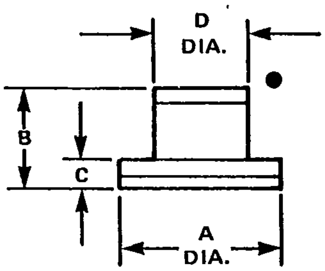


DIM.	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.119	0.127	3,02	3,23
B	0.115	0.129	2,92	3,28
C	0.060	0.064	1,52	1,63
D	0.060	0.062	1,52	1,57
E	0.077	0.083	1,96	2,11
F	0.016	0.024	0,41	0,61
G	0.055	0.065	1,40	1,65

C_P = 0.15 pF Typical
L_S = 0.17 nH Typical

94

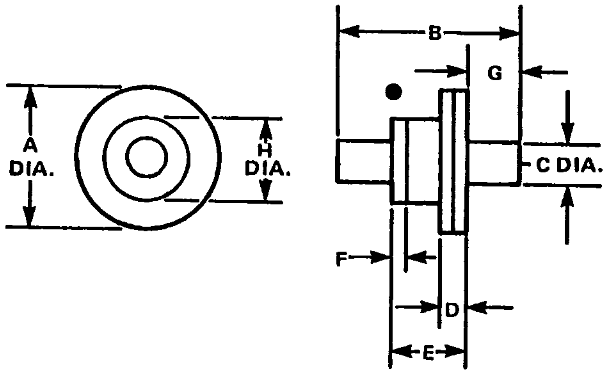


DIM.	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.078	0.086	1,98	2,18
B	0.040	0.050	1,02	1,27
C	— —	0.015	— —	0,38
D	0.047	0.053	1,19	1,35

C_P = 0.15 pF Typical
L_S = 0.17 nH Typical

Case Styles (Cont'd)

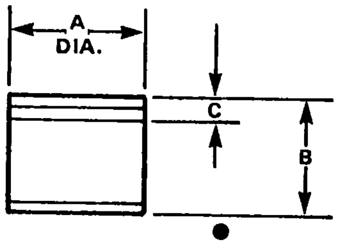
97



DIM.	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.076	0.086	1,98	2,18
B	0.100	0.110	2,54	2,79
C	0.024	0.026	0,61	0,66
D	— —	0.015	— —	0,38
E	0.040	0.050	1,02	1,27
F	0.004	0.010	0,10	0,25
G	0.029	0.031	0,74	0,79
H	0.047	0.053	1,19	1,35

C_P = 0.15 pF Typical
L_S = 0.17 nH Typical

120



DIM.	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.051	0.055	1,30	1,40
B	0.040	0.050	1,02	1,27

C_P = 0.13 pF Typical
L_S = 0.40 nH Typical

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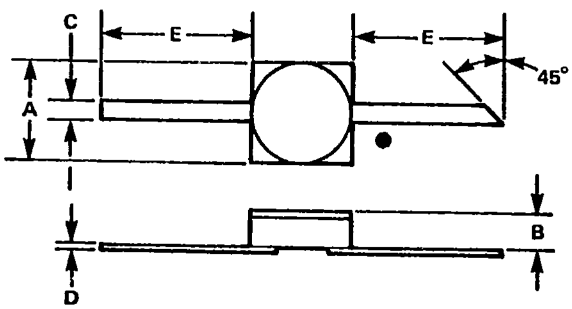

DIM.	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.094	0.102	2,39	2,59
B	0.031	0.044	0,79	1,12
C	0.019	0.021	0,48	0,53
D	0.003	0.006	0,76	0,15
E	0.130	0.170	3,30	4,32

C_P = 0.15 pF Typical
L_S = 0.40 nH Typical

Case Styles (Cont'd)

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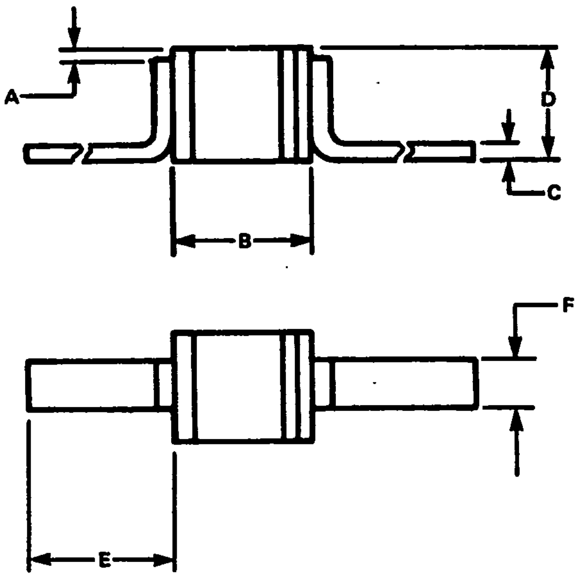

DIM.	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.010	0.020	0,254	0,508
B	0.040	0.050	1,02	1,27
C	— —	0.005	— —	0,127
D	0.051	0.055	1,29	1,39
E	0.200	— —	5,08	— —
F	0.019	0.021	0,483	0,533

C_P = 0.13 pF Typical
L_S = 0.40 nH Typical

Chip Style

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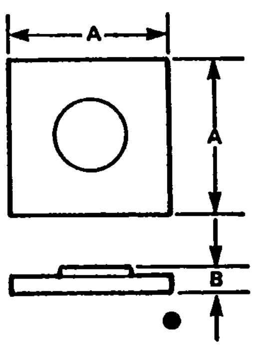

DIM.	INCHES MIN.	INCHES MAX.	MILLIMETERS MIN.	MILLIMETERS MAX.
A	0.010	0.012	0,25	0,31
B	0.004	0.005	0,10	0,13