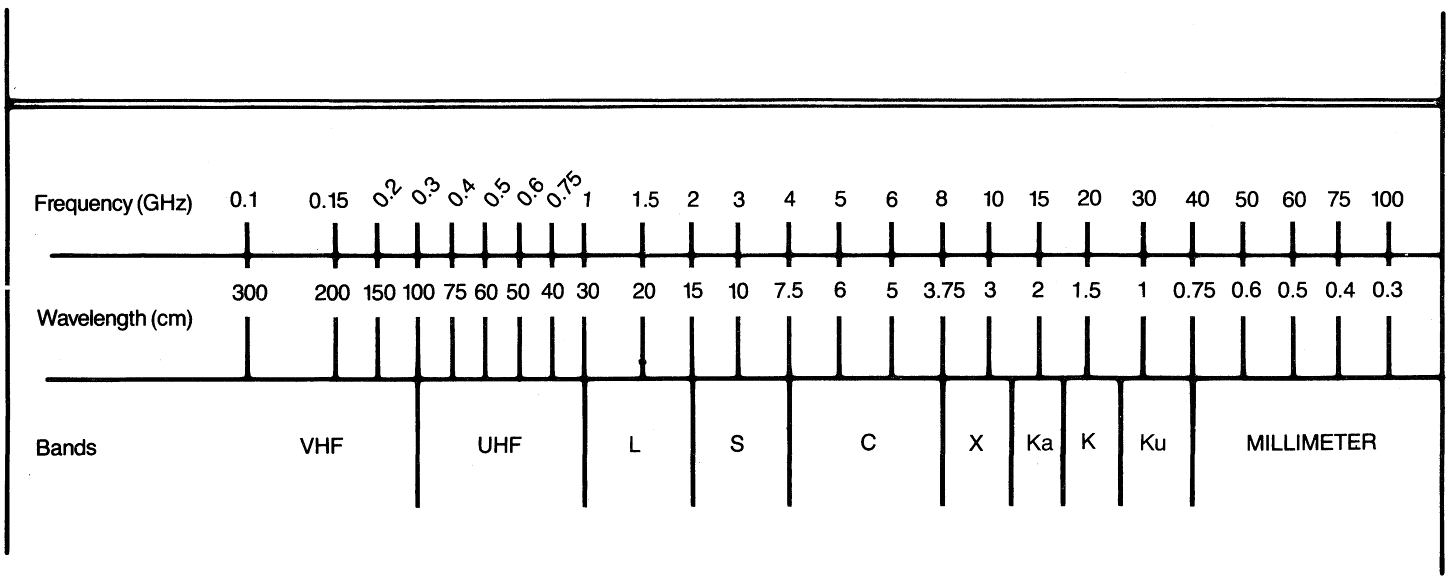
Specifications
Application Notes
Packages

Microwave Semiconductors & Modules

• **Si/GaAs Schottky Mixer/Detector Diodes** • Ferrites • Frequency Meters/Attenuators • GaAs FET Amplifiers • Garnets • **Gunn Diodes/Modules** • Hermetic PIN Diode Switches • **Hyperabrupt Tuning Diodes** • Isolators • Microwave/Millimeter Wave Integrated Subsystems • Beam Lead Schottky Diodes • **MIS Capacitors** • Mixers • Millimeter Wave Phase Locked Sources • **Parametric Amplifier Diodes** • Antennas • Circulators • PIN Diode Attenuators • PIN Diode Limiters • **PIN Diode Switches** • **Point Contact Mixer/Detector Diodes** • Power FET Amplifiers • **Power Gunn Devices** • **SOTs** • **PIN and Limiter Diodes** • Dielectrics • **SRD/Multiplier Diodes** • Multifunction Assemblies • **Si/GaAs Tuning Diodes** • Millimeter Wave Amplifiers • Waveguide Components • Dielectric Resonator Materials • DSOs • Millimeter Wave Oscillators • **Motion Detectors** • **Beam Lead PINs** •

Alpha

MICROWAVE-FREQUENCY DESIGNATION CHART



Alpha

Alpha

SEMICONDUCTOR DIVISION

SUBJECT

A comprehensive listing of the Semiconductor Division's products and capabilities with specifications, application notes, and packages.

ALPHA INDUSTRIES, INC.

SEMICONDUCTOR DIVISION
20 Sylvan Road, Woburn, MA 01801
(617) 935-5150 TWX: 710-393-1236
TELEX: 949436

- **Point Contact Mixer/Detector Diodes**
- **Si/GaAs Schottky Mixer/Detector Diodes**
- **PIN and Limiter Diodes**
- **Si/GaAs Abrupt Tuning Diodes**
- **Si/GaAs Hyperabrupt Tuning Diodes**
- **Gunn Diodes/Modules/Sources**
- **SRD/Multiplier Diodes**
- **Parametric Amplifier Diodes**
- **MIS Capacitors**
- **Microwave Integrated Devices®**

CENTRAL MICROWAVE COMPANY
12180 Pritchard Farm Road,
Maryland Heights, MO 63043
(314) 291-5270 TWX: 910-762-0649

- Microwave Solid State Sources
- Power Gunn Devices
- Power FET Amplifiers
- Millimeter Wave Oscillators
- Millimeter Wave Amplifiers
- Voltage Controlled Oscillators
- Dielectric Stabilized Oscillators
- Microwave/Millimeter Multifunction Subsystems
- Millimeter Phase Locked Sources

MICROWAVE COMPONENTS DIVISION
90 Glenn Street, Lawrence, MA 01843
(617) 681-8520 TWX: 710-342-8033

- Hermetic PIN Diode Switches
- PIN Diode Switches
- PIN Diode Limiters
- PIN Diode Attenuators
- Microwave Multifunctional Assemblies
- GaAs FET Amplifiers
- Switch Drivers

TRANS-TECH, INC.
5520 Adamstown Road, Adamstown, MD 21710
(301) 695-9400 TWX: 710-854-8418

- Microwave Ferrites
- Microwave Garnets
- Microwave Dielectrics
- Dielectric Resonator Materials
- Multi-Component Technical Ceramic Powders

MICROELECTRONICS DIVISION
3015 Advance Lane, Colmar, PA 18915
(215) 822-1311 TWX: 510-661-7370

- RF Microwave Multifunction Subassemblies
- RF Microwave Modular Amplifiers
- RF Microwave Switches
- RF Microwave Attenuators
- Analog and Digital Hybrid Microcircuits

MILLIMETER WAVE DIVISION
20 Sylvan Road, Woburn, MA 01801
(617) 935-5150 TWX: 710-393-1236
Telex: 949436

- Waveguide Components
- Millimeter Multipliers/Detectors/Switches/Upconverters
- Millimeter Circulators/Isolators/Mixers
- Frequency Meters/Attenuators
- Millimeter Phase Locked Oscillators
- Antennas
- Millimeter Multifunction Subsystems
- Radiometers
- Millimeter Radio Front Ends

Preface

This catalog contains comprehensive information about Alpha's semiconductor devices. In addition to the technical data sheets, which contain detailed specifications, the catalog contains application notes and package outline drawings. A section-by-section breakdown of the catalog is as follows:

Section 1 gives a brief overview of Alpha's Semiconductor Division.

Sections 2 through 5 contain comprehensive information on Mixer and Detector Diodes (including Schottky barrier and point contact diodes), Control Diodes (including PIN switching, attenuator, and limiter diodes, and Silicon and GaAs Tuning diodes), Power Generation Devices (including Gunn diodes and modules, and GaAs and silicon parametric amplifier diodes), and silicon and GaAs multiplier and step recovery diodes. These sections contain detailed technical data sheets, as well as quick reference charts and application notes.

Section 6 gives complete data on Alpha's line of MIS capacitors.

Section 7 contains three application notes on bonding methods for diode chips, beam-lead diodes and capacitors; reliability testing and screening of semiconductors; and Alpha's high-reliability diodes for space and military applications.

Section 8 includes outline drawings of all products which appear in this catalog, listed by package number. Also, a package silhouette chart shows actual size silhouettes with corresponding package numbers, grouped by "families."

Section 9 is a speed index, listing every part number that appears in this catalog alphanumerically, with its corresponding page number.

Section 10 presents Alpha ordering information, as well as Alpha's domestic and international sales offices and representatives.

Publication Number 50010010 **February 1985**

Contents

Contents

Section 1
Introduction

Alpha Industries is a leading manufacturer of highly sophisticated microwave materials, devices, components, and subsystems. For over twenty years, the Semiconductor Division, Alpha's largest operating group, has been designing and producing microwave devices and components that are used in the generation, amplification, detection, and control of microwave energy. Among the division's strengths are its flexibility and willingness to meet unique customer requirements with quick reaction time and the maintenance of strict quality standards.

The Semiconductor Division manufactures one of the broadest product lines in the industry with extensive in-house silicon and gallium arsenide capabilities. The line includes Mixer and Detector diodes — both Schottky Barrier and Point Contact types — a broad variety of control and generating devices including PIN, Beam-Lead PIN, Limiter, Gunn, Tuning, and Multiplier diodes, and Parametric Amplifier Varactors, as well as special devices such as Beam-Lead and Chip Capacitors.

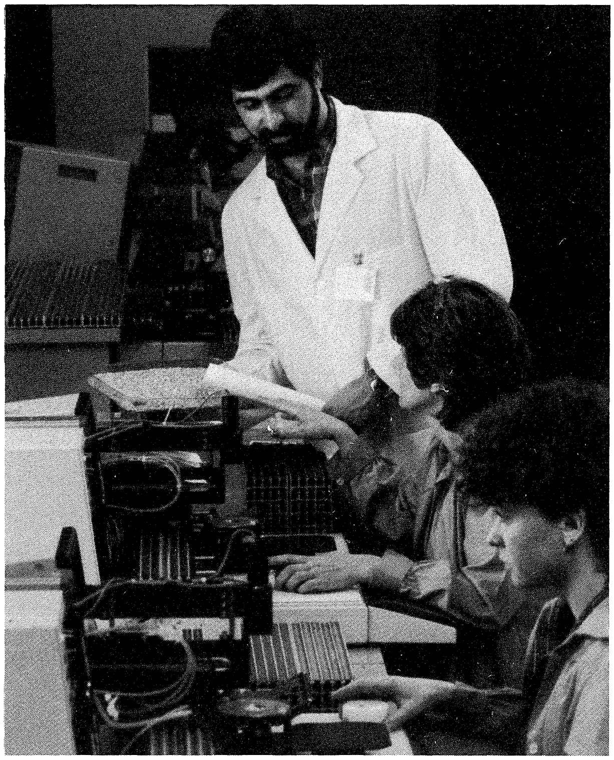
Alpha's state-of-the-art production facilities are among the most advanced in the industry. Sophisticated automatic equipment, much of it designed by Alpha engineers, provides for the processing, assembling, and testing of micro-miniature devices and assemblies.

Elaborate precautions taken at each manufacturing stage ensure the integrity of materials used and allow complete wafer traceability. Process methodologies extend from vapor phase epitaxial (reactors) to ion implantation. A complex of fully-equipped class 1000 clean rooms totaling 4400 square feet provide a stringently-controlled environment for each processing chip.

Quality Control is always a top priority at Alpha, exemplified by one of the industry's best performance records. Alpha's Semiconductor Division has placed devices on virtually every major program requiring high reliability from military aircraft, ships, and missiles to deep space satellites.

A significant problem facing microwave designers today is the difficulty in matching device parameters to inherent circuit characteristics. Optimum performance can best be achieved through close communication between the designer and Alpha's staff of Applications Engineers. The result is a broad inventory of devices totaling in excess of 25 million chips. In many cases, immediate samples can be provided for the most unique device.

This catalog is a guide to assist you in designing and specifying your particular needs. More than 75% of Alpha's business is non-catalog items. If you do not find exactly what you are looking for in this catalog, contact your local representative or call us at (617) 935-5150 for further assistance.



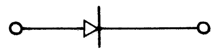
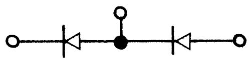
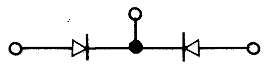
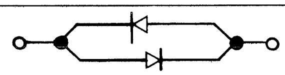
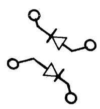
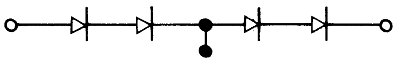
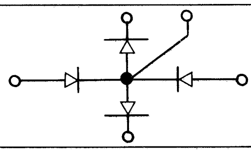
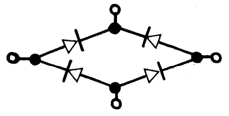
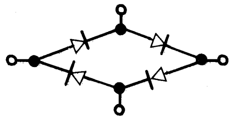
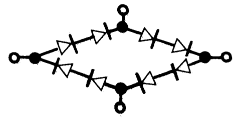
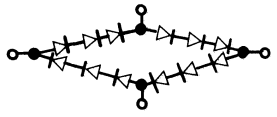
Alpha is committed to continuing development of state-of-the-art manufacturing processes. These diode bonding machines with video monitors are among the most advanced in the industry.

Section 2
Mixer and Detector Diodes

Schottky Barrier Diodes

Point Contact Diodes

Schottky Barrier Mixer and Detector Diodes Quick Reference Chart

Monolithic Beam-Lead Device	Electrical Circuit	Features
Single		Ideal for use as mixers or detectors on MICs.
Series Pair		Ideal for use anywhere a closely matched pair of diodes is required.
Reverse Series Pair		Same as above except for polarity.
Common Cathode Pair		Ideal for signal comparison detectors.
Antiparallel Pair		Ideal for subharmonically pumped mixers in which case odd harmonics are suppressed.
Split Pair		Ideal for temperature compensated detector use.
Four Junction Pair		Ideal for high level up-converters.
Star Quad		Ideal for use in Star mixer circuits, which do not require an IF balun.
Quad Bridge		Ideal for use in termination-insensitive mixers or biased mixers.
Quad Ring		Ideal for use in double balanced mixers.
Eight Junction Ring		Ideal for use in double balanced mixers requiring higher compression point and/or better IM performance.
Twelve Junction Ring		Ideal for use in double balanced mixers where highest compression point and/or best IM performance is required.

Schottky Barrier Mixer and Detector Diodes
Quick Reference Chart

Description

This selection chart identifies the standard line of Alpha Schottky barrier mixer and detector diodes by basic construction, package style and frequency band.

Pressure Contact

Type	Actual Size	Alpha Package	Notes	MIXERS			DETECTORS
				S-Band	X-Band	Ku-Band	X-Band
Glass		075-001	Medium Drive	DMC5501	DMC5504		
			Low Drive		DMF6130		
			Low 1/f Noise		DMC4037		DDL6672
			Zero Bias				DDC4562
Ceramic		005-801	Low 1/f Noise	DMC5910	DMB5880		DDL6725
			Low 1/f Noise		DMB6411		
			Low 1/f Noise		DMC6224		
					DMF6724		
			Zero Bias				DDC4561
MQM		013-001	Medium Drive	DMC5503	DMC5506[1]	DMC5507[1]	

Note:
1. Low Drive available upon request.

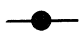
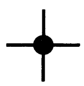
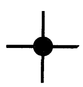
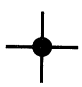
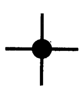
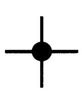
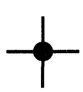
Schottky Barrier Mixer and Detector Diodes Quick Reference Chart

Beam-Lead — Unmounted

Type	Actual Size	Alpha Pkg.	Descrip.	Mixers L	Mixers S	Mixers X	Mixers Ku	Mixers Ka	Mixers mm	Detectors X	Detectors Ku	Detectors K
Single		174-002	Zero Bias							DDC4565		
		174-001	Low Drive		DMF5817	DMF5818	DMF5600			DDE6316	DDE6890	
		174-002	Low 1/f Noise			DMB4500	DMB4501			DDB4503	DDB4504	DDB3265
		174-001	Medium Drive		DME3127	DME6957	DME6507					
			High Drive		DMJ5034	DMJ6777	DMJ6778					
			GaAs			DMK6604	DMK6605	DMK6606	DMK4791			
		366-001	GaAs						DMK4784			
Series Pair		378-012	Low Drive		DMF5835	DMF5819	DMF4788					
			Medium Drive		DME3050	DME3051	DME6553					
			High Drive		DMJ3092	DMJ3093	DMJ4705					
Series Pair		378-016	Low Drive			DMF6958	DMF3223					
			Medium Drive				DME3177					
			GaAs				DMK6591	DMK3241				
Common Cathode Pair		378-013	Low Drive		DMF3182	DMF3183	DMF3184					
			Medium Drive		DME3205	DME3206	DME3207					
			High Drive		DMJ3208	DMJ3209	DMJ3210					
Anti-parallel Pair		396-025	Low Drive		DMF3185	DMF3186	DMF3187					
			Medium Drive		DME3282	DME3283	DME3284					
			High Drive		DMJ3303	DMJ3304	DMJ3246					
			GaAs				DMK3307					
Split Pair		408-009	Low Drive		DMF3196	DMF3197	DMF3198					
			Medium Drive		DME3199	DME3200	DME3201					
			High Drive		DMJ3202	DMJ3203	DMJ3204					
Four-Junction Pair		407-029	High Drive			DMJ3180	DMJ3181					
Quad Ring		399-003	Zero Bias				DMH3159					
		294-003	Low Drive		DMF6829	DMF4011	DMF4012					
			Medium Drive		DME6561	DME6562	DME6563					
			High Drive		DMJ4502	DMJ6990	DMJ6667					
			GaAs				DMK6592					
Quad Bridge		294-004	Low Drive		DMF3076	DMF3077	DMF3078					
			Medium Drive		DME3029	DME3030	DME3031					
			High Drive		DMJ4312	DMJ3088	DMJ4768					
			GaAs			DMK4746						
Star Quad		397-034	Low Drive		DMF3188	DMF3189	DMF3190					
			Medium Drive		DME3191	DME3192	DME3178					
			High Drive		DMJ3193	DMJ3194	DMJ3195					
8-Junction Ring		294-021	Low Drive			DMF3287	DMF3288					
			Medium Drive			DME3273	DME3274					
			High Drive			DMJ4759	DMJ4771					
12-Junction Ring		398-022	High Drive				DMJ6564					

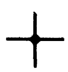
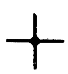
Schottky Barrier Mixer and Detector Diodes Quick Reference Chart

Beam-Lead — Mounted Ceramic (100 mil diameter)

Type	Actual Size	Alpha Pkg.	Descrip.	Mixers						Detectors		
				L	S	X	Ku	Ka	mm	X	Ku	K
Single		130-011	Zero Bias							DDC4582		
			Low Drive		DMF5845	DMF5827	DMF6022					
			Low 1/f Noise			DMB6780	DMB6782			DDB4719	DDB3263	DDB5098
			Medium Drive		DME3128	DME3055	DME3056					
			High Drive		DMJ6784	DMJ6786	DMJ6670					
			GaAs			DMK6571						
Series Pair		131-012	Low Drive		DMF5846	DMF6460	DMF6459					
			Medium Drive		DME3012	DME3013	DME3014					
			High Drive		DMJ6531	DMJ4317	DMJ3081					
Anti-parallel Pair		130-025	Low Drive		DMF3226	DMF3245	DMF3286					
			Medium Drive		DME3270	DME3271	DME3272					
			High Drive		DMJ3294	DMJ3295	DMJ3296					
Split Pair		132-008	Low Drive		DMF4040	DMF5828	DMF6023					
			Low 1/f Noise								DDB5138	
			Medium Drive		DME3009	DME3010	DME3011					
			High Drive		DMJ3095	DMJ3096	DMJ3097					
Quad Ring		132-002	Zero Bias				DMH4383					
			Low Drive	DMF4000	DMF5847	DMF5829	DMF6395					
			Low 1/f Noise			DMB3211						
			Medium Drive	DME6549	DME3038	DME4756	DME3039					
			High Drive		DMJ4007	DMJ6788	DMJ3082					
Quad Bridge		132-004	Low Drive	DMF3059	DMF5848	DMF6288	DMF6298					
			Medium Drive		DME3040	DME4370	DME3041					
			High Drive		DMJ6575	DMJ4313	DMJ3083					
Crossover Ring Quad		132-010	Low Drive		DMF4384	DMF6555						
			Medium Drive		DME3028							
			High Drive		DMJ6708							
8-Junction Ring		132-020	Low Drive		DMF3242							
			Medium Drive		DME4399							
			High Drive		DMJ6754	DMJ4708	DMJ3091					
12-Junction Ring		132-022	High Drive				DMJ4766					

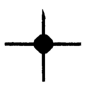
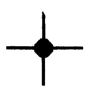
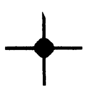
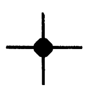
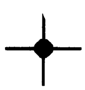
Schottky Barrier Mixer and Detector Diodes Quick Reference Chart

Beam-Lead — Mounted Ceramic (50 × 50 mil square)

Type	Actual Size	Alpha Pkg.	Descrip.	Mixers						Detectors		
				L	S	X	Ku	Ka	mm	X	Ku	K
Single		295-011	Zero Bias							DDC6980		
			Low Drive		DMF3175	DMF3068	DMF3069					
			Low 1/f Noise			DMB3000	DMB3001			DDB3221	DDB3266	DDB3267
			Medium Drive			DME3057	DME3058					
			High Drive			DMJ3151	DMJ3152					
			GaAs			DMK6583						
Series Pair		295-012	Low Drive		DMF3215	DMF3066	DMF6554					
			Medium Drive			DME6569	DME3054					
			High Drive			DMJ3101	DMJ3102					
			GaAs			DMK3167						
Anti-parallel Pair		295-025	Low Drive		DMF3230	DMF3289	DMF3290					
			Medium Drive		DME3275	DME3276	DME3277					
			High Drive		DMJ3297	DMJ3298	DMJ3299					
Split Pair		295-008	Low Drive			DMF3074	DMF3073					
			Medium Drive			DME3015	DME3016					
			High Drive			DMJ3099	DMJ3100					
Quad Ring		295-002	Zero Bias				DMH6570					
			Low Drive		DMF4549	DMF4745	DMF4574					
			Medium Drive		DME3043	DME4750	DME4541					
			High Drive		DMJ3086	DMJ3087	DMJ4397					
Quad Bridge		295-004	Low Drive		DMF3067	DMF6558	DMF6574					
			Medium Drive		DME3052	DME6567	DME3053					
			High Drive		DMJ3114	DMJ3115	DMJ3116					
8-Junction Ring		295-020	High Drive			DMJ3094	DMJ4747					
12-Junction Ring		295-022	High Drive				DMJ6596					
Double Quad Ring	 (8 leads)	418-038	Low Drive				DMF3243					
			Medium Drive				DME3261					
			High Drive				DMJ3262					

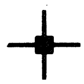
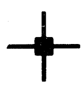
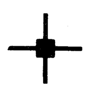
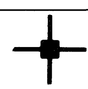
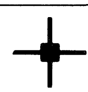
Schottky Barrier Mixer and Detector Diodes Quick Reference Chart

Beam-Lead — Mounted Hermetically Sealed (100 × 100 mil square, 110 mil diagonal)

Type	Actual Size	Alpha Pkg.	Descrip.	Mixers						Detectors		
				L	S	X	Ku	Ka	mm	X	Ku	K
Single		364-011	Zero Bias							DDC4722		
			Low Drive		DMF4365	DMF3064	DMF3065					
			Low 1/f Noise			DMB3003	DMB3004			DDB3268	DDB4393	DDB3269
			Medium Drive		DME3124	DME3125	DME3126					
			High Drive		DMJ3153	DMJ3154	DMJ3155					
			GaAs			DMK3308						
Series Pair		364-012	Low Drive			DMF4526	DMF4734					
			Medium Drive			DME3025	DME3026					
			High Drive			DMJ4760	DMJ3089					
Split Pair		364-008	Low Drive			DMF4713	DMF3062					
			Medium Drive			DME3023	DME3024					
			High Drive			DMJ3106	DMJ3107					
			GaAs				DMK6986					
Quad Ring		364-002	Zero Bias				DMH3158					
			Low Drive			DMF3074	DMF3075					
			Medium Drive		DME3238	DME4790	DME3047					
			High Drive		DMJ3237	DMJ3108	DMJ3109					
Quad Bridge		364-004	Low Drive			DMF3079	DMF3080					
			Medium Drive			DME3036	DME3037					
			High Drive			DMJ3122	DMJ3123					
Star Quad		364-034	Low Drive		DMF3251	DMF3252	DMF3253					
			Medium Drive		DME3254	DME3255	DME3256					
			High Drive		DMJ3257	DMJ3258	DMJ3259					
8-Junction Ring		364-020	High Drive			DMJ3112	DMJ3113					

Schottky Barrier Mixer and Detector Diodes Quick Reference Chart

Beam-Lead — Mounted
Hermetically Sealed (100 × 100 mil square, 140 mil diagonal)

Type	Actual Size	Alpha Pkg.	Descrip.	Mixers						Detectors		
				L	S	X	Ku	Ka	mm	X	Ku	K
Singles		325-011	Zero Bias							DDC4717		
			Low Drive		DMF5079	DMF4035						
			Low 1/f Noise			DMB6781					DDB4371	
			Medium Drive		DME3006	DME3005						
			High Drive		DMJ6785	DMJ6789						
			GaAs			DMK4712	DMK6635					
Series Pair		325-012	Low Drive		DMF6576	DMF6704						
			Medium Drive		DME3012	DME3022						
			High Drive		DMJ4783	DMJ3090						
			GaAs			DMK4525						
Anti-parallel Pair		325-025	Low Drive		DMF3291	DMF3292	DMF3293					
			Medium Drive		DME3278	DME3279	DME3280					
			High Drive		DMJ3300	DMJ3301	DMJ3302					
Split Pair		325-008	Low Drive		DMF3070	DMF3071						
			Medium Drive		DME3019	DME3020	DME3232					
			High Drive		DMJ3098	DMJ3105	DMJ3234					
Quad Ring		325-002	Zero Bias				DMH3157					
			Low Drive		DMF4059	DMF5080						
			Medium Drive		DME3044	DME6557						
			High Drive		DMJ6668	DMJ6669						
Quad Bridge		325-004	Low Drive		DMF3063	DMF4352						
			Medium Drive		DME3032	DME3033						
			High Drive		DMJ3120	DMJ3121						
8-Junction Ring		325-020	Low Drive		DMF3179							
			High Drive		DMJ4394							
12-Junction Ring		325-022	High Drive				DMJ3216					

Schottky Barrier Mixer and Detector Diodes
Quick Reference Chart

Beam-Lead — Mounted
Hermetically Sealed (70 × 70 mil square, 98 mil diagonal)

Type	Actual Size	Alpha Pkg.	Descrip.	Mixers						Detectors		
				L	S	X	Ku	Ka	mm	X	Ku	K
Single		404-011	Zero Bias							DDC3218		
			Low Drive			DMF3222						
Series Pair		404-012										
Split Pair		404-008	Medium Drive			DME3224						
Quad Ring		404-002										
Quad Bridge		404-004										
8-Junction Ring		404-020										

Other types available.
Consult factory for part numbers.

Beam-Lead — Mounted
Plastic

Type	Actual Size	Alpha Pkg.	Descrip.	Mixers						Detectors		
				L	S	X	Ku	Ka	mm	X	Ku	K
Quad Ring		313-002	Low Drive	DMF4792								
			Medium Drive	DME3027								

Beam-Lead — Mounted
Fiberglass

Quad Ring		337-002	Zero Bias							DDC6755		
			Low Drive	DMF4520								
			Medium Drive	DME3045	DME5805							
			High Drive	DMJ4590								
Quad Bridge		337-004	Low Drive	DMF4540								

Beam-Lead — Mounted
Ceramic (Low Parasitics)

Crossover Ring Quad		401-031	Low Drive				DMF3214					
			Medium Drive				DME3285					
			High Drive				DMJ3305					
Crossover Bridge Quad		401-040	Low Drive				DMF3213					
			Medium Drive				DME3281					
			High Drive				DMJ3306					

Schottky Barrier Mixer and Detector Diodes Quick Reference Chart

Chip

Type	Actual Size	Alpha Pkg.	Descrip.	Mixers						Detectors		
				L	S	X	Ku	K	Ka	X	Ku	K
Chip		270-804	Zero Bias							CDC7609		
		270-805	Low Drive		DMG6412	DMG6413	DMG6414	DMG7599	DMG6415			
		270-804	Low 1/f Noise			CMB7602	CMB7601			CDB7605	CDB7606	
		270-807	GaAs			CMK7703	CMK7704		CMK7705			

Chip — Packaged

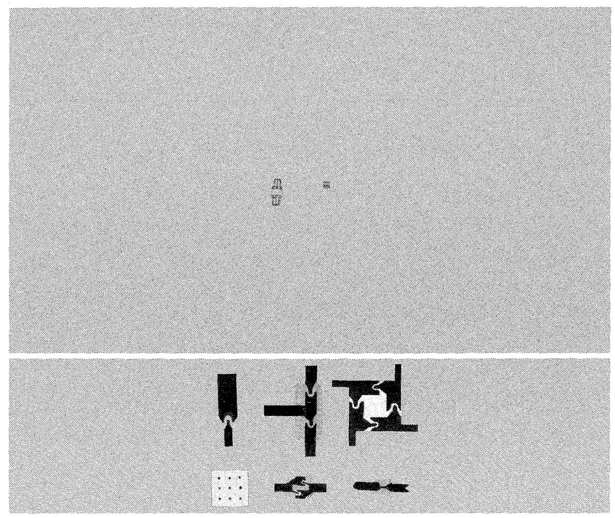
Type	Actual Size	Alpha Pkg.	Descrip.	Mixers						Detectors		
				L	S	X	Ku	Ka	mm	X	Ku	K
Ceramic		207-001	Zero Bias							DDC4563		
			Low Drive		DMF6887	DMF6106	DMF6107	DMF5078				
			Low 1/f Noise			DMB4009		DMF5078Y				DDB6673Y
			Medium Drive			DME4008						
			GaAs			DMK6600	DMK6602	DMK6603				
Mini Ceramic		247-001	Zero Bias							DDC4564		
			Low Drive		DMF6898	DMF4018	DMF4019	DMF4039				
			Low 1/f Noise				DMB4799			DDB3212		DDB4585
			Medium Drive			DME3174						
			High Drive		DMJ3236	DMJ4770						
			GaAs			DMK6601	DMK5068	DMK4058				

GaAs Schottky Barrier Mixer Diodes

Features

- Low Noise Figure
- Excellent Cutoff
- Ideal for Image Enhancement Mixers
- Passivated Planar Construction for Reliability

Actual Size



Magnification: 10X

Description

Alpha's series of gallium arsenide Schottky barrier diodes are available in beam-lead, chip and packaged forms for mixer applications through 100 GHz. They are designed for low junction capacitance as well as low series resistance and exhibit calculated cutoff frequencies in excess of 1,000 GHz.

The packaged diodes are hermetically sealed and may be used in waveguide, stripline or coaxial configurations.

Beam-lead diodes are particularly well suited for MIC work. The beam-lead design eliminates the problems associated with bonding to the junction, as is the case with a chip diode. A line of chip diodes is available for those who prefer to use chip and wire techniques for their MIC work. Capacitance ranges and series resistances on the beam-lead and chip diodes are comparable to those of their packaged counterparts.

Beam-lead and chip diodes may be mounted on a variety of standard or special substrates; if desired, Alpha will also bond them directly into a customer circuit.

These diodes are categorized by noise figure for mixer applications in three frequency ranges: X, Ku, and Ka-bands. Gallium arsenide diodes are particularly well suited for image enhancement mixer circuits due to their high cutoff frequency. Conversion loss for these diodes approaches the theoretical minimum of 3.0 dB (single sideband) in X-band and is significantly lower than silicon Schottky diodes at frequencies above 12 GHz.

Matched pairs of mixer diodes are used in conjunction with a hybrid or magic-tee primarily for suppressing noise originating in the local oscillator. They are also used to isolate the local oscillator arm from the signal arm, thus minimizing radiation and absorption of signal power. Other uses are for specific reflection of signals through the hybrid and for balanced modulators and discriminators.

The matching criteria for packaged mixer diodes are as follows:

a) Conversion loss (within 0.3 dB of each other)
b) IF impedance (within 25 ohms of each other)

These specifications allow the noise figure of the receiver to deteriorate no greater than 0.1 dB due to local oscillator noise.

A typical V_f vs I_f curve is plotted in Figure 1. Figure 2 shows a typical plot of Capacitance vs Bias Voltage.

Noise figure and IF Impedance as a function of Local Oscillator Drive Level with DC bias is shown in Figure 3.

Diodes may also be especially tailored to meet your particular electrical specifications or package configuration needs.

See Sections 2 and 7 for Application Notes:

80800	Mixer and Detector Diodes
80850	Handling Precautions for Schottky Barrier and Point Contact Mixer and Detector Diodes
80000	Bonding Methods: Diode Chips, Beam-Lead Diodes and Capacitors

Typical Ku-Band Mixer Diodes

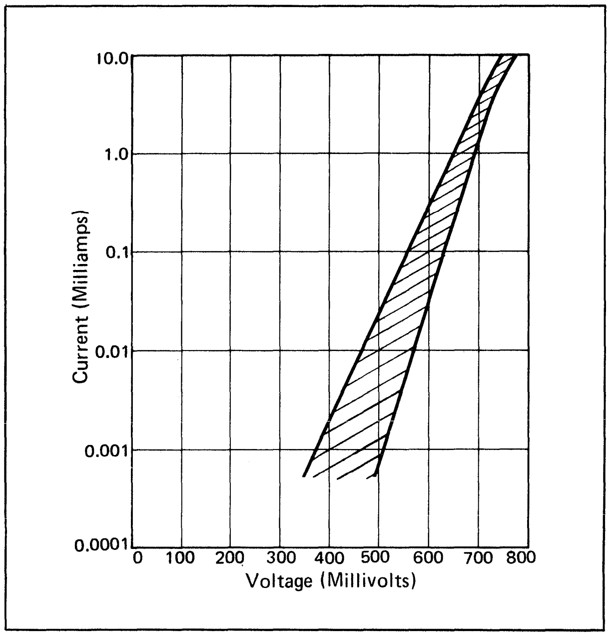


Figure 1. Forward DC Characteristic Curve Range — Voltage vs Current

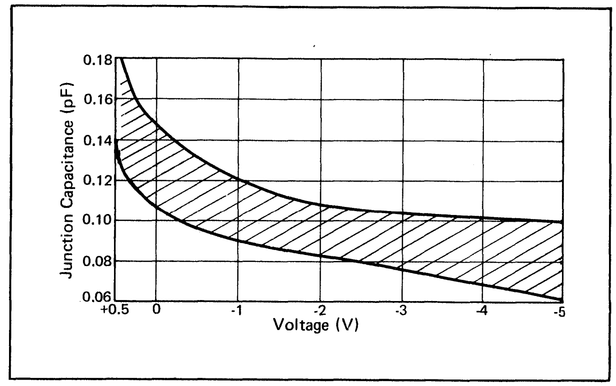


Figure 2. Junction Capacitance Range vs Voltage

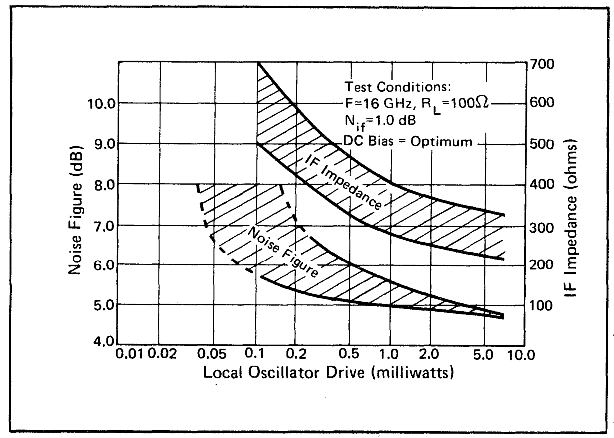


Figure 3. RF Parameters vs Local Oscillator Drive Level

GaAs Schottky Barrier Mixer Diodes

Frequency Band	Type Number	Package Outline	Electrical Characteristics: $NF^{(1)}$ dB Max.	$F_{co}^{(2)}$ GHz Min.	C_J@0V pF Min.	C_J@0V pF Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	V_B 10μA V Min.
Packaged:									
X	DMK6600A	207-001	5.0	750	0.10	0.20	600	800	3.0
X	DMK6601A	247-001	5.0	750	0.10	0.20	600	800	3.0
X	DMK6600	207-001	5.5	500	0.10	0.20	600	800	3.0
X	DMK6601	247-001	5.5	500	0.10	0.20	600	800	3.0
Ku	DMK6602A	207-001	5.3	750	0.05	0.15	600	800	3.0
Ku	DMK5068A	247-001	5.3	750	0.05	0.15	600	800	3.0
Ku	DMK6602	207-001	5.8	500	0.05	0.15	600	800	3.0
Ku	DMK5068	247-001	5.8	500	0.05	0.15	600	800	3.0
Ka	DMK6603A	207-001	6.5	600	—	0.08	600	800	3.0
Ka	DMK4058A	247-001	6.5(3)	600	—	0.08	600	800	3.0
Ka	DMK6603	207-001	7.0	350	—	0.08	600	800	3.0
Ka	DMK4058	247-001	7.0(3)	350	—	0.08	600	800	3.0
Beam-Lead Singles:(6)									
X	DMK6604A	174-001	6.0(3)	500	0.10	0.20	600	800	3.0
X	DMK6604	174-001	7.0(3)	350	0.10	0.20	600	800	3.0
X	DMK6583A	295-011	6.0(3)	500	0.10	0.20	600	800	3.0
X	DMK6583	295-011	7.0(3)	350	0.10	0.20	600	800	3.0
X	DMK3308A	364-011	6.0(3)	500	0.10	0.20	600	800	3.0
X	DMK3308	364-011	7.0(3)	350	0.10	0.20	600	800	3.0
Ku	DMK6605A	174-001	6.3(3)	500	0.05	0.15	600	800	3.0
Ku	DMK6605	174-001	7.3(3)	350	0.05	0.15	600	800	3.0
Ka	DMK6606A	174-001	7.0(3)	350	—	0.10	600	800	3.0
Ka	DMK6606	174-001	8.0(3)	300	—	0.10	600	800	3.0
mm	DMK4791A	174-001	—	900	—	0.07	600	800	2.0
mm	DMK4791	174-001	—	650	—	0.07	600	800	2.0
mm	DMK4784(5)	366-001	—	1000	—	0.04	600	800	3.0
Beam-Lead Pairs:(6,7)									
Ku	DMK6591	378-016	7.3	350	0.05	0.15	600	800	3.0
Ku	DMK3307	396-025	7.3	350	0.05	0.15	600	800	3.0
Beam-Lead Quads:(6,7)									
Ku	DMK6592	294-003	7.3	500	0.05	0.15	600	800	—
Chips:									
X	CMK7703A	270-807	5.0(3)	750	0.10	0.20	600	800	3.0
X	CMK7703	270-807	5.5(3)	500	0.10	0.20	600	800	3.0
Ku	CMK7704A	270-807	5.3(3)	750	0.05	0.15	600	800	3.0
Ku	CMK7704	270-807	5.8(3)	500	0.05	0.15	600	800	3.0
Ka	CMK7705A	270-807	6.5(3)	600	—	0.08	600	800	3.0
Ka	CMK7705	270-807	7.0(3)	350	—	0.08	600	800	3.0

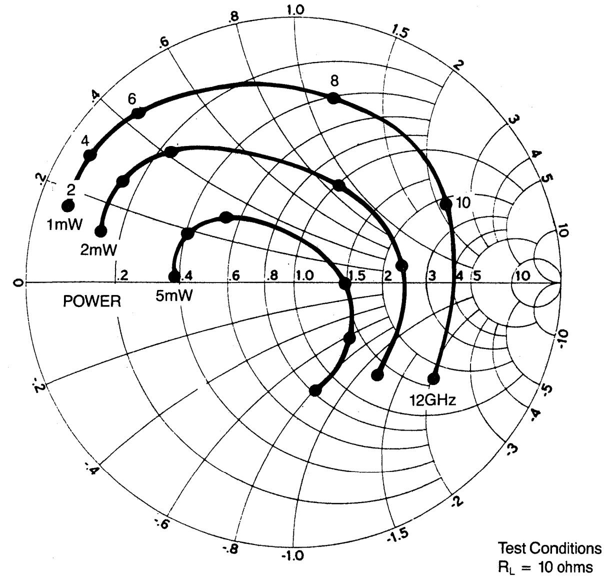
Note:
Maximum operating temperature = 150°C
Note 1. Single sideband noise figure measured with L.O. = 7 mW and including N_{if} = 1.0 dB.
Note 2. $F_{co} = \frac{1}{2\pi R_S C_{J0}}$ where $R_S = R_T$ (@ 10 mA) − R_B; $R_B = \frac{28}{10}$ (for 10 mA).
Note 3. Noise figure is determined by lot sampling.
Note 4. Electrical characteristics are specified for each diode in a pair or quad configuration.
Note 5. To be supplied bonded by Alpha on customer substrate.
Note 6. Also available in standard packages, e.g. 295 and 364 series.
Note 7. Forward Voltage at 1mA matched to within 10mV on pairs, 15mV on quads.

Frequency Table

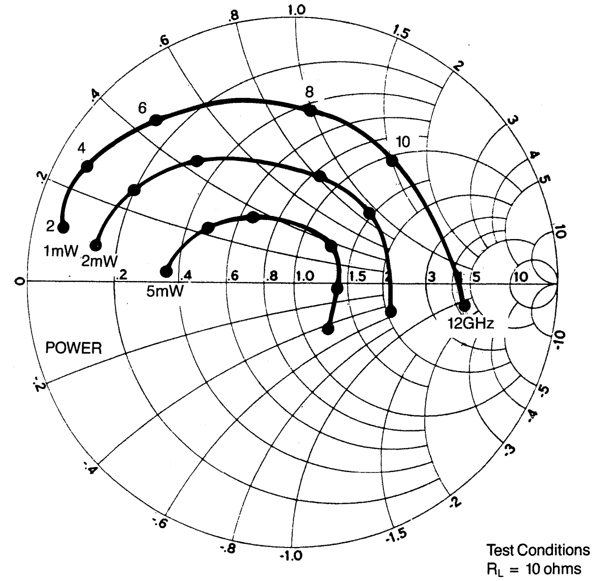
Band	Freq. (GHz)
X	8.2–12.4
Ku	12.4–18.0
Ka	26.5–40.0
mm	40.0–100.0

CAUTION
SENSITIVE ELECTRONIC DEVICES

GaAs Schottky Barrier Mixer Diodes

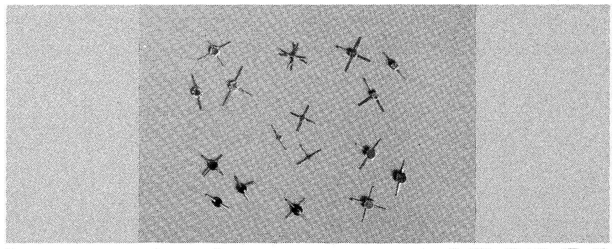


Typical DMK6583
GaAs X-Band Mixer Diode
Admittance Characteristics



Typical DMK3308
GaAs X-Band Mixer Diode
Admittance Characteristics

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes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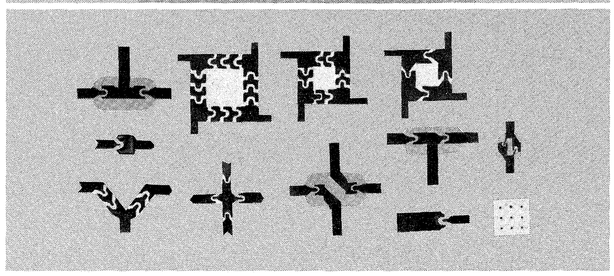

Magnification: 10X

Features

- Ideal for MIC
- Low 1/f Noise
- Low Intermodulation Distortion
- Low Turn On
- Hermetically Sealed Packages

Description

Alpha beam-lead and chip Schottky barrier mixer diodes are designed for applications through 40 GHz in Ka-band. The beam-lead design eliminates the problem of bonding to the very small junction area that is characteristic of the low capacitance involved in microwave devices.

Beam-lead Schottky barrier mixer diodes are made by deposition of a suitable barrier metal on an epitaxial silicon substrate to form the junction. The process and choice of materials result in low series resistance along with a narrow spread of capacitance values for close impedance control.

A variety of forward knees is available, ranging from a low value for low, or starved, local oscillator drive levels to a higher value for high drive, low intermod mixer applications.

The beam-lead diodes are available in a wide range of packages as shown. They may also be mounted on the customer's circuit or on other substrate configurations. For those customers who prefer chip and wire for their MIC work, Alpha can supply a complete line of bondable chips. Capacitance ranges and series resistances are comparable with the packaged devices that are available through Ka-band. The unmounted diodes are especially well suited for use in microwave integrated circuits. The mounted devices can be easily inserted as hybrid elements in stripline, microstrip and other such circuitry.

Applications

Beam-lead and chip Schottky barrier diodes are categorized by noise figure for mixer applications in four frequency ranges: S, X, Ku and Ka-bands. However, they can also be used as modulators, high speed switches and low power limiters.

RF parameters, capacitance and breakdown voltage on chips and beam-lead diodes are tested on a sample basis, while production testing consists of series resistance and forward voltage measurements. A separate data sheet in this section describes beam-lead and chip diodes that are optimized for detector applications.

Several types of semiconductor-barrier metal systems are available, thus allowing proper selection for optimum mixer design. For most applications the N-type silicon, low drive types are preferable, especially for starved L.O. mixers. For doppler mixers, motion detectors or applications requiring low audio (1/f) noise, the P-type silicon, low drive types are preferred. For high level mixer applications requiring low intermodulation products, the N-type silicon, high drive types are most desirable.

Beam-lead diodes are ideally suited for balanced mixers, since they exhibit low parasitics and are extremely uniform. A typical V_f vs I_f curve is shown in Figure 1.

Typical noise figure vs L.O. drive is shown in Figure 2 for single N-type, low drive diode types.

Typical mixer circuits are shown in Figure 3 in order of complexity. The circuits shown in Figures 3a and 3b are recommended for narrower band applications.

The matching network can be an "L" network using discrete components at lower frequencies or a section of transmission line. The double balanced mixer in Figure 3c is recommended for broadband operation where noise figure is less important. The use of high drive diodes in this circuit allows the use of increased L.O. drive with a resultant decrease in intermodulation distortion.

See Sections 2 and 7 for Application Notes:

80800	Mixer and Detector Diodes
80850	Handling Precautions for Schottky Barrier and Point Contact Mixer and Detector Diodes
80000	Bonding Methods: Diode Chips, Beam-Lead Diodes and Capacitors

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

FREQUENCY TABLE

Band	Frequencies (GHz)
S	2 to 4
C	4 to 8
X	8.2 to 12.4
Ku	12.4 to 18.0
K	18.0 to 26.5
Ka	26.5 to 40.0

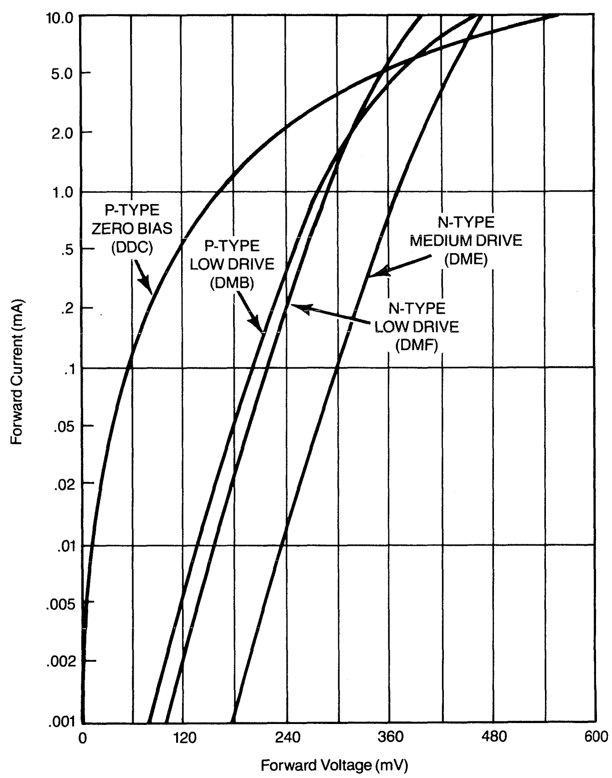


Figure 1a. Typical Forward DC Characteristic Curves — Voltage vs Current

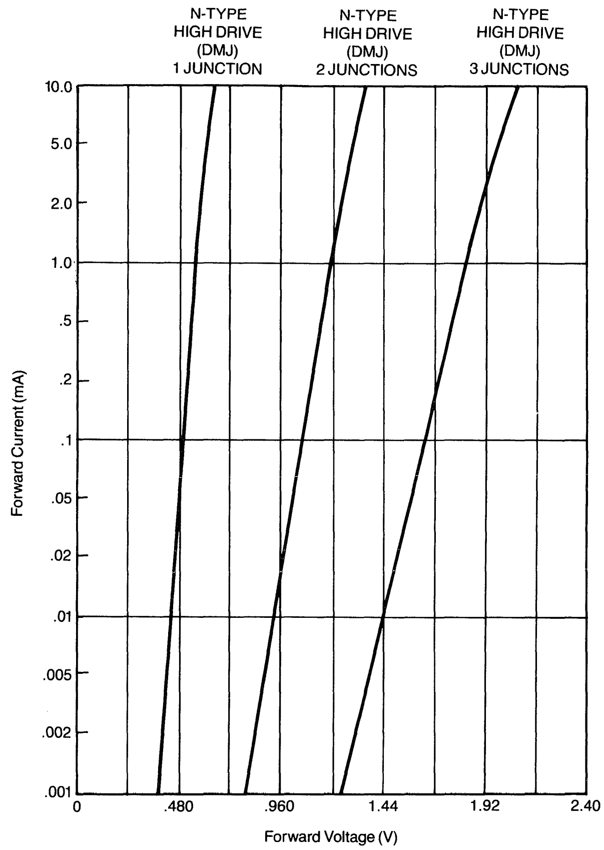


Figure 1b. Typical Forward DC Characteristic Curves — Voltage vs Current

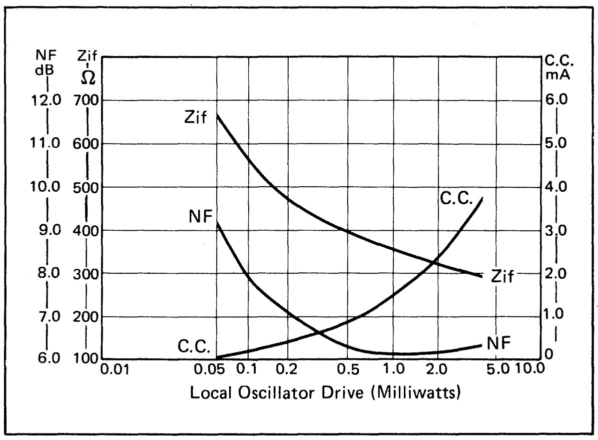


Figure 2. Typical X-Band Low Drive Mixer Diode — RF Parameters vs Local Oscillator Drive

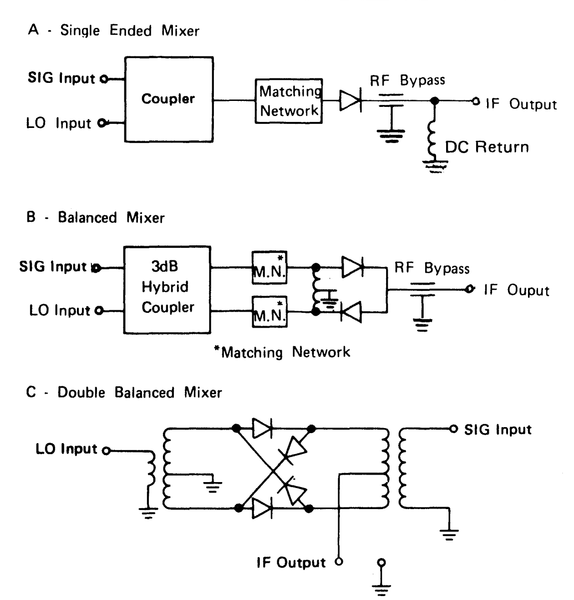
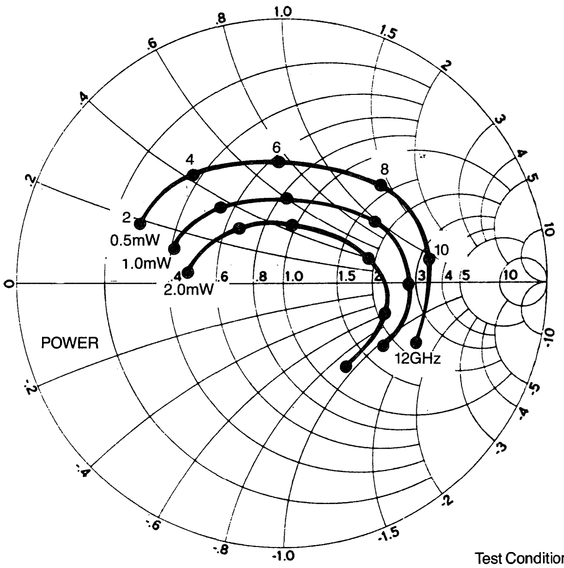
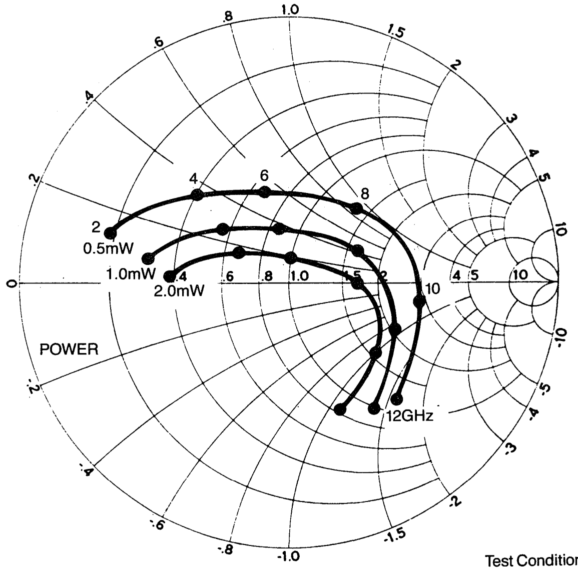


Figure 3. Typical Mixer Circuits



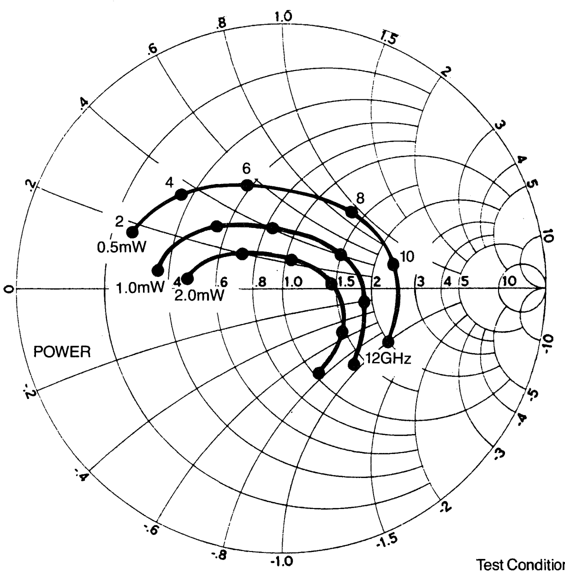
Test Conditions
R_L = 10 ohms

Typical DMB6780
Low Drive X-Band Mixer Diode
Admittance Characteristics



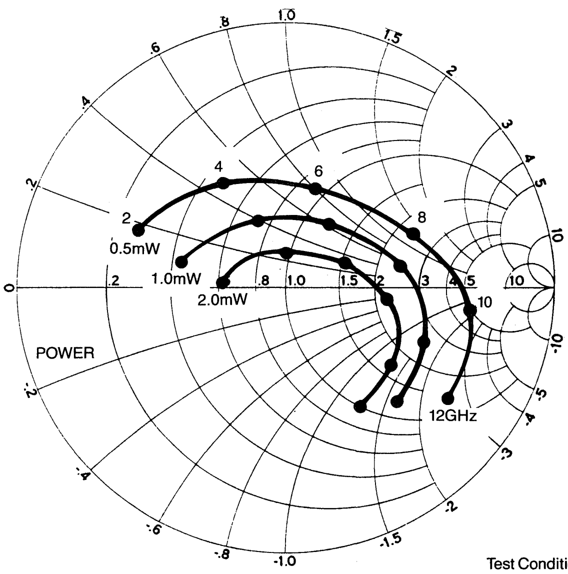
Test Conditions
R_L = 10 ohms

Typical DMB3000
Low Drive X-Band Mixer Diode
Admittance Characteristics



Test Conditions
R_L = 10 ohms

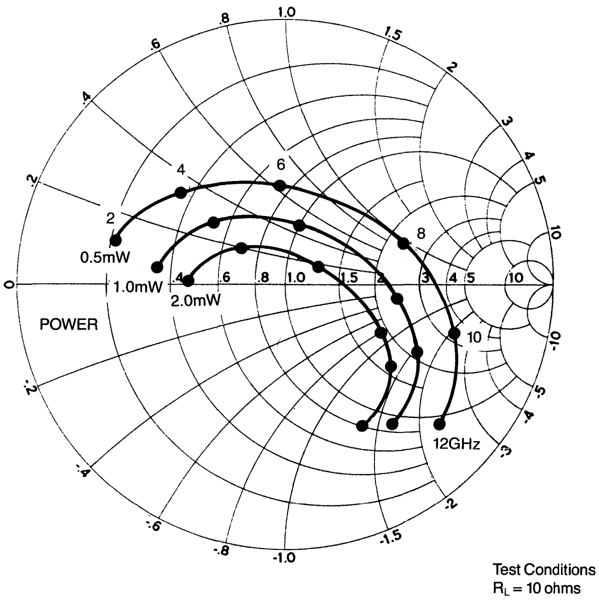
Typical DMB3003
Low Drive X-Band Mixer Diode
Admittance Characteristics



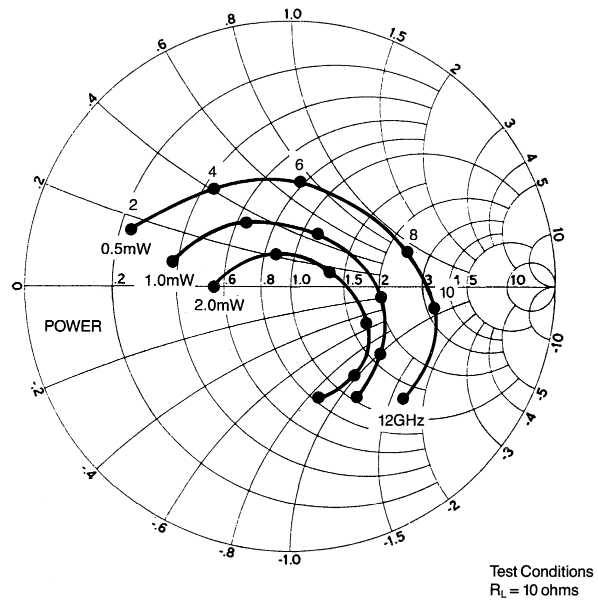
Test Conditions
R_L = 10 ohms

Typical DMF5827
Low Drive X-Band Mixer Diode
Admittance Characteristics

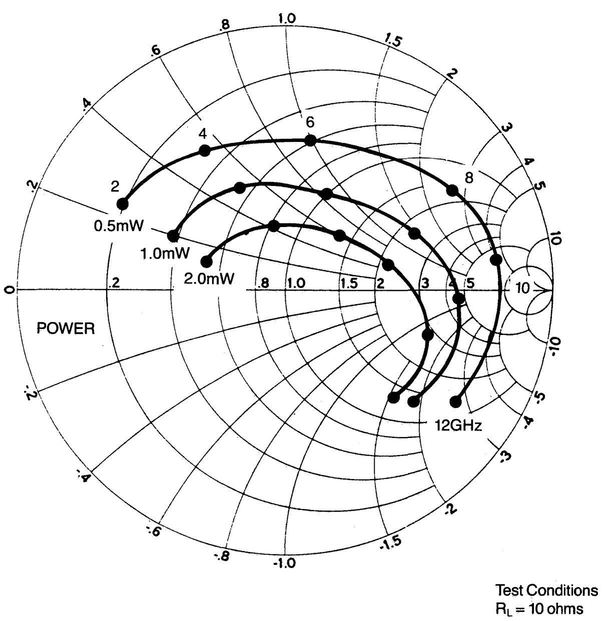
Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes



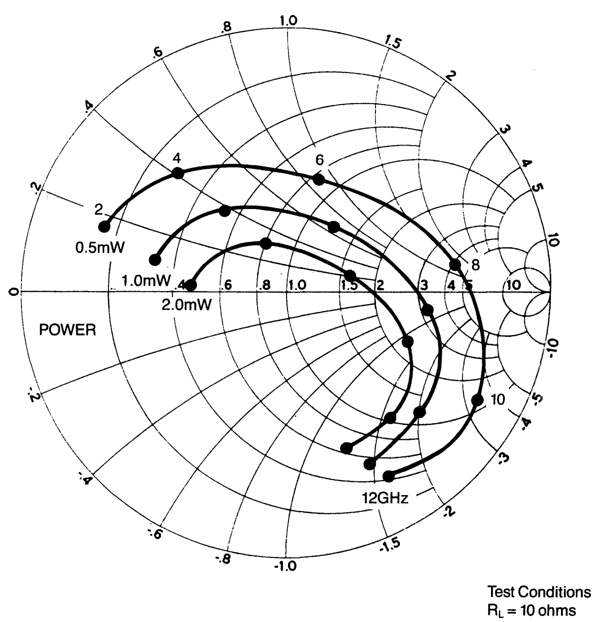
Typical DMF3068
Low Drive X-Band Mixer Diode
Admittance Characteristics



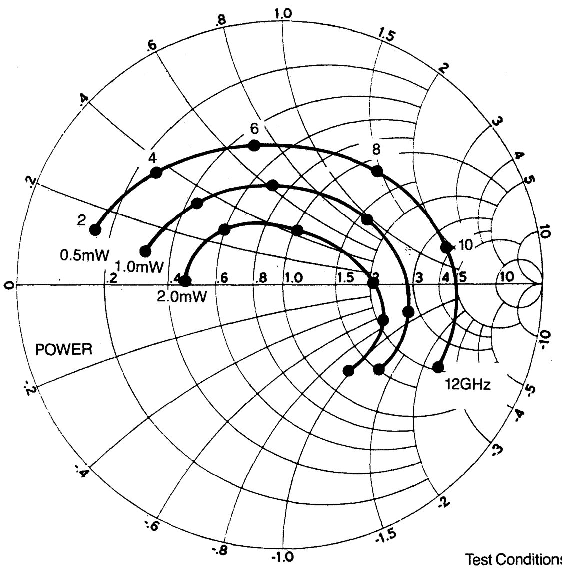
Typical DMF3064
Low Drive X-Band Mixer Diode
Admittance Characteristics



Typical DME3055
Medium Drive X-Band Mixer Diode
Admittance Characteristics

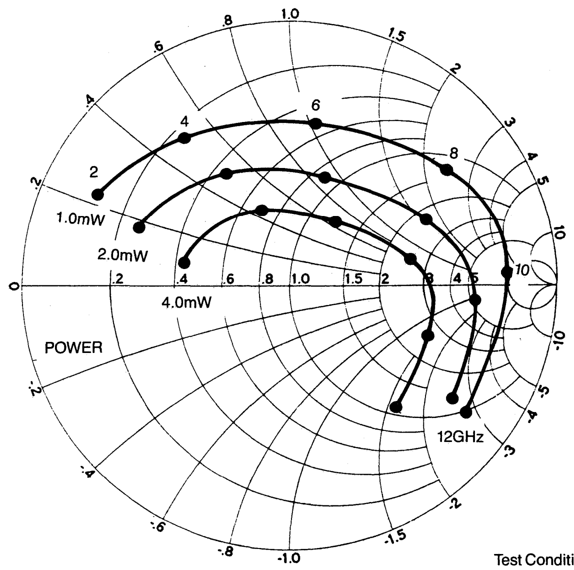


Typical DME3057
Medium Drive X-Band Mixer Diode
Admittance Characteristics



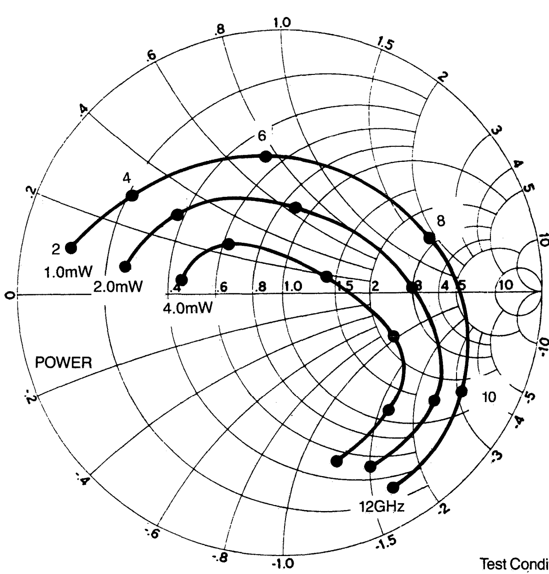
Test Conditions
R_L = 10 ohms

Typical DME3125
Medium Drive X-Band Mixer Diode
Admittance Characteristics



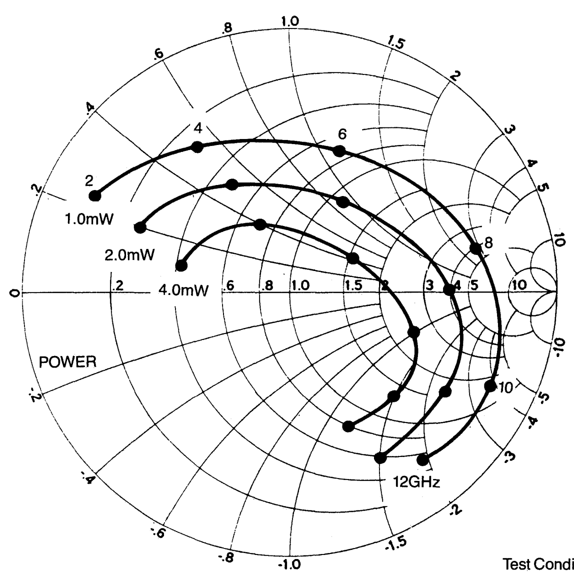
Test Conditions
R_L = 10 ohms

Typical DMJ6786
High Drive X-Band Mixer Diode
Admittance Characteristics



Test Conditions
R_L = 10 ohms

Typical DMJ3151
High Drive X-Band Mixer Diode
Admittance Characteristics



Test Conditions
R_L = 10 ohms

Typical DMJ3154
High Drive X-Band Mixer Diode
Admittance Characteristics

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Singles, P-Type, Low Drive, Low 1/f Noise (6.0 dB Max.)

Frequency Band	Type Number	Outline	NF[1] dB Max.	C_J 0V pF Min.	Max.	Rs[2] — Ω Max.	V_F 1mA mV Min.	Max.	V_B 10µA V Min.
X	DMB6780A	130-011	6.5	0.15	0.30	12	200	300	2.0
X	DMB6780	130-011	7.0	0.15	0.30	18	200	300	2.0
X	DMB4500A	174-002	6.5	0.15	0.30	12	200	300	2.0
X	DMB4500	174-002	7.0	0.15	0.30	18	200	300	2.0
X	DMB3000A	295-011	6.5	0.15	0.30	12	200	300	2.0
X	DMB3000	295-011	7.0	0.15	0.30	18	200	300	2.0
X	DMB6781A	325-011	6.5	0.15	0.30	12	200	300	2.0
X	DMB6781	325-011	7.0	0.15	0.30	18	200	300	2.0
X	DMB3003A	364-011	6.5	0.15	0.30	12	200	300	2.0
X	DMB3003	364-011	7.0	0.15	0.30	18	200	300	2.0
Ku	DMB6782A	130-011	7.5	0.05	0.15	16	200	350	2.0
Ku	DMB6782	130-011	8.0	0.05	0.15	25	200	350	2.0
Ku	DMB4501A	174-002	7.5	0.05	0.15	16	200	350	2.0
Ku	DMB4501	174-002	8.0	0.05	0.15	25	200	350	2.0
Ku	DMB3001A	295-011	7.5	0.05	0.15	16	200	350	2.0
Ku	DMB3001	295-011	8.0	0.05	0.15	25	200	350	2.0
Ku	DMB3004A	364-011	7.5	0.05	0.15	16	200	350	2.0
Ku	DMB3004	364-011	8.0	0.05	0.15	25	200	350	2.0

Beam-Lead Singles, N-Type, Low Drive

Frequency Band	Type Number	Outline	NF[1] dB Max.	C_J 0V pF Min.	Max.	Rs[2] — Ω Max.	V_F 1mA mV Min.	Max.	V_B 10µA V Min.
S	DMF5845A	130-011	6.0	0.30	0.50	3	225	300	2.0
S	DMF5845	130-011	6.5	0.30	0.50	7	225	300	2.0
S	DMF5817A	174-001	6.0	0.30	0.50	3	225	300	2.0
S	DMF5817	174-001	6.5	0.30	0.50	7	225	300	2.0
S	DMF5079A	325-011	6.0	0.30	0.50	3	225	300	2.0
S	DMF5079	325-011	6.5	0.30	0.50	7	225	300	2.0
S	DMF4365A	364-011	6.0	0.30	0.50	3	225	300	2.0
S	DMF4365	364-011	6.5	0.30	0.50	7	225	300	2.0
X	DMF5827A	130-011	6.5	0.15	0.30	7	250	325	2.0
X	DMF5827	130-011	7.0	0.15	0.30	12	250	325	2.0
X	DMF5818A	174-001	6.5	0.15	0.30	7	250	325	2.0
X	DMF5818	174-001	7.0	0.15	0.30	12	250	325	2.0
X	DMF3068A	295-011	6.5	0.15	0.30	7	250	325	2.0
X	DMF3068	295-011	7.0	0.15	0.30	12	250	325	2.0
X	DMF4035A	325-011	6.5	0.15	0.30	7	250	325	2.0
X	DMF4035	325-011	7.0	0.15	0.30	12	250	325	2.0
X	DMF3064A	364-011	6.5	0.15	0.30	7	250	325	2.0
X	DMF3064	364-011	7.0	0.15	0.30	12	250	325	2.0

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Singles, N-Type, Low Drive (cont.)

Frequency Band	Type Number	Outline	NF[1] dB Max.	C_J 0V pF		Rs[2] — Ω Max.	V_F 1mA mV		V_B 10μA V Min.
				Min.	Max.		Min.	Max.	
Ku	DMF6022A	130-011	7.5	0.05	0.15	16	275	350	2.0
Ku	DMF6022	130-011	8.0	0.05	0.15	25	275	350	2.0
Ku	DMF5600A	174-001	7.5	0.05	0.15	16	275	350	2.0
Ku	DMF5600	174-001	8.0	0.05	0.15	25	275	350	2.0
Ku	DMF3069A	295-011	7.5	0.05	0.15	16	275	350	2.0
Ku	DMF3069	295-011	8.0	0.05	0.15	25	275	350	2.0
Ku	DMF3065A	364-011	7.5	0.05	0.15	16	275	350	2.0
Ku	DMF3065	364-011	8.0	0.05	0.15	25	275	350	2.0

Beam-Lead Singles, N-Type, Medium Drive

Frequency Band	Type Number	Outline	NF[1] dB Max.	C_J 0V pF		Rs[2] — Ω Max.	V_F 1mA mV		V_B 10μA V Min.
				Min.	Max.		Min.	Max.	
S	DME3128	130-011	6.0	0.30	0.50	4	300	400	3.0
S	DME3127	174-001	6.0	0.30	0.50	4	300	400	3.0
S	DME3006	325-011	6.0	0.30	0.50	4	300	400	3.0
S	DME3124	364-011	6.0	0.30	0.50	4	300	400	3.0
X	DME3055	130-011	6.5	0.15	0.30	9	325	425	3.0
X	DME6957	174-001	6.5	0.15	0.30	9	325	425	3.0
X	DME3057	295-011	6.5	0.15	0.30	9	325	425	3.0
X	DME3005	325-011	6.5	0.15	0.30	9	325	425	3.0
X	DME3125	364-011	6.5	0.15	0.30	9	325	425	3.0
Ku	DME3056	130-011	7.5	0.05	0.15	16	350	450	3.0
Ku	DME6507	174-001	7.5	0.05	0.15	16	350	450	3.0
Ku	DME3058	295-011	7.5	0.05	0.15	16	350	450	3.0
Ku	DME3126	364-011	7.5	0.05	0.15	16	350	450	3.0

Beam-Lead Singles, N-Type, High Drive

Frequency Band	Type Number	Outline	NF[1] dB Max.	C_J 0V pF		Rs[2] — Ω Max.	V_F 1mA mV		V_B 10μA V Min.
				Min.	Max.		Min.	Max.	
S	DMJ6784	130-011	6.0	0.30	0.50	4	550	625	4.0
S	DMJ5034	174-001	6.0	0.30	0.50	4	550	625	4.0
S	DMJ6785	325-011	6.0	0.30	0.50	4	550	625	4.0
S	DMJ3153	364-011	6.0	0.30	0.50	4	550	625	4.0
X	DMJ6786	130-011	6.5	0.15	0.30	9	550	650	5.0
X	DMJ6777	174-001	6.5	0.15	0.30	9	550	650	5.0
X	DMJ3151	295-011	6.5	0.15	0.30	9	550	650	5.0
X	DMJ6789	325-011	6.5	0.15	0.30	9	550	650	5.0
X	DMJ3154	364-011	6.5	0.15	0.30	9	550	650	5.0
Ku	DMJ6670	130-011	7.5	0.05	0.15	13	600	750	5.0
Ku	DMJ6778	174-001	7.5	0.05	0.15	13	600	750	5.0
Ku	DMJ3152	295-011	7.5	0.05	0.15	13	600	750	5.0
Ku	DMJ3155	364-011	7.5	0.05	0.15	13	600	750	5.0

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Pairs, N-Type, Low Drive

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F(4) 1mA mV Max.	V_B 10μA V Min.
S	DMF3226A	130-025	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF3226	130-025	6.5	0.30	0.50	7	225	300	10	2.0
S	DMF5846A	131-012	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF5846	131-012	6.5	0.30	0.50	7	225	300	10	2.0
S	DMF4040A	132-008	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF4040	132-008	6.5	0.30	0.50	7	225	300	10	2.0
S	DMF3230A	295-025	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF3230	295-025	6.5	0.30	0.50	7	225	300	10	2.0
S	DMF3070A	325-008	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF3070	325-008	6.5	0.30	0.50	7	225	300	10	2.0
S	DMF6576A	325-012	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF6576	325-012	6.5	0.30	0.50	7	225	300	10	2.0
S	DMF3291A	325-025	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF3291	325-025	6.5	0.30	0.50	7	225	300	10	2.0
S	DMF5835A	378-012	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF5835	378-012	6.5	0.30	0.50	7	225	300	10	2.0
S	DMF3182A	378-013	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF3182	378-013	6.5	0.30	0.50	7	225	300	10	2.0
S	DMF3185A	396-025	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF3185	396-025	6.5	0.30	0.50	7	225	300	10	2.0
S	DMF3196A	408-009	6.0	0.30	0.50	3	225	300	10	2.0
S	DMF3196	408-009	6.5	0.30	0.50	7	225	300	10	2.0
X	DMF3245A	130-025	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF3245	130-025	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF6460A	131-012	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF6460	131-012	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF5828A	132-008	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF5828	132-008	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF3072A	295-008	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF3072	295-008	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF3066A	295-012	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF3066	295-012	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF3289A	295-025	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF3289	295-025	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF3071A	325-008	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF3071	325-008	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF6704A	325-012	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF6704	325-012	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF3292A	325-025	6.5	0.15	0.30	7	250	325	10	2.0

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10 mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

4 Difference in forward voltage between leads within a pair or quad.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Pairs, N-Type, Low Drive (cont.)

Frequency Band	Type Number	Outline	NF[1] dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs[2] Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F[4] 1mA mV Max.	V_B 10μA V Min.
X	DMF3292	325-025	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF4713A	364-008	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF4713	364-008	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF4526A	364-012	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF4526	364-012	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF5819A	378-012	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF5819	378-012	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF3183A	378-013	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF3183	378-013	7.0	0.15	0.30	12	250	325	10	2.0
X	DMF3186A	396-025	6.5	0.15	0.30	7	250	325	10	—
X	DMF3186	396-025	7.0	0.15	0.30	12	250	325	10	—
X	DMF3197A	408-009	6.5	0.15	0.30	7	250	325	10	2.0
X	DMF3197	408-009	7.0	0.15	0.30	12	250	325	10	2.0
Ku	DMF3286A	130-025	7.5	0.05	0.15	16	275	350	10	2.0
Ku	DMF3286	130-025	8.0	0.05	0.15	25	275	350	10	2.0
Ku	DMF6459A	131-012	7.5	0.05	0.15	16	275	350	10	2.0
Ku	DMF6459	131-012	8.0	0.05	0.15	25	275	350	10	2.0
Ku	DMF6023A	132-008	7.5	0.05	0.15	16	275	350	10	2.0
Ku	DMF6023	132-008	8.0	0.05	0.15	25	275	350	10	2.0
Ku	DMF3073A	295-008	7.5	0.05	0.15	16	275	350	10	2.0
Ku	DMF3073	295-008	8.0	0.05	0.15	25	275	350	10	2.0
Ku	DMF6554A	295-012	7.5	0.05	0.15	16	275	350	10	2.0
Ku	DMF6554	295-012	8.0	0.05	0.15	25	275	350	10	2.0
Ku	DMF3290A	295-025	7.5	0.05	0.15	16	275	350	10	—
Ku	DMF3290	295-025	8.0	0.05	0.15	25	275	350	10	—
Ku	DMF3293A	325-025	7.5	0.05	0.15	16	275	350	10	—
Ku	DMF3293	325-025	8.0	0.05	0.15	25	275	350	10	—
Ku	DMF3062A	364-008	7.5	0.05	0.15	16	275	350	10	2.0
Ku	DMF3062	364-008	8.0	0.05	0.15	25	275	350	10	2.0
Ku	DMF4734A	364-012	7.5	0.05	0.15	16	275	350	10	2.0
Ku	DMF4734	364-012	8.0	0.05	0.15	25	275	350	10	2.0
Ku	DMF4788A	378-012	7.5	0.05	0.15	16	275	350	10	2.0
Ku	DMF4788	378-012	8.0	0.05	0.15	25	275	350	10	2.0
Ku	DMF3184A	378-013	7.5	0.05	0.15	16	275	350	10	2.0
Ku	DMF3184	378-013	8.0	0.05	0.15	25	275	350	10	2.0
Ku	DMF3187A	396-025	7.5	0.05	0.15	16	275	350	10	—
Ku	DMF3187	396-025	8.0	0.05	0.15	25	275	350	10	—
Ku	DMF3198A	408-009	7.5	0.05	0.15	16	275	350	10	2.0
Ku	DMF3198	408-009	8.0	0.05	0.15	25	275	350	10	2.0

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10 mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

4 Difference in forward voltage between leads within a pair or quad.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Pairs, N-Type, Medium Drive

Frequency Band	Type Number	Outline	NF[1] dB Max.	C_J 0V pF Min.	Max.	Rs[2] — Ω Max.	V_F 1mA mV Min.	Max.	ΔV_F[4] 1mA mV Max.	V_B 10μA V Min.
S	DME3270	130-025	6.0	0.30	0.50	4	300	400	10	—
S	DME3012	131-012	6.0	0.30	0.50	4	300	400	10	3.0
S	DME3009	132-008	6.0	0.30	0.50	4	300	400	10	3.0
S	DME3275	295-025	6.0	0.30	0.50	4	300	400	10	—
S	DME3019	325-008	6.0	0.30	0.50	4	300	400	10	3.0
S	DME3021	325-012	6.0	0.30	0.50	4	300	400	10	3.0
S	DME3278	325-025	6.0	0.30	0.50	4	300	400	10	—
S	DME3050	378-012	6.0	0.30	0.50	4	300	400	10	3.0
S	DME3205	378-013	6.0	0.30	0.50	4	300	400	10	3.0
S	DME3282	396-025	6.0	0.30	0.50	4	300	400	10	—
S	DME3199	408-009	6.0	0.30	0.50	4	300	400	10	3.0
X	DME3271	130-025	6.5	0.15	0.30	9	325	425	10	—
X	DME3013	131-012	6.5	0.15	0.30	9	325	425	10	3.0
X	DME3010	132-008	6.5	0.15	0.30	9	325	425	10	3.0
X	DME3015	295-008	6.5	0.15	0.30	9	325	425	10	3.0
X	DME6569	295-012	6.5	0.15	0.30	9	325	425	10	3.0
X	DME3276	295-025	6.5	0.15	0.30	9	325	425	10	—
X	DME3020	325-008	6.5	0.15	0.30	9	325	425	10	3.0
X	DME3022	325-012	6.5	0.15	0.30	9	325	425	10	3.0
X	DME3279	325-025	6.5	0.15	0.30	9	325	425	10	—
X	DME3023	364-008	6.5	0.15	0.30	9	325	425	10	3.0
X	DME3025	364-012	6.5	0.15	0.30	9	325	425	10	3.0
X	DME3051	378-012	6.5	0.15	0.30	9	325	425	10	3.0
X	DME3206	378-013	6.5	0.15	0.30	9	325	425	10	3.0
X	DME3283	396-025	6.5	0.15	0.30	9	325	425	10	—
X	DME3200	408-009	6.5	0.15	0.30	9	325	425	10	3.0
Ku	DME3272	130-025	7.5	0.05	0.15	16	350	450	10	—
Ku	DME3014	131-012	7.5	0.05	0.15	16	350	450	10	3.0
Ku	DME3011	132-008	7.5	0.05	0.15	16	350	450	10	3.0
Ku	DME3016	295-008	7.5	0.05	0.15	16	350	450	10	3.0
Ku	DME3054	295-012	7.5	0.05	0.15	16	350	450	10	3.0
Ku	DME3277	295-025	7.5	0.05	0.15	16	350	450	10	—
Ku	DME3280	325-025	7.5	0.05	0.15	16	350	450	10	—
Ku	DME3024	364-008	7.5	0.05	0.15	16	350	450	10	3.0
Ku	DME3026	364-012	7.5	0.05	0.15	16	350	450	10	3.0
Ku	DME6553	378-012	7.5	0.05	0.15	16	350	450	10	3.0
Ku	DME3207	378-013	7.5	0.05	0.15	16	350	450	10	3.0
Ku	DME3284	396-025	7.5	0.05	0.15	16	350	450	10	—
Ku	DME3201	408-009	7.5	0.05	0.15	16	350	450	10	3.0

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

4 Difference in forward voltage between leads within a pair or quad.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Pairs, N-Type, High Drive

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	$\triangle V_F$(4) 1mA mV Max.	V_B 10μA V Min.
S	DMJ3294	130-025	6.0	0.30	0.50	4	550	625	10	—
S	DMJ6531	131-012	6.0	0.30	0.50	4	550	625	10	4.0
S	DMJ3095	132-008	6.0	0.30	0.50	4	550	625	10	4.0
S	DMJ3297	295-025	6.0	0.30	0.50	4	550	625	10	—
S	DMJ3098	325-008	6.0	0.30	0.50	4	550	625	10	4.0
S	DMJ4783	325-012	6.0	0.30	0.50	4	550	625	10	4.0
S	DMJ3300	325-025	6.0	0.30	0.50	4	550	625	10	—
S	DMJ3092	378-012	6.0	0.30	0.50	4	550	625	10	4.0
S	DMJ3208	378-013	6.0	0.30	0.50	4	550	625	10	4.0
S	DMJ3303	396-025	6.0	0.30	0.50	4	550	625	10	—
S	DMJ3202	408-009	6.0	0.30	0.50	4	550	625	10	4.0
X	DMJ3295	130-025	6.5	0.15	0.30	9	550	650	10	—
X	DMJ4317	131-012	6.5	0.15	0.30	9	550	650	10	5.0
X	DMJ3096	132-008	6.5	0.15	0.30	9	550	650	10	5.0
X	DMJ3099	295-008	6.5	0.15	0.30	9	550	650	10	5.0
X	DMJ3101	295-012	6.5	0.15	0.30	9	550	650	10	5.0
X	DMJ3298	295-025	6.5	0.15	0.30	9	550	650	10	—
X	DMJ3105	325-008	6.5	0.15	0.30	9	550	650	10	5.0
X	DMJ3090	325-012	6.5	0.15	0.30	9	550	650	10	5.0
X	DMJ3301	325-025	6.5	0.15	0.30	9	550	650	10	—
X	DMJ3106	364-008	6.5	0.15	0.30	9	550	650	10	5.0
X	DMJ4760	364-012	6.5	0.15	0.30	9	550	650	10	5.0
X	DMJ3093	378-012	6.5	0.15	0.30	9	550	650	10	5.0
X	DMJ3209	378-013	6.5	0.15	0.30	9	550	650	10	5.0
X	DMJ3304	396-025	6.5	0.15	0.30	9	550	650	10	—
X	DMJ3203	408-009	6.5	0.15	0.30	9	550	650	10	5.0
Ku	DMJ3296	130-025	7.5	0.05	0.15	13	600	750	10	—
Ku	DMJ3081	131-012	7.5	0.05	0.15	13	550	750	10	5.0
Ku	DMJ3097	132-008	7.5	0.05	0.15	13	600	750	10	5.0
Ku	DMJ3100	295-008	7.5	0.05	0.15	13	600	750	10	5.0
Ku	DMJ3102	295-012	7.5	0.05	0.15	13	600	750	10	5.0
Ku	DMJ3299	295-025	7.5	0.05	0.15	13	600	750	10	—
Ku	DMJ3302	325-025	7.5	0.05	0.15	13	600	750	10	—
Ku	DMJ3107	364-008	7.5	0.05	0.15	13	600	750	10	5.0
Ku	DMJ3089	364-012	7.5	0.05	0.15	13	600	750	10	5.0
Ku	DMJ4705	378-012	7.5	0.05	0.15	13	600	750	10	5.0
Ku	DMJ3210	378-013	7.5	0.05	0.15	13	600	750	10	5.0
Ku	DMJ3246	396-025	7.5	0.05	0.15	13	600	750	10	—
Ku	DMJ3204	408-009	7.5	0.05	0.15	13	600	750	10	5.0

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10 mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

4 Difference in forward voltage between leads within a pair or quad.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Pairs, N-Type, High Drive, 4-Junction

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	$\triangle V_F$(4) 1mA mV Max.	V_B 10μA V Min.
X	DMJ3180	407-029	—	0.15	0.30	14	1100	1400	15	8.0
Ku	DMJ3181	407-029	—	0.05	0.15	18	1100	1400	15	10.0

Beam-Lead Quad Rings, P-Type, Zero Bias

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Typ.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	$\triangle V_F$ 1mA mV Max.
Ku	DMH4383	132-002	—	0.10	40	100	250	15
Ku	DMH6570	295-002	—	0.10	40	100	250	15
Ku	DMH3156	309-002	—	0.10	40	100	250	15
Ku	DMH3157	325-002	—	0.10	40	100	250	15
Ku	DMH3158	364-002	—	0.10	40	100	250	15
Ku	DMH3159	399-003	—	0.10	40	100	250	15

Beam-Lead Quad Rings, N-Type, Low Drive

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	$\triangle V_F$(4) 1mA mV Max.
L	DMF4000	132-002	—	—	1.20	9	225	350	15
L	DMF4792	313-002	—	—	1.20	9	225	350	15
L	DMF4520	337-002	—	—	1.20	9	225	350	15
S	DMF5847A	132-002	6.0	0.30	0.50	3	225	300	15
S	DMF5847	132-002	6.5	0.30	0.50	7	225	300	15
S	DMF4384A	132-010	6.0	0.30	0.50	3	225	300	15
S	DMF4384	132-010	6.5	0.30	0.50	7	225	300	15
S	DMF6829A	294-003	6.0	0.30	0.50	3	225	300	15
S	DMF6829	294-003	6.5	0.30	0.50	7	225	300	15
S	DMF4549A	295-002	6.0	0.30	0.50	3	225	300	15
S	DMF4549	295-002	6.5	0.30	0.50	7	225	300	15
S	DMF4059A	325-002	6.0	0.30	0.50	3	225	300	15
S	DMF4059	325-002	6.5	0.30	0.50	7	225	300	15
X	DMF5829A	132-002	6.5	0.15	0.30	7	250	325	15
X	DMF5829	132-002	7.0	0.15	0.30	12	250	325	15
X	DMF4011A	294-003	6.5	0.15	0.30	7	250	325	15
X	DMF4011	294-003	7.0	0.15	0.30	12	250	325	15
X	DMF4745A	295-002	6.5	0.15	0.30	7	250	325	15
X	DMF4745	295-002	7.0	0.15	0.30	12	250	325	15
X	DMF5080A	325-002	6.5	0.15	0.30	7	250	325	15
X	DMF5080	325-002	7.0	0.15	0.30	12	250	325	15
X	DMF3074A	364-002	6.5	0.15	0.30	7	250	325	15

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10 mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

4 Difference in forward voltage between leads within a pair or quad.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Quad Rings, N-Type, Low Drive (cont.)

Frequency Band	Type Number	Outline	NF[1] dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs[2] — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F[4] 1mA mV Max.
X	DMF3074	364-002	7.0	0.15	0.30	12	250	325	15
Ku	DMF6395A	132-002	7.5	0.05	0.15	16	275	350	15
Ku	DMF6395	132-002	8.0	0.05	0.15	25	275	350	15
Ku	DMF4012A	294-003	7.5	0.05	0.15	16	275	350	15
Ku	DMF4012	294-003	8.0	0.05	0.15	25	275	350	15
Ku	DMF4574A	295-002	7.5	0.05	0.15	16	275	350	15
Ku	DMF4574	295-002	8.0	0.05	0.15	25	275	350	15
Ku	DMF3075A	364-002	7.5	0.05	0.15	16	275	350	15
Ku	DMF3075	364-002	8.0	0.05	0.15	25	275	350	15

Beam-Lead Quad Rings, N-Type, Medium Drive

Frequency Band	Type Number	Outline	NF[1] dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs[2] — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F[4] 1mA mV Max.
L	DME6549	132-002	—	—	1.20	9	225	350	15
L	DME3027	313-002	—	—	1.20	9	225	350	15
L	DME3045	337-002	—	—	1.20	9	225	350	15
S	DME3038	132-002	6.0	0.30	0.50	4	300	400	15
S	DME3028	132-010	6.0	0.30	0.50	4	300	400	15
S	DME6561	294-003	6.0	0.30	0.50	4	300	400	15
S	DME3043	295-002	6.0	0.30	0.50	4	300	400	15
S	DME3044	325-002	6.0	0.30	0.50	4	300	400	15
X	DME4756	132-002	6.5	0.15	0.30	9	325	425	15
X	DME6562	294-003	6.5	0.15	0.30	9	325	425	15
X	DME4750	295-002	6.5	0.15	0.30	9	325	425	15
X	DME6557	325-002	6.5	0.15	0.30	9	325	425	15
X	DME4790	364-002	6.5	0.15	0.30	9	325	425	15
Ku	DME3039	132-002	7.5	0.05	0.15	16	350	450	15
Ku	DME6563	294-003	7.5	0.05	0.15	16	350	450	15
Ku	DME4541	295-002	7.5	0.05	0.15	16	350	450	15
Ku	DME3047	364-002	7.5	0.05	0.15	16	350	450	15

Beam-Lead Quad Rings, N-Type, High Drive, 4 Junction

Frequency Band	Type Number	Outline	NF[1] dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs[2] — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F[4] 1mA mV Max.
S	DMJ4007	132-002	6.0	0.30	0.50	4	550	625	15
S	DMJ4502	294-003	6.0	0.30	0.50	4	550	625	15
S	DMJ3086	295-002	6.0	0.30	0.50	4	550	625	15
S	DMJ6668	325-002	6.0	0.30	0.50	4	550	625	15

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

4 Difference in forward voltage between leads within a pair or quad.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Quad Rings, N-Type, High Drive, 4 Junction (cont.)

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F(4) 1mA mV Max.
X	DMJ6788	132-002	6.5	0.15	0.30	9	550	650	15
X	DMJ6990	294-003	6.5	0.15	0.30	9	550	650	15
X	DMJ3087	295-002	6.5	0.15	0.30	9	550	650	15
X	DMJ6669	325-002	6.5	0.15	0.30	9	550	650	15
X	DMJ3108	364-002	6.5	0.15	0.30	9	550	650	15
Ku	DMJ3082	132-002	7.5	0.05	0.15	13	600	750	15
Ku	DMJ6667	294-003	7.5	0.05	0.15	13	600	750	15
Ku	DMJ4397	295-002	7.5	0.05	0.15	13	600	750	15
Ku	DMJ3109	364-002	7.5	0.05	0.15	13	600	750	15

Beam-Lead Quad Rings, N-Type, Low Drive, 8 Junction

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F(4) 1mA mV Max.
X	DMF3287A	294-021	—	0.15	0.30	6	450	700	20
X	DMF3287	294-021	—	0.15	0.30	14	450	700	20
Ku	DMF3288A	294-021	—	0.05	0.15	14	450	700	20
Ku	DMF3288	294-021	—	0.05	0.15	24	450	700	20

Beam-Lead Quad Rings, N-Type, Medium Drive, 8 Junction

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F(4) 1mA mV Max.
X	DME3273	294-021	—	0.15	0.30	8	600	850	20
Ku	DME3274	294-021	—	0.05	0.15	18	600	850	20

Beam-Lead Quad Rings, N-Type, High Drive, 8 Junction

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F(4) 1mA mV Max.
X	DMJ4708	132-020	—	0.15	0.30	14	1100	1400	20
X	DMJ4759	294-021	—	0.15	0.30	14	1100	1400	20
X	DMJ3094	295-020	—	0.15	0.30	14	1100	1400	20
X	DMJ4394	325-020	—	0.15	0.30	14	1100	1400	20
X	DMJ3112	364-020	—	0.15	0.30	14	1100	1400	20
Ku	DMJ3091	132-020	—	0.05	0.15	18	1100	1400	20
Ku	DMJ4771	294-021	—	0.05	0.15	18	1100	1400	20
Ku	DMJ4747	295-020	—	0.05	0.15	18	1100	1400	20
Ku	DMJ3113	364-020	—	0.05	0.15	18	1100	1400	20

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10 mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

4 Difference in forward voltage between leads within a pair or quad.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Quad Rings, N-Type, High Drive, 12 Junction

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	Max.	$\triangle V_F$(4) 1mA mV Max.
Ku	DMJ4766	132-022	—	0.05	0.15	21	1650	2250	25
Ku	DMJ6564	398-022	—	0.05	0.15	21	1650	2250	25

Beam-Lead Quad Bridges, N-Type, Low Drive

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	Max.	$\triangle V_F$(4) 1mA mV Max.	V_B 10μA V Min.
L	DMF3059	132-004	—	—	1.20	9	225	350	15	1.0
L	DMF4540	337-004	—	—	1.20	9	225	350	15	1.0
S	DMF5848A	132-004	6.0	0.30	0.50	3	225	300	15	2.0
S	DMF5848	132-004	6.5	0.30	0.50	7	225	300	15	2.0
S	DMF3076A	294-004	6.0	0.30	0.50	3	225	300	15	2.0
S	DMF3076	294-004	6.5	0.30	0.50	7	225	300	15	2.0
S	DMF3067A	295-004	6.0	0.30	0.50	3	225	300	15	2.0
S	DMF3067	295-004	6.5	0.30	0.50	7	225	300	15	2.0
S	DMF3063A	325-004	6.0	0.30	0.50	3	225	300	15	2.0
S	DMF3063	325-004	6.5	0.30	0.50	7	225	300	15	2.0
X	DMF6288A	132-004	6.5	0.15	0.30	7	250	325	15	2.0
X	DMF6288	132-004	7.0	0.15	0.30	12	250	325	15	2.0
X	DMF3077A	294-004	6.5	0.15	0.30	7	250	325	15	2.0
X	DMF3077	294-004	7.0	0.15	0.30	12	250	325	15	2.0
X	DMF6558A	295-004	6.5	0.15	0.30	7	250	325	15	2.0
X	DMF6558	295-004	7.0	0.15	0.30	12	250	325	15	2.0
X	DMF4352A	325-004	6.5	0.15	0.30	7	250	325	15	2.0
X	DMF4352	325-004	7.0	0.15	0.30	12	250	325	15	2.0
X	DMF3079A	364-004	6.5	0.15	0.30	7	250	325	15	2.0
X	DMF3079	364-004	7.0	0.15	0.30	12	250	325	15	2.0
Ku	DMF6298A	132-004	7.5	0.05	0.15	16	275	350	15	2.0
Ku	DMF6298	132-004	8.0	0.05	0.15	25	275	350	15	2.0
Ku	DMF3078A	294-004	7.5	0.05	0.15	16	275	350	15	2.0
Ku	DMF3078	294-004	8.0	0.05	0.15	25	275	350	15	2.0
Ku	DMF6574A	295-004	7.5	0.05	0.15	16	275	350	15	2.0
Ku	DMF6574	295-004	8.0	0.05	0.15	25	275	350	15	2.0
Ku	DMF3080A	364-004	7.5	0.05	0.15	16	275	350	15	2.0
Ku	DMF3080	364-004	8.0	0.05	0.15	25	275	350	15	2.0

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2. $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).
3. Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.
4. Difference in forward voltage between leads within a pair or quad.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Quad Bridges, N-Type, Medium Drive

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F(4) 1mA mV Max.	V_B 10μA V Min.
L	DME3042	132-004	—	—	1.20	9	300	450	15	2.0
S	DME3040	132-004	6.0	0.30	0.50	4	300	400	15	3.0
S	DME3029	294-004	6.0	0.30	0.50	4	300	400	15	3.0
S	DME3052	295-004	6.0	0.30	0.50	4	300	400	15	3.0
S	DME3032	325-004	6.0	0.30	0.50	4	300	400	15	3.0
X	DME4370	132-004	6.5	0.15	0.30	9	325	425	15	3.0
X	DME3030	294-004	6.5	0.15	0.30	9	325	425	15	3.0
X	DME6567	295-004	6.5	0.15	0.30	9	325	425	15	3.0
X	DME3033	325-004	6.5	0.15	0.30	9	325	425	15	3.0
X	DME3036	364-004	6.5	0.15	0.30	9	325	425	15	3.0
Ku	DME3041	132-004	7.5	0.05	0.15	16	350	450	15	3.0
Ku	DME3031	294-004	7.5	0.05	0.15	16	350	450	15	3.0
Ku	DME3053	295-004	7.5	0.05	0.15	16	350	450	15	3.0
Ku	DME3037	364-004	7.5	0.05	0.15	16	350	450	15	3.0

Beam-Lead Quad Bridges, N-Type, High Drive

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F(4) 1mA mV Max.	V_B 10μA V Min.
S	DMJ6575	132-004	6.0	0.30	0.50	4	550	625	15	4.0
S	DMJ4312	294-004	6.0	0.30	0.50	4	550	625	15	4.0
S	DMJ3114	295-004	6.0	0.30	0.50	4	550	625	15	4.0
S	DMJ3120	325-004	6.0	0.30	0.50	4	550	625	15	4.0
X	DMJ4313	132-004	6.5	0.15	0.30	9	550	650	15	5.0
X	DMJ3088	294-004	6.5	0.15	0.30	9	550	650	15	5.0
X	DMJ3115	295-004	6.5	0.15	0.30	9	550	650	15	5.0
X	DMJ3121	325-004	6.5	0.15	0.30	9	550	650	15	5.0
X	DMJ3122	364-004	6.5	0.15	0.30	9	550	650	15	5.0
Ku	DMJ3083	132-004	7.5	0.05	0.15	13	600	750	15	5.0
Ku	DMJ4768	294-004	7.5	0.05	0.15	13	600	750	15	5.0
Ku	DMJ3116	295-004	7.5	0.05	0.15	13	600	750	15	5.0
Ku	DMJ3123	364-004	7.5	0.05	0.15	13	600	750	15	5.0

Beam-Lead Special Quads, N-Type, Low Drive

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs(2) — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F(4) 1mA mV Max.	V_B 10μA V Min.
S	DMF4384A	132-010	6.0	0.30	0.50	3	225	300	15	—
S	DMF4384	132-010	6.5	0.30	0.50	7	225	300	15	—
S	DMF3251A	364-034	6.0	0.30	0.50	3	225	300	15	2.0

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10 mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

4 Difference in forward voltage between leads within a pair or quad.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Special Quads, N-Type, Low Drive (cont.)

Frequency Band	Type Number	Outline	NF[(1)] dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs[(2)] — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F[(4)] 1mA mV Max.	V_B 10μA V Min.
S	DMF3251	364-034	6.5	0.30	0.50	7	225	300	15	2.0
S	DMF3188A	397-034	6.0	0.30	0.50	3	225	300	15	2.0
S	DMF3188	397-034	6.5	0.30	0.50	7	225	300	15	2.0
X	DMF3252A	364-034	6.5	0.15	0.30	7	250	325	15	2.0
X	DMF3252	364-034	7.0	0.15	0.30	12	250	325	15	2.0
X	DMF3189A	397-034	6.5	0.15	0.30	7	250	325	15	2.0
X	DMF3189	397-034	7.0	0.15	0.30	12	250	325	15	2.0
Ku	DMF3253A	364-034	7.5	0.05	0.15	16	275	350	15	2.0
Ku	DMF3253	364-034	8.0	0.05	0.15	25	275	350	15	2.0
Ku	DMF3190A	397-034	7.5	0.05	0.15	16	275	350	15	2.0
Ku	DMF3190	397-034	8.0	0.05	0.15	25	275	350	15	2.0
Ku	DMF3214A	401-031	7.5	0.05	0.15	16	275	350	15	—
Ku	DMF3214	401-031	8.0	0.05	0.15	25	275	350	15	—
Ku	DMF3213A	401-040	7.5	0.05	0.15	16	275	350	15	2.0
Ku	DMF3213	401-040	8.0	0.05	0.15	25	275	350	15	2.0
Ku	DMF3243A	418-038	7.5	0.05	0.15	16	275	350	15	—
Ku	DMF3243	418-038	8.0	0.05	0.15	25	275	350	15	—

Beam-Lead Special Quads, N-Type, Medium Drive

Frequency Band	Type Number	Outline	NF[(1)] dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs[(2)] — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F[(4)] 1mA mV Max.	V_B 10μA V Min.
S	DME3028	132-010	6.0	0.30	0.50	4	300	400	15	—
S	DME3254	364-034	6.0	0.30	0.50	4	300	400	15	3.0
S	DME3191	397-034	6.0	0.30	0.50	4	300	400	15	3.0
X	DME3255	364-034	6.5	0.15	0.30	9	325	425	15	3.0
X	DME3192	397-034	6.5	0.15	0.30	9	325	425	15	3.0
Ku	DME3256	364-034	7.5	0.05	0.15	16	350	450	15	3.0
Ku	DME3178	397-034	7.5	0.05	0.15	16	350	450	15	3.0
Ku	DME3285	401-031	7.5	0.05	0.15	16	350	450	15	—
Ku	DME3281	401-040	7.5	0.05	0.15	16	350	450	15	3.0
Ku	DME3261	418-038	7.5	0.05	0.15	16	350	450	15	—

Beam-Lead Special Quads, N-Type, High Drive

Frequency Band	Type Number	Outline	NF[(1)] dB Max.	C_J 0V pF Min.	C_J 0V pF Max.	Rs[(2)] — Ω Max.	V_F 1mA mV Min.	V_F 1mA mV Max.	ΔV_F[(4)] 1mA mV Max.	V_B 10μA V Min.
S	DMJ6708	132-010	6.0	0.30	0.50	4	550	625	15	—
S	DMJ3257	364-034	6.0	0.30	0.50	4	550	625	15	4.0
S	DMJ3193	397-034	6.0	0.30	0.50	4	550	625	15	4.0

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

4 Difference in forward voltage between leads within a pair or quad.

Silicon Beam-Lead and Chip Schottky Barrier Mixer Diodes

Beam-Lead Special Quads, N-Type, High Drive

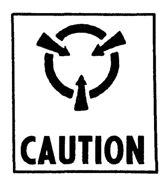
Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF		Rs(2) — Ω Max.	V_F 1mA mV		$\triangle V_F$(4) 1mA mV Max.	V_B 10μA V Min.
				Min.	Max.		Min.	Max.		
X	DMJ3258	364-034	6.5	0.15	0.30	9	550	650	15	5.0
X	DMJ3194	397-034	6.5	0.15	0.30	9	550	650	15	5.0
Ku	DMJ3259	364-034	7.5	0.05	0.15	13	600	750	15	5.0
Ku	DMJ3195	397-034	7.5	0.05	0.15	13	600	750	15	5.0
Ku	DMJ3305	401-031	7.5	0.05	0.15	13	600	750	15	—
Ku	DMJ3306	401-040	7.5	0.05	0.15	13	600	750	15	5.0
Ku	DMJ3262	418-038	7.5	0.05	0.15	13	600	750	15	—

Chips, P-Type, Low Drive, Low 1/f Noise (6.0 dB Max.)

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF		Rs(2) — Ω Max.	V_F 1mA mV		V_B 10μA V Min.
				Min.	Max.		Min.	Max.	
X	CMB7602	270-804	7.0	0.12	0.24	18	200	300	2.0
Ku	CMB7601	270-804	7.5	0.08	0.16	25	200	350	2.0

Chips, N-Type, Low Drive

Frequency Band	Type Number	Outline	NF(1) dB Max.	C_J 0V pF		Rs(2) — Ω Max.	V_F 1mA mV		V_B 10μA V Min.
				Min.	Max.		Min.	Max.	
S	DMG6412A	270-805	6.0	0.15	0.30	8	200	300	2.0
S	DMG6412	270-805	6.5	0.15	0.30	8	200	300	2.0
X	DMG6413B	270-805	6.0	0.12	0.24	12	200	300	2.0
X	DMG6413A	270-805	6.5	0.12	0.24	12	200	300	2.0
Ku	DMG6414B	270-805	6.5	0.08	0.16	16	200	350	2.0
Ku	DMG6414A	270-805	7.0	0.08	0.16	16	200	350	2.0
K	DMG7599	270-805	9.0	0.05	0.10	22	200	350	2.0
Ka	DMG6415	270-805	10.0	0.02	0.07	35	200	350	2.0



SENSITIVE ELECTRONIC DEVICES

Notes:

1 N_{if} = 1.5 dB, L.O. = 1.0 mW, R_L = 100Ω

Band	Test Frequency (GHz)
S	3.1
X	9.4
Ku	16.0
K	24.0
Ka	34.9

2 $R_s = R_t - R_B$ where R_t is the total resistance measured across the diode terminals and R_B is the barrier resistance (2.8Ω for a Schottky barrier diode measured at 10 mA. For multiple junction devices, the R_B would be 2.8Ω times the number of junctions between the diode terminals).

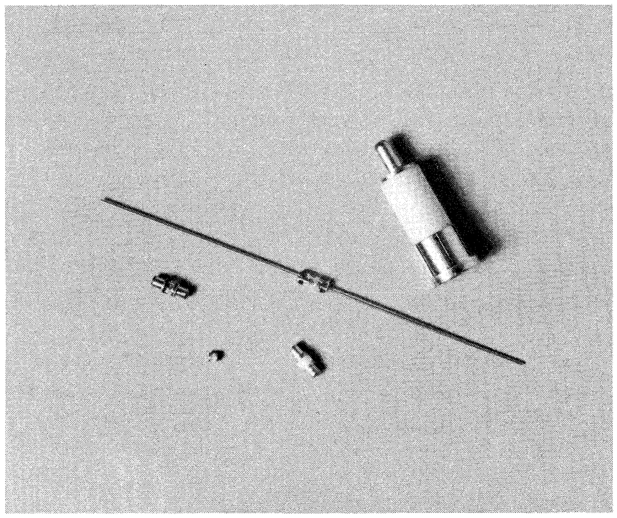
3 Electrical characteristics are specified for each junction except for those devices containing two or more junctions in series per arm. For these cases, the specification is for the arm.

4 Difference in forward voltage between leads within a pair or quad.

Silicon Bonded and Pressure Contact Schottky Barrier Mixer Diodes

Features

- Bonded Junctions for Reliability
- Low 1/f Noise
- Low Turn On for Starved L.O. Applications
- Planar Passivated Dice for Reliability
- Uniform Characteristics



Actual Size

Description

Alpha's silicon Schottky barrier mixer diodes are designed for applications through 40 GHz and are made by deposition of a suitable metal on an epitaxial silicon substrate to form the junction. The process and choice of materials result in low series resistance along with a narrow spread of capacitance values for close impedance control.

Three types of Schottky barrier diodes are included in this section. These three series are identified on the tabular listing as follows:

N-type, low drive level:	For use in conventional and low or starved local oscillator drive applications.
P-type, low drive level:	Low 1/f noise for use in doppler radar and motion detector applications. These may also be used for low or starved local oscillator drive applications.
P-type, medium drive level:	For use in conventional mixer applications where the minimum local oscillator drive level is 0.5 milliwatts. These also exhibit low 1/f noise and are suitable for use in doppler radar and motion detector applications.

These Schottky barrier mixer diodes are available in a wide range of packages which make them suitable for use in waveguide, coaxial and stripline applications. In addition, Alpha can supply a complete line of Schottky barrier beam-lead diodes or chips.

Applications

These diodes are categorized by noise figure for mixer applications in four different frequency ranges: S, X, Ku, and Ka-bands. However they can also be used as modulators, high speed switches and low power limiters.

Matched pairs of mixer diodes are used in conjunction with a hybrid or magic-tee primarily for suppressing noise originating in the local oscillator. They are also used to isolate the local oscillator arm from the signal arm, thus minimizing radiation and absorption of signal power. Other uses are for specific reflection of signals through the hybrid and for balanced modulators and discriminators. The matching criteria for mixer diodes are as follows:

a) Conversion loss (within 0.3 dB of each other)
b) IF impedance (within 25 ohms of each other)
c) The VSWR of individual diodes, when not otherwise restricted (such as 1.3 on premium units) is limited to 1.6 max.

These specifications allow the noise figure of the receiver to deteriorate no greater than 0.1 dB due to local oscillator noise. The VSWR limit allows a maximum of 5% leakage; in practice, this leakage is generally less than 2%.

Matched diodes are supplied in either forward pairs (M) or forward/reverse pairs (MR). The forward/reverse pair allows for a simpler IF circuit design.

A typical V_f vs I_f curve is shown in Figure 1. Typical noise figure vs L.O. drive is shown in Figure 2 for single diodes. Typical mixer circuits are shown in Figure 3 in order of complexity.

The circuits described in Figures 3a and 3b are recommended for narrower band applications where the lowest possible noise figure is desired. The matching network can be an "L" network using discrete components at lower frequencies or a section of transmission line. The double balanced mixer shown in Figure 3c is recommended for broadband operation where noise figure is less important.

Silicon Bonded and Pressure Contact Schottky Barrier Mixer Diodes

Figure 4 depicts the circuit configuration of a balanced mixer using two diodes of the same polarity for L.O. noise suppression. In order to attain local oscillator noise suppression, the IF outputs of the two diodes must differ by 180°. In this circuit the phase reversal is accomplished in the IF combining network as shown.

A much easier method of obtaining the 180° phase reversal is to use one forward and one reverse diode as shown in Figure 5. This substantially simplifies the mixer-IF amplifier interface design.

See Sections 2 and 7 for Application Notes:

80800 Mixer and Detector Diodes
80850 Handling Precautions for Schottky Barrier and Point Contact Mixer and Detector Diodes
80000 Bonding Methods: Diode Chips, Beam-Lead Diodes and Capacitors

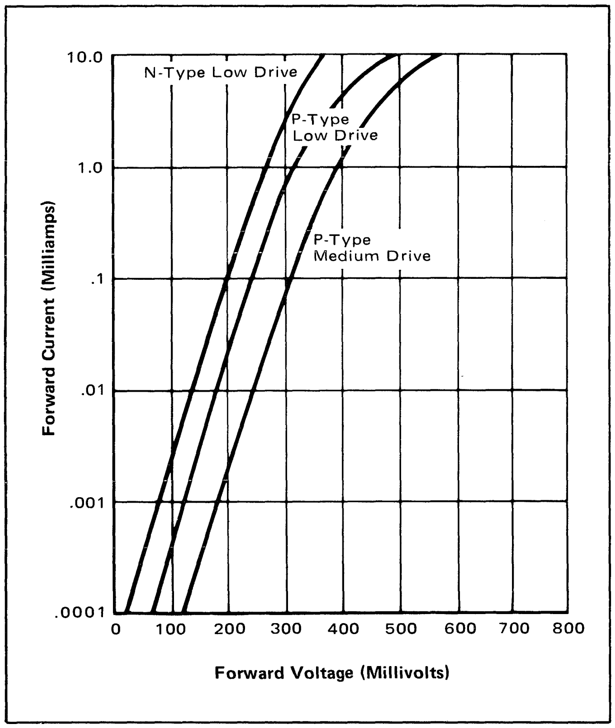


Figure 1. Typical Forward DC Characteristic Curves — Voltage vs Current

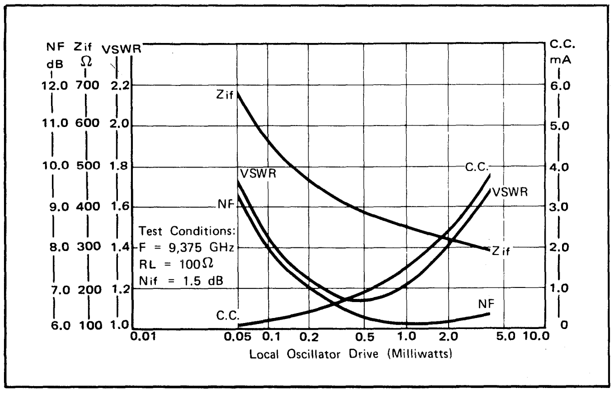


Figure 2. Typical X-Band Low Drive Mixer Diode — RF Parameters vs Local Oscillator Drive

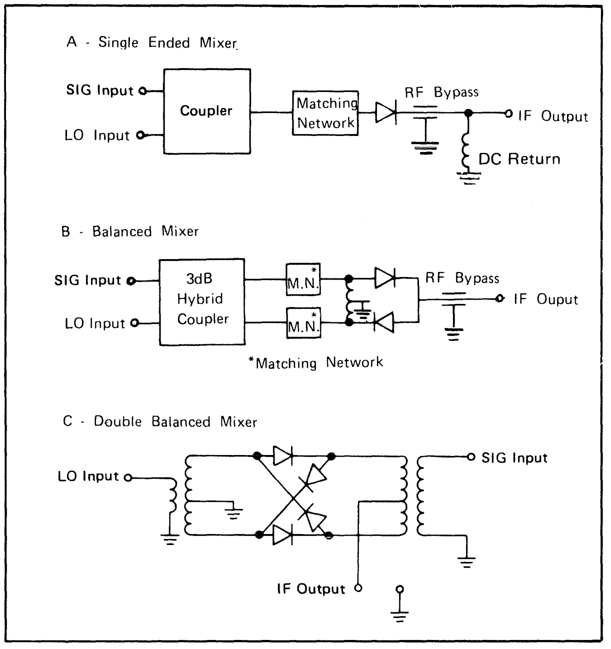


Figure 3. Typical Mixer Circuits

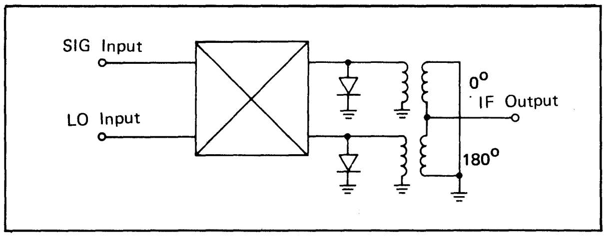


Figure 4.

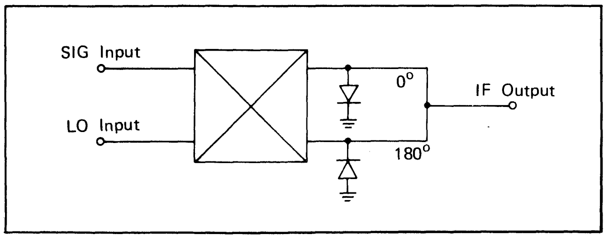


Figure 5.

Silicon Bonded and Pressure Contact Schottky Barrier Mixer Diodes

	Type Number					Electrical Characteristics			Test Conditions			N-Type Drive Level	P-Type Drive Level	
	Polarity	Matched Pairs				Z_{if} OHMS								
Frequency Band	Reversible	Two Forward—Polarity Diodes	One Forward, One Reverse—Polarity Diodes	NF(2) dB Max.	Package Outline	Min.	Max.	VSWR Max.	Frequency GHz	L.O. Power mW	Holder	Low	Low	Med
S	DMC5501C	DMC5501CM		5.5	075-001	250	450	1.7	3.1	1.0	P-028			X
S	DMC5503C	DMC5503CM		5.5	013-001	150	350	1.7	3.1	1.0	P-029			X
S	DMF6887C	DMF6887CM		5.5	207-001(5)	100	300	1.7	3.1	1.0	P-029	X		
S	DMF6898C	DMF6898CM		5.5	247-001(5)	—	—	—	3.1	1.0	—	X		
S	DMC5910C	DMC5910CM	DMC5910CMR	5.5	005-801	350	450	1.3	3.1	0.5	264-JAN			X
S	DMC5503B	DMC5503BM		6.0	013-001	150	350	1.8	3.1	1.0	P-029			X
S	DMC5501B	DMC5501BM		6.0	075-001	250	450	1.8	3.1	1.0	P-028			X
S	DMF6887B	DMF6887BM		6.0	207-001(5)	100	300	1.8	3.1	1.0	P-029	X		
S	DMF6898B	DMF6898BM		6.0	247-001(5)	—	—	—	3.1	1.0	—	X		
S	DMC5910B	DMC5910BM	DMC5910BMR	6.0	005-801	350	450	1.3	3.1	0.5	264-JAN			X
S	DMC5501A	DMC5501AM		6.5	075-001	250	450	2.0	3.1	1.0	P-028			X
S	DMC5503A	DMC5503AM		6.5	013-001	150	350	2.0	3.1	1.0	P-029			X
S	DMF6887A	DMF6887AM		6.5	207-001(5)	100	300	2.0	3.1	1.0	P-029	X		
S	DMF6898A	DMF6898AM		6.5	247-001(5)	—	—	—	3.1	1.0	—	X		
S	DMC5910A	DMC5910AM	DMC5910AMR	6.5	005-801	350	450	1.3	3.1	0.5	264-JAN			X
S	DMC5501	DMC5501M		7.0	075-001	250	450	2.3	3.1	1.0	P-028			X
S	DMC5503	DMC5503M		7.0	013-001	150	350	2.3	3.1	1.0	P-029			X
S	DMC5910	DMC5910M	DMC5910MR	7.0	005-801	350	450	1.3	3.1	0.5	264-JAN			X
X	DMF6106C	DMF6106CM		5.5	207-001(5)	200	500	1.6	9.4	1.0	P-107	X		
X	DMF4018C	DMF4018CM		5.5	247-001(5)	—	—	—	9.4	1.0	—	X		
X	DMF6130B	DMF6130BM		6.0	075-001	200	500	1.6	9.4	1.0	P-075	X		
X	DMF6106B	DMF6106BM		6.0	207-001(5)	200	500	1.6	9.4	1.0	P-107	X		
X	DMF4018B	DMF4018BM		6.0	247-001(5)	—	—	—	9.4	1.0	—	X		
X	DMB5880C	DMB5880CM	DMB5880CMR	6.0	005-801	335	465	1.3	9.4	1.0	105-JAN		X	
X	DMB6411C	DMB6411CM	DMB6411CMR	6.0	005-801	335	465	1.5	9.4	1.0	105-JAN		X	
X	DMC5506(6)	DMC5506CM(6)		6.5	013-001	300	600	1.6	9.4	1.0	P-017			X
X	DMC5504C	DMC5504CM		6.5	075-001(5)	300	600	1.6	9.4	1.0	P-075			X
X	DMB5880B	DMB5880BM	DMB5880BMR	6.5	005-801	335	465	1.3	9.4	1.0	105-JAN		X	
X	DMB6411B	DMB6411BM	DMB6411BMR	6.5	005-801	335	465	1.5	9.4	1.0	105-JAN		X	
X	DMF6130A	DMF6130AM		6.5	075-001	200	500	1.6	9.4	1.0	P-075	X		
X	DMF6106A	DMF6106AM		6.5	207-001(5)	200	500	1.6	9.4	1.0	P-017	X		
X	DMF4018A	DMF4018AM		6.5	247-001(5)	—	—	—	9.4	1.0	—	X		
X	DMC5506B(6)	DMC5506BM(6)		7.0	013-001	300	600	1.6	9.4	1.0	P-017			X
X	DMC5504B	DMC5504BM		7.0	075-001	300	600	1.6	9.4	1.0	P-075			X
X	DMB5880A	DMB5880AM	DMB5880AMR	7.0	005-801	335	465	1.3	9.4	1.0	105-JAN		X	
X	DMB6411A	DMB6411AM	DMB6411AMR	7.0	005-801	335	465	1.5	9.4	1.0	105-JAN		X	
X	DMF6130	DMF6130M		7.0	075-001	200	500	1.6	9.4	1.0	P-075	X		
X	DMB5880	DMB5880M	DMB5880MR	7.5	005-801	335	465	1.3	9.4	1.0	105-JAN		X	
X	DMB6411	DMB6411M	DMB6411MR	7.5	005-801	335	465	1.5	9.4	1.0	105-JAN		X	
X	DMC5506A(6)	DMC5506AM(6)		8.0	013-001	300	600	2.0	9.4	1.0	P-017		X	
X	DMC5504A	DMC5504AM		8.0	075-001	300	600	2.0	9.4	1.0	P-075			X

Notes:

Maximum operating temperature = 150°C.

1 Nominal range (not specified).
2 Nif = 1.5 dB.
3 Integrated noise in the band of 8 Hz to 60 kHz.
4 Calculated noise figure.
5 Thermal compression bonded junction.
6 Low Drive available upon request.

For stripline applications; all diodes in the 075-001 package are available with flattened leads.

Silicon Bonded and Pressure Contact Schottky Barrier Mixer Diodes

Frequency Band	Type Number: Polarity: Reversible	Type Number: Matched Pairs: Two Forward—Polarity Diodes	Type Number: Matched Pairs: One Forward, One Reverse—Polarity Diodes	NF[2] dB Max.	Package Outline	Electrical Characteristics: Z_{if} OHMS Min.	Electrical Characteristics: Z_{if} OHMS Max.	Electrical Characteristics: VSWR Max.	Test Conditions: Frequency GHz	Test Conditions: L.O. Power mW	Test Conditions: Holder	N-Type Drive Level: Low	P-Type Drive Level: Low	P-Type Drive Level: Med
Ku	DMF6107C	DMF6107CM		6.0	207-001[5]	200	500	1.6	16.0	1.0	P-041	X		
Ku	DMF4019C	DMF4019CM		6.0	247-001[5]	—	—	—	16.0	1.0	—	X		
Ku	DMF6107B	DMF6107BM		6.5	207-001[5]	200	500	1.6	16.0	1.0	P-041	X		
Ku	DMF4019B	DMF4019BM		6.5	247-001[5]	—	—	—	16.0	1.0	—	X		
Ku	DMC5507C[6]	DMC5507CM[6]		7.0	013-001	300	600	1.6	16.0	1.0	P-041			X
Ku	DMF6107A	DMF6107AM		7.0	207-001[5]	200	500	1.6	16.0	1.0	P-041	X		
Ku	DMF4019A	DMF4019AM		7.0	207-001[5]	—	—	—	16.0	1.0	—	X		
Ku	DMC5507B[6]	DMC5507BM[6]		7.5	013-001	300	600	1.8	16.0	1.0	P-041			X
Ka	DMF5078D	DMF5078DM		7.0[4]	207-001[5]	300[1]	700[1]	—	34.9	1.0	P-076	X		
Ka	DMF4039D	DMF4039DM		7.0[4]	247-001[5]	—	—	—	34.9	1.0	—	X		
Ka	DMF5078C	DMF5078CM		7.5[4]	207-001[5]	300[1]	700[1]	—	34.9	1.0	P-076	X		
Ka	DMF4039C	DMF4039CM		7.5[4]	247-001[5]	—	—	—	34.9	1.0	—	X		
Ka	DMF5078B	DMF5078BM		8.0[4]	207-001[5]	300[1]	700[1]	—	34.9	1.0	P-076	X		
Ka	DMF4039B	DMF4039BM		8.0[4]	247-001[5]	—	—	—	34.9	1.0	—	X		
Ka	DMF5078A	DMF5078AM		9.0[4]	207-001[5]	300[1]	700[1]	—	34.9	1.0	P-076	X		
Ka	DMF4039A	DMF4039AM		9.0[4]	247-001[5]	—	—	—	34.9	1.0	—	X		
Ka	DMF5078	DMF5078M		10.0[4]	207-001[5]	300[1]	700[1]	—	34.9	1.0	P-076	X		
Ka	DMF4039	DMF4039M		10.0[4]	247-001[5]	—	—	—	34.9	1.0	—	X		

Low Audio Noise Diode for Use in Slow Speed Motion Detector Applications

Frequency Band	Type Number: Polarity: Reversible	ANr[3] dB Max.	NF[2] dB Max.	Package Outline	Electrical Characteristics: Z_{if} OHMS Min.	Electrical Characteristics: Z_{if} OHMS Max.	Electrical Characteristics: VSWR Max.	Test Conditions: Frequency GHz	Test Conditions: L.O. Power mW	Test Conditions: Holder	N-Type Drive Level: Low	P-Type Drive Level: Low	P-Type Drive Level: Med.
X	DMC6224	6.0	7.5	005-801	335[1]	465[1]	1.5[1]	9.38	1.0	105-JAN			X
X	DMB4009	6.0	7.0	207-001[5]	—	—	—	9.38	1.0	P-017		X	
X	DMC4037	6.0	7.5	075-001	—	—	—	9.38	1.0	P-075			X
X	DMF6724	6.0	6.5	005-801	335[1]	465[1]	1.5[1]	9.38	1.0	105-JAN	X		
K	DMF5078Y	6.0	12.0	207-001[5]	300[1]	600[1]	—	24.15	1.0	—	X		

Notes:

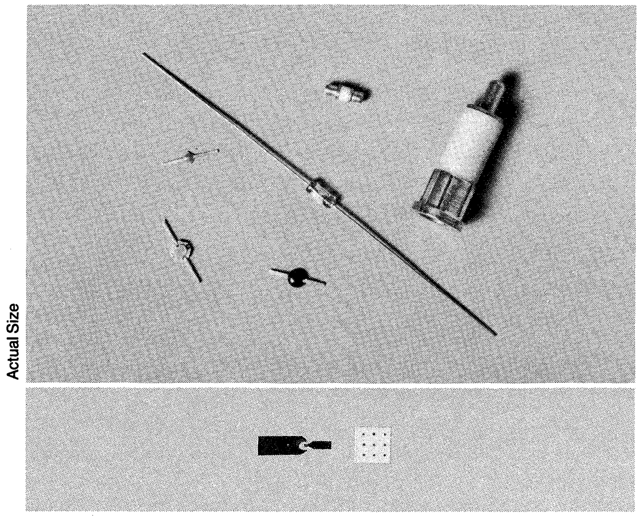
Maximum operating temperature = 150°C.
1. Nominal range (not specified).
2. N_{if} = 1.5 dB.
3. Integrated noise in the band of 8 Hz to 60 kHz.
4. Calculated noise figure.
5. Thermal compression bonded junction.
6. Low Drive available upon request.

For stripline applications; all diodes in the 075-001 package are available with flattened leads.

Silicon Schottky Barrier Detector Diodes

Features

- Low 1/f Noise
- Bonded Junctions for Reliability
- Planar Passivated Beam-Lead and Chip Construction



Magnification: 10X

Description

Alpha packaged, beam-lead and chip Schottky barrier detector diodes are designed for applications through 40 GHz in Ka-band. They are made by the deposition of a suitable barrier metal on an epitaxial silicon substrate to form the junction. The process and choice of materials result in low series resistance along with a narrow spread of capacitance values for close impedance control. P-type silicon is used to obtain superior 1/f noise characteristics.

The packaged diodes are suitable for use in waveguide, coaxial, and stripline applications.

The beam-lead and chip diodes can also be mounted in a variety of packages (such as the 130, 307, and 325 series) as well as the LID package or on special customer substrates.

Unmounted beam-lead diodes are especially well suited for use in MIC applications. Mounted beam-lead diodes can be easily used in MIC, stripline or other such circuitry.

A complete line of chips is shown for those MIC applications where the chip and wire approach is more desirable.

Applications

These diodes are categorized by TSS (Tangential Signal Sensitivity) for detector applications in four frequency ranges: S, X, Ku, and Ka-band. However, they can also be used as modulators, high speed switches and low power limiters. RF parameters on chips and beam-lead diodes are tested on a sample basis, while breakdown voltage, video impedance, 1/f noise and capacitance measurements are 100% tested. Packaged diodes are 100% RF tested.

TSS is the one parameter that best describes a diode's use as a video detector. It is defined as the amount of signal power, below a one milliwatt reference level, required to produce an output pulse whose amplitude is sufficient to raise the noise fluctuations by an amount equal to the average noise level. TSS is approximately 4 dB above the Minimum Detectable Signal.

The Schottky barrier diodes in this data sheet are of P-type construction and are optimized for low noise, particularly in the 1/f region. They require a small forward bias (to overcome the barrier potential) if efficient operation is required, especially at power levels below − 20 dBm. Bias not only increases sensitivity but also greatly reduces parameter variation due to temperature change. Video impedance is a direct function of bias and closely follows the 28/I(mA) relationship. This is important to pulse fidelity, since the video impedance in conjunction with the detector output capacitance affects the effective amplifier bandwidth.

Bias does, however, increase noise, particularly in the 1/f region. Therefore, it should be kept at as low a level as possible (typically 5–50 microamps).

Voltage output versus power input as a function of load resistance and bias is shown in Figures 1a and 1b.

Matched Pairs

Matched pairs of detector diodes are used when near equal sensitivities are required. This is achieved by matching the voltage outputs at a point in the square law region.

The voltage outputs are matched within 1 dB as follows:

$$\Delta dB = 10 \log \frac{M1}{M2} = 1\ dB$$

where M1 is the higher Figure of Merit of the two diodes. The video impedances are also matched:

$$\Delta Z_v = 20\%\ Max.$$

Custom matching may be performed to other tolerances or as a function of frequency, power level and load resistance.

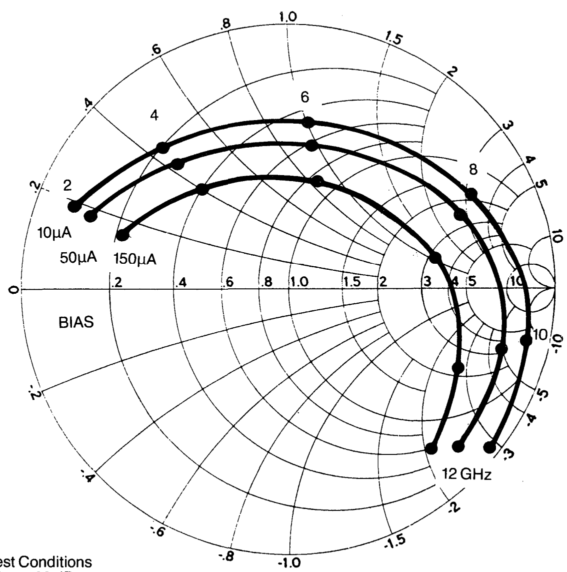
Typical Circuits

The Multi Octave-High Sensitivity circuit would be used in ECM and similar applications. Since video detectors are inherently high impedance devices, an RF matching structure that will present the maximum power at the diode junction must be incorporated to insure maximum sensitivity. The use of bias will reduce the diode VSWR as well as its video impedance. Figure 2 shows two typical detector circuits with and without forward dc bias.

The Broadband-Low Sensitivity circuit would be used where low input VSWR is required. In this circuit the low VSWR is accomplished by the use of the 50 ohm terminating resistor. Sensitivity, however, is degraded by typically 10 dB from the Multi Octave-High Sensitivity circuit. The most common use for this circuit is in the broadband, flat detector used primarily in the laboratory.

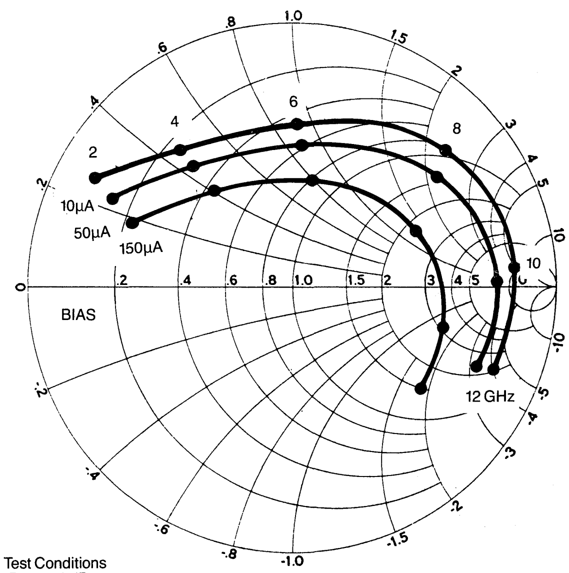
See Sections 2 and 7 for Application Notes:

80800 Mixer and Detector Diodes
80850 Handling Precautions for Schottky Barrier and Point Contact Mixer and Detector Diodes
80000 Bonding Methods: Diode Chips, Beam-Lead Diodes and Capacitors



Test Conditions
P = −20 dBm

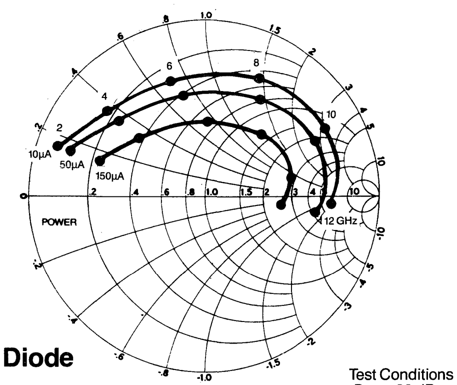
Typical DDB 3263
Low Drive X-Band Detector Diode
Admittance Characteristics



Test Conditions
P = −20 dBm

Typical DDB 4393
Low Drive X-Band Detector Diode
Admittance Characteristics

Silicon Schottky Barrier Detector Diodes



Typical DDB 3266
Low Drive X-Band Detector Diode
Admittance Characteristics

Test Conditions
P = −20 dBm

CAUTION
SENSITIVE ELECTRONIC DEVICES

PACKAGED Low 1/f Noise (6.0 dB Max.)

Frequency Band	Type Number	Electrical Characteristics: TSS[1,2] dBm Min.	Z_v[1] ohms Min.	Z_v[1] ohms Max.	C_J @ 0V pF Max.	Test Conditions: Frequency GHz	Test Conditions: Holder	Package Outline
C-X	DDB4517A	50	500	700	—	5 & 11	P-066	207-001
C-X	DDL6672A	48	500	700	—	5 & 11	P-085	075-001
C-X	DDB4517	47	500	700	—	5 & 11	P-066	207-001
C-X	DDL6672	45	500	700	—	5 & 11	P-085	075-001
X	DDL6725	48	500	700	—	10.525	Optimized	005-801
K	DDB6673Y	50	—	—	0.10	24.15	Optimized	207-001
Ka	DDB6673	40	500	700	—	34.86	P-064	207-001

BEAM-LEAD Low 1/f Noise (6.0 dB Max.)

Frequency Band	Type Number	Electrical Characteristics: TSS[1,2] dBm Min.	Z_v[1] ohms Min.	Z_v[1] ohms Max.	C_J @ 0V pF Max.	Test Conditions: Frequency GHz	Test Conditions: Holder	Package Outline
X	DDB4719	50	500	700	0.15	10	—	130-011
X	DDB4503	50	500	700	0.15	10	—	174-002
X	DDB3221	50	500	700	0.15	10	—	295-011
X	DDB3268	50	500	700	0.15	10	—	364-011
Ku	DDB3263	48	500	700	0.10	16	—	130-011
Ku	DDB4504	48	500	700	0.10	16	—	174-002
Ku	DDB3266	48	500	700	0.10	16	—	295-011
Ku	DDB4393	48	500	700	0.10	16	—	364-011
K	DDB5098	50[5]	800[5]	1200[5]	0.10	24.15	—	130-011
K	DDB3265	50[5]	800[5]	1200[5]	0.10	24.15	—	174-002
K	DDB3267	50[5]	800[5]	1200[5]	0.10	24.15	—	295-011
K	DDB3269	50[5]	800[5]	1200[5]	0.10	24.15	—	364-011

CHIP Low 1/f Noise (6.0 dB Max.)

Frequency Band	Type Number	Electrical Characteristics: TSS[1,2] dBm Min.	Z_v[1] ohms Min.	Z_v[1] ohms Max.	C_J @ 0V pF Max.	Test Conditions: Frequency GHz	Test Conditions: Holder	Package Outline
X	CDB7605	50	500	700	0.15	10	—	270-804
Ku	CDB7606	48	500	700	0.10	16	—	270-804

Notes:
1. Bias = 50μA.
2. Video bandwidth = 10 MHz.
3. For stripline applications, all diodes in the 075-001 package are available with flattened leads.
4. Maximum operating temperature = 150°C.
5. Bias = 30μA.

Silicon Schottky Barrier Detector Diodes

Typical X-Band Detector Diode

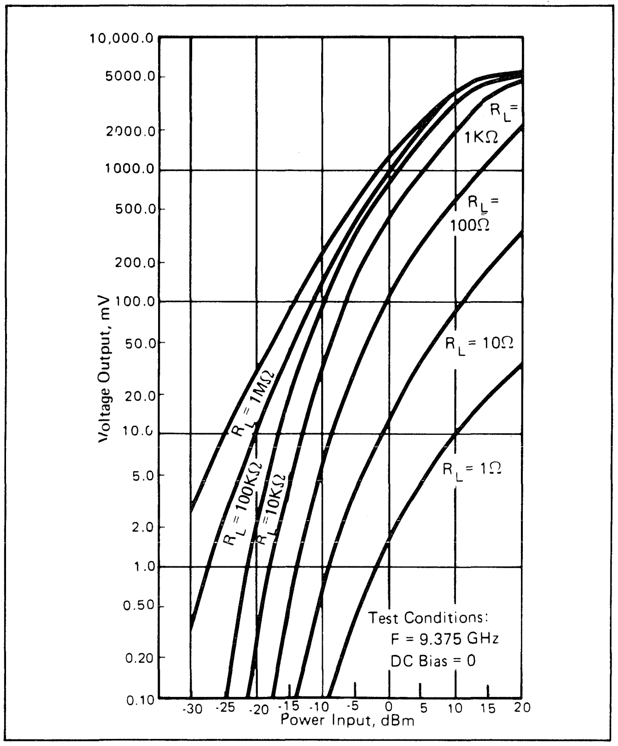


Figure 1a. Voltage Output vs Power Input as a Function of Load Resistance

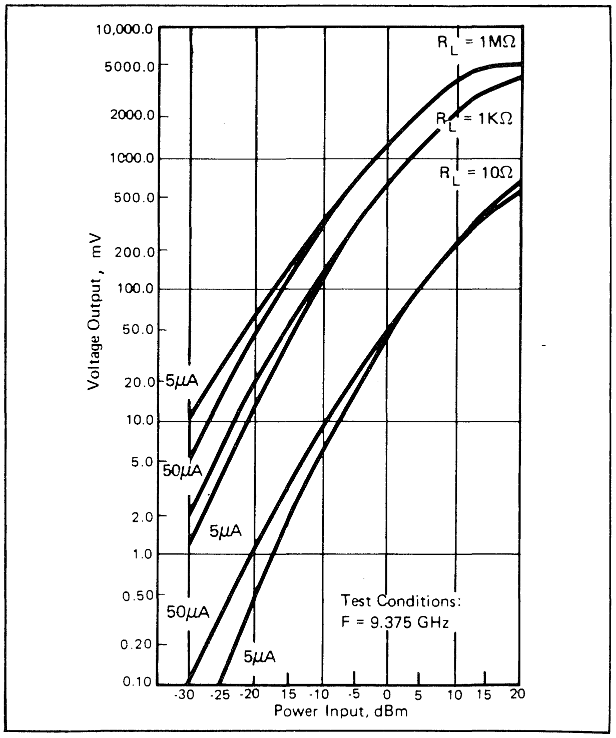


Figure 1b. Voltage Output vs Power Input as a Function of Load Resistance and Bias

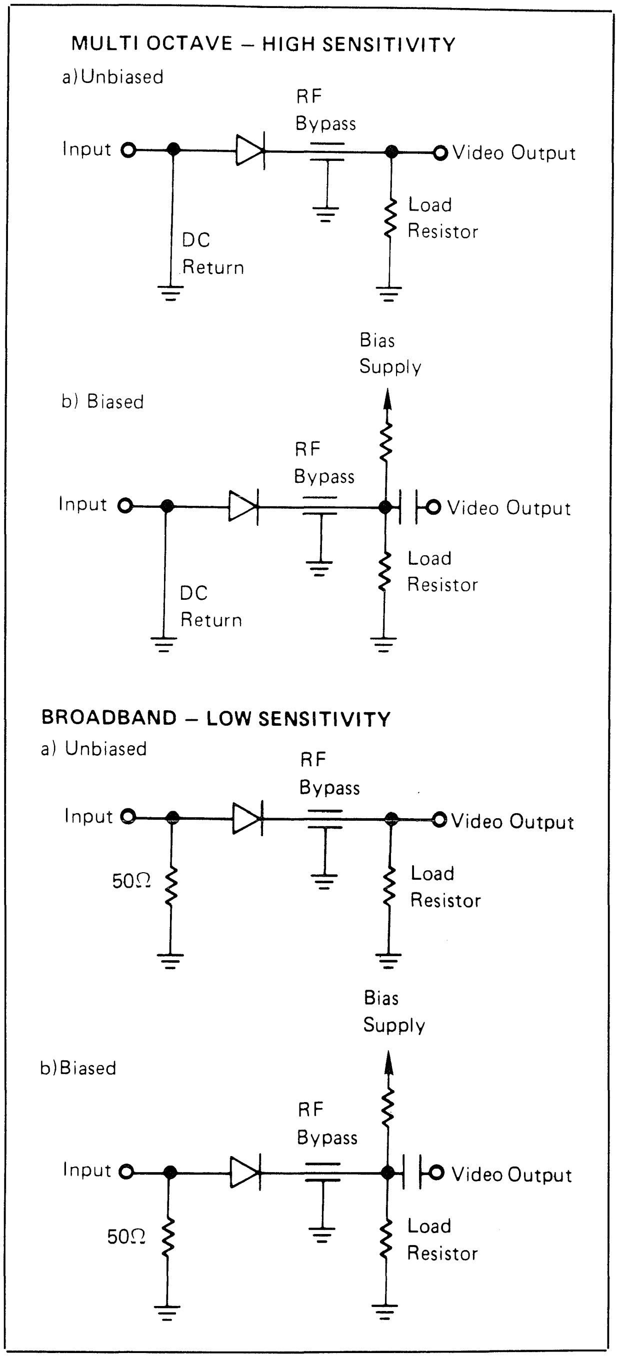


Figure 2. Typical Video Detector Circuits

Frequency Table

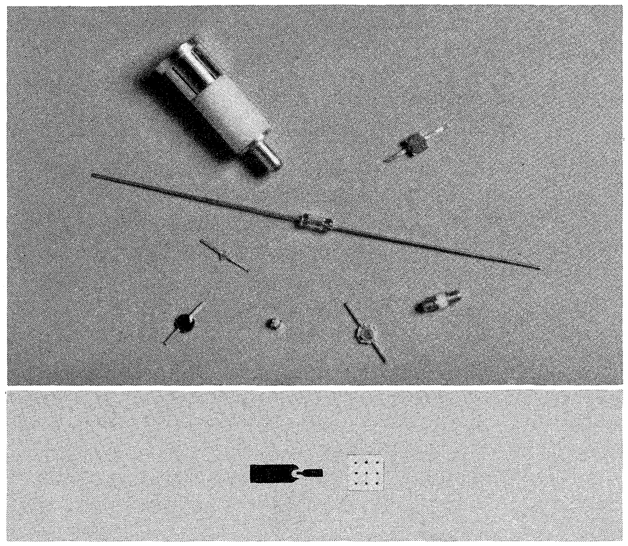
Band	Frequencies (GHz)
S	2 to 4
C	4 to 8
X	8.2 to 12.4
Ku	12.4 to 18.0
K	18.0 to 26.5
Ka	26.5 to 40.0

Zero Bias Silicon Schottky Barrier Detector Diodes

Features

- Zero Turn On, No Bias Required
- Low Video Impedance

Actual Size



Magnification: 10X

Description

Alpha's series of packaged, beam-lead and chip zero bias Schottky barrier detector diodes are designed for applications through Ku-band. The choice of barrier metal and process techniques results in a diode with a wide selection of video impedance ranges.

The packaged diodes are suitable for use in wave-guide, coaxial and stripline applications. The beam-lead and chip diodes can also be mounted in a variety of packages (such as the 130, 295 and 325 series) as well as the LID package or on special customer substrates.

Unmounted beam-lead diodes are especially well suited for use in MIC applications. Mounted beam-lead diodes can be easily used in MIC, stripline and other such circuitry.

A complete line of chips is shown for those MIC applications where the chip and wire approach is more desirable.

Applications

The zero bias Schottky detector diodes are designed for detector applications through 12 GHz and are useful to 26 GHz. They require no bias and operate efficiently even at tangential signal power levels. Since they require no bias, noise is at a minimum. Their low video impedance means a short R-C time constant and hence wide video bandwidth and excellent pulse fidelity. As power monitors these diodes may also be used to drive metering circuits directly even at low power input levels. These diodes are categorized by TSS (Tangential Signal Sensitivity), voltage output and video impedance for detector applications to 12 GHz.

When selecting a detector diode for a particular application, it is desirable to choose the one with the lowest video impedance that will provide the required circuit sensitivity. By choosing in this manner, the R-C time constant of the output circuit will be lowest, and hence the input signal will be most accurately reproduced.

TSS is the parameter that best describes a diode's use as a video detector. It is defined as the amount of signal power, below a one milliwatt reference level, required to produce an output pulse whose amplitude is sufficient to raise the noise fluctuations by an amount equal to the average noise level. TSS is approximately 4 dB above the Minimum Detectable Signal.

Voltage output is another useful parameter, since it can be used in the design of threshold detectors and power monitor circuits. Since voltage output is a function of the diode's video impedance, a different minimum value is specified for each video impedance range.

Figure 1 is a plot of the forward DC characteristics. In Figure 2 voltage output is plotted as a function of power input for diodes of various video impedances. Tangential Signal Sensitivity as a function of video impedance is shown in Figure 3. Figure 4 shows two typical detector circuits. The Multi Octave-High Sensitivity circuit would be used in ECM and similar applications. An RF matching structure that will present the maximum power at the diode junction must be incorporated to insure maximum sensitivity. The Broadband-Low Sensitivity circuit would be used where low input VSWR is required. In this circuit the low VSWR is accomplished by the use of the 50 ohm terminating resistor. Sensitivity, however, is degraded by typically 10 dB from the Multi Octave-High Sensitivity circuit. The most common use for this circuit is in the broadband, flat detector used primarily in the laboratory.

Zero Bias Silicon Schottky Barrier Detector Diodes

See Sections 2 and 7 for Application Notes:

80800 Mixer and Detector Diodes
80850 Handling Precautions for Schottky Barrier and Point Contact Mixer and Detector Diodes
80000 Bonding Methods: Diode Chips, Beam-Lead Diodes and Capacitors

Zero Bias Schottky Detector Diodes

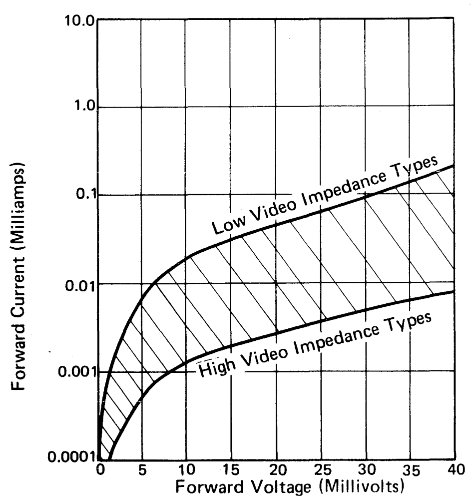


Figure 1. Typical Forward DC Characteristics

Figures 2 & 3 Typical Zero Bias X-Band Detector Diodes

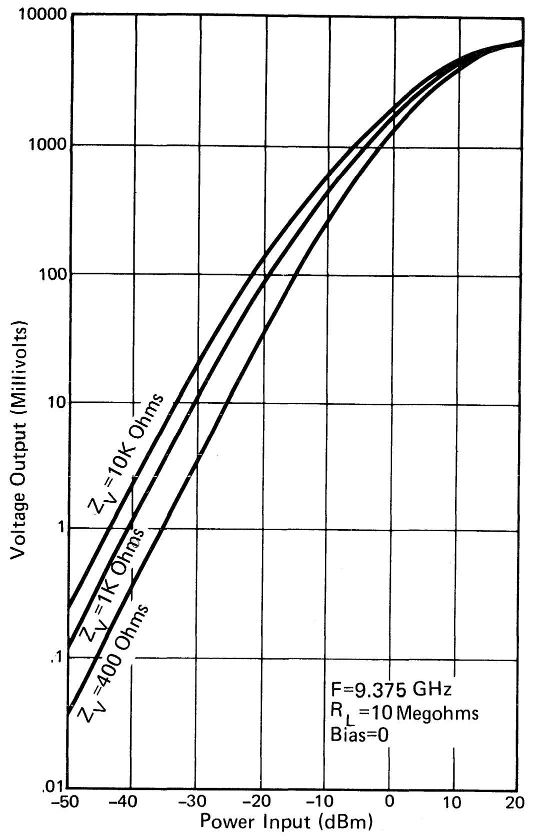


Figure 2. Voltage Output vs Power Input as a Function of Video Impedance

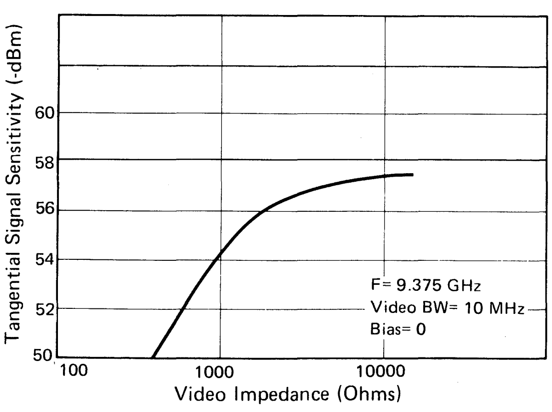


Figure 3. Tangential Signal Sensitivity vs Video Impedance

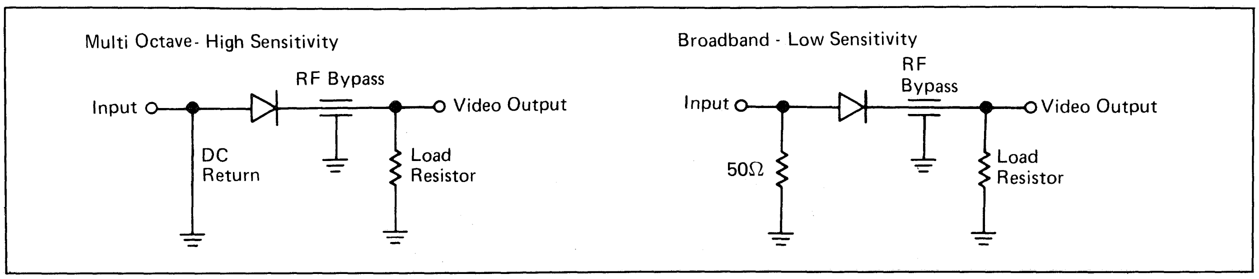
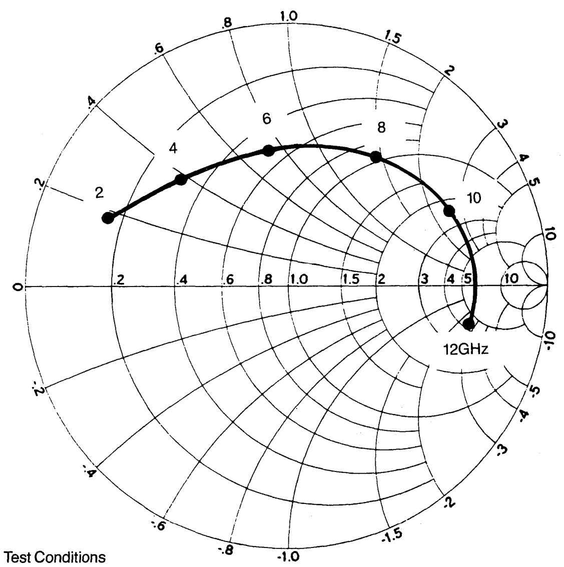
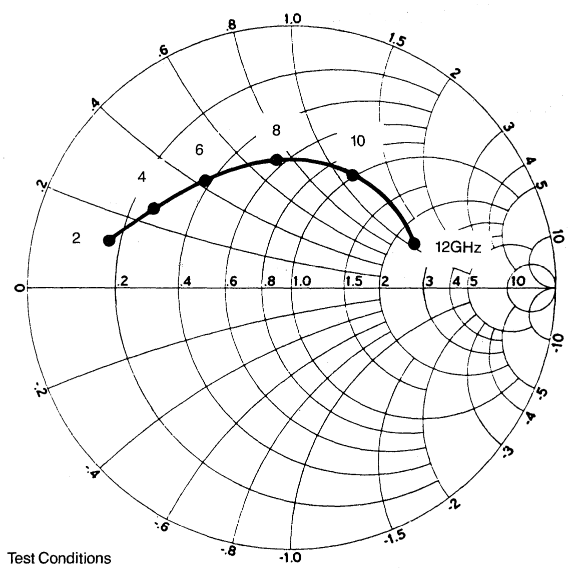


Figure 4. Typical Video Detector Circuits



Test Conditions
P = –20dBm

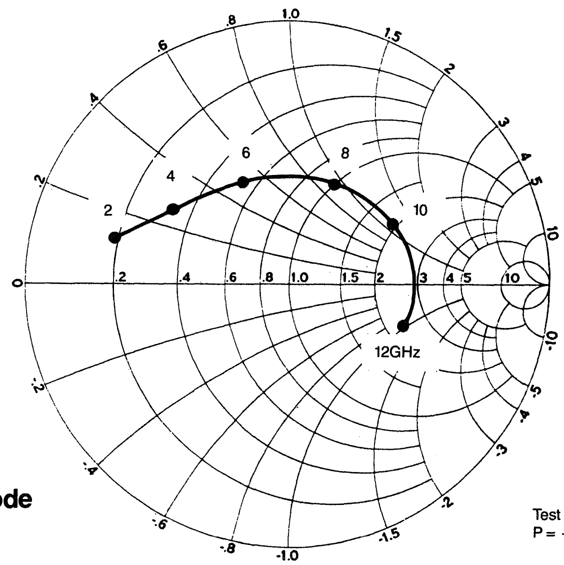
Typical DDC 4582
Zero Bias X-Band Detector Diode
Admittance Characteristics



Test Conditions
P = –20dBm

Typical DDC 6980
Zero Bias X-Band Detector Diode
Admittance Characteristics

Zero Bias Silicon Schottky Barrier Detector Diodes



Typical DDC 4722
Zero Bias X-Band Detector Diode
Admittance Characteristics

Zero Bias Schottky Barrier Detector Diodes

Frequency Band	Type Number	Electrical Characteristics TSS[1] -dBm Min.	Eo[2] mV Min.	Z_v ohms Min.	Max.	Package Outline
X	DDC4561	49	3.0	—	500	005-801
X	DDC4562	49	3.0	—	500	075-001
X	DDC4563	49	3.0	—	500	207-001
X	DDC4564	49	3.0	—	500	247-001
X	DDC4582	49	3.0	—	500	130-011
X	DDC6980	49	3.0	—	500	295-011
X	DDC4717	49	3.0	—	500	325-011
X	DDC4722	49	3.0	—	500	364-011
X	DDC4561A	49	4.0	500	1000	005-801
X	DDC4562A	49	4.0	500	1000	075-001
X	DDC4563A	49	4.0	500	1000	207-001
X	DDC4564A	49	4.0	500	1000	247-001
X	DDC4582A	49	4.0	500	1000	130-011
X	DDC6980A	49	4.0	500	1000	295-011
X	DDC4717A	49	4.0	500	1000	325-011
X	DDC4722A	49	4.0	500	1000	364-011
X	DDC4561B	52	8.0	1000	2000	005-801
X	DDC4562B	52	8.0	1000	2000	075-001
X	DDC4563B	52	8.0	1000	2000	207-001
X	DDC4564B	52	8.0	1000	2000	247-001
X	DDC4582B	52	8.0	1000	2000	130-011
X	DDC6980B	52	8.0	1000	2000	295-011
X	DDC4717B	52	8.0	1000	2000	325-011
X	DDC4722B	52	8.0	1000	2000	364-011
X	DDC4561C	55	12.0	2000	5000	005-801
X	DDC4562C	55	12.0	2000	5000	075-001
X	DDC4563C	55	12.0	2000	5000	207-001
X	DDC4564C	55	12.0	2000	5000	247-001
X	DDC4582C	55	12.0	2000	5000	130-011

Frequency Table

Band	Frequencies (GHz)
UHF	Up to 1
L	1 to 2
S	2 to 4
C	4 to 8
X	8.2 to 12.4
Ku	12.4 to 18.0
K	18.0 to 26.5
Ka	26.5 to 40.0

Zero Bias Schottky Barrier Detector Diodes (cont.)

Frequency Band	Type Number	Electrical Characteristics				Package Outline
		TSS[1] -dBm Min.	Eo[2] mV Min.	Z_v ohms Min.	Z_v ohms Max.	
X	DDC6980C	55	12.0	2000	5000	295-011
X	DDC4717C	55	12.0	2000	5000	325-011
X	DDC4722C	55	12.0	2000	5000	364-011
X	DDC4561D	56	15.0	5000	15000	005-801
X	DDC4562D	56	15.0	5000	15000	075-001
X	DDC4563D	56	15.0	5000	15000	207-001
X	DDC4564D	56	15.0	5000	15000	247-001
X	DDC4582D	56	15.0	5000	15000	130-011
X	DDC6980D	56	15.0	5000	15000	295-011
X	DDC4717D	56	15.0	5000	15000	325-011
X	DDC4722D	56	15.0	5000	15000	364-011

Beam-Lead

Frequency Band	Type Number	Electrical Characteristics				Package Outline
		TSS[1] -dBm Min.	Eo[2] mV Min.	Z_v ohms Min.	Z_v ohms Max.	
X	DDC4565	49	3.0	—	500	174-002
X	DDC4565A	49	4.0	500	1000	174-002
X	DDC4565B	52	8.0	1000	2000	174-002
X	DDC4565C	55	12.0	2000	5000	174-002
X	DDC4565D	56	15.0	5000	15000	174-002

Chip

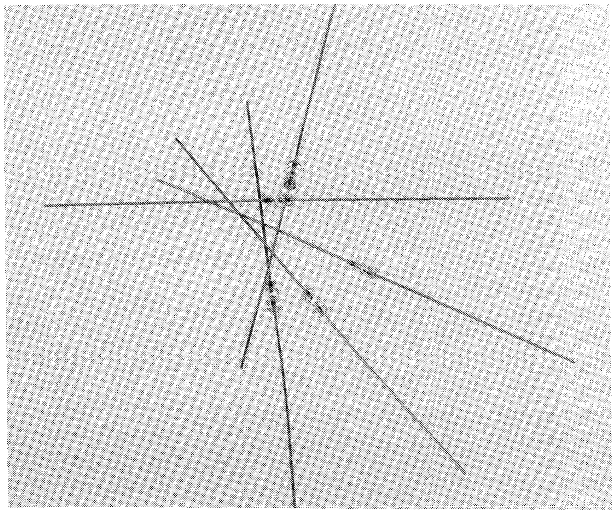
Frequency Band	Type Number	Electrical Characteristics				Package Outline
		TSS[1] -dBm Min.	Eo[2] mV Min.	Z_v ohms Min.	Z_v ohms Max.	
X	CDC7609	49	3.0	—	500	270-804
X	CDC7609A	49	4.0	500	1000	270-804
X	CDC7609B	52	8.0	1000	2000	270-804
X	CDC7609C	55	12.0	2000	5000	270-804
X	CDC7609D	56	15.0	5000	15000	270-804

Notes:
Maximum operating temperature = 150°C.
1. Video bandwidth = 10 MHz
2. P = −30dBm, $R_L > 1M\Omega$, frequency = 9.375 GHz

For stripline applications, all diodes in the 075-001 package are available with flattened leads.

CAUTION
SENSITIVE ELECTRONIC DEVICES

Pressure Contact Schottky Barrier Switching Diodes



Features

- Fast Switching Time
- High Breakdown Voltage
- Hermetically Sealed

Types

- DSN6566
- DSH4787

Description

The Alpha DSN6566 and DSH4787 are high voltage Schottky barrier diodes for applications involving switching times in the picosecond range. The devices are packaged in the miniature glass axial lead package.

These Schottky barrier diodes are made by deposition of a suitable metal on an epitaxial silicon substrate to form the junction. The process and choice of materials result in low series resistance along with a narrow spread of capacitance values for close parameter control. Since the process results in a majority carrier device, the diodes exhibit extremely fast switching speed characteristics.

The devices are designed primarily for high speed switching, clamping, pulse shaping, and other applications where switching times in the picosecond range are desired. These devices are also well suited for low frequency mixing (up to 2.0 GHz). Application information with more detail is available on request from Alpha Industries.

Maximum Ratings

	DSN Series	DSH Series
Operating Temperature	−65°C to +200°C	−65°C to +150°C
Storage Temperature	−65°C to +200°C	−65°C to +150°C
Power Dissipation DC	250 mW$^{(1)}$	150 mW$^{(2)}$

1 Derate linearly above 25°C at 1.43 mW/°C
2 Derate linearly above 25°C at 1.2 mW/°C

Electrical Characteristics

Type Number	Breakdown Voltage Vdc (Min.)		Forward Voltage Vdc (Max.)						Reverse Current nA (Max.)					Capacitance pF (Max.)
Polarity Reversible	V_B @ 10 µA	V_B @ 100 µA	V_F @ 1 mA	V_F @ 10 mA	V_F @ 15 mA	V_F @ 20 mA	V_F @ 35 mA	V_F @ 50 mA	I_R @ 1V	I_R @ 5V	I_R @ 8V	I_R @ 15V	I_R @ 50V	C_T @ V_R = 0V @ f = 1.0 MHz
DSN 6566-50	70	—	0.55	—	1.0	—	—	—	—	—	—	—	200	2.0
DSH 4787-40	30	—	0.40	—	—	—	—	1.0	—	—	—	300	—	1.0
DSH 4787-30	20	—	0.40	—	—	—	1.0	—	—	—	—	500	—	1.0
DSH 4787-20	15	—	0.41	—	—	1.0	—	—	—	—	100	—	—	1.2
DSH 4787-15	10	—	0.40	—	—	1.0	—	—	—	100	—	—	—	1.2
DSH 4787-10	—	5	0.34	0.45			—	—	100		—	—	—	1.0

1 Upon request, diodes can be supplied matched. Some typical matching requirements are $\triangle V_F = 20$ mV at $I_F = 1$ mA, 10 mA and 20 mA, $\triangle Co = 0.2$pF, F = 1 MHz.

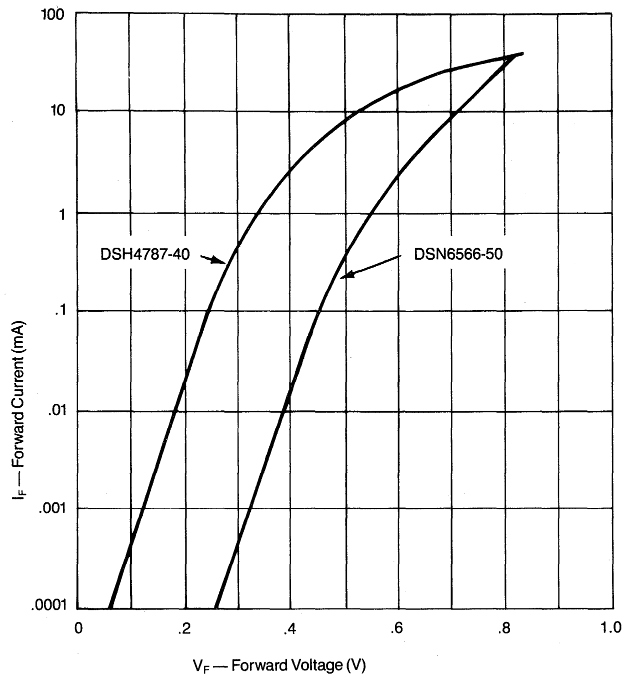


Figure 1. Typical Forward D.C. Characteristic Curves (DSH4787-40 and DSN6566-50)

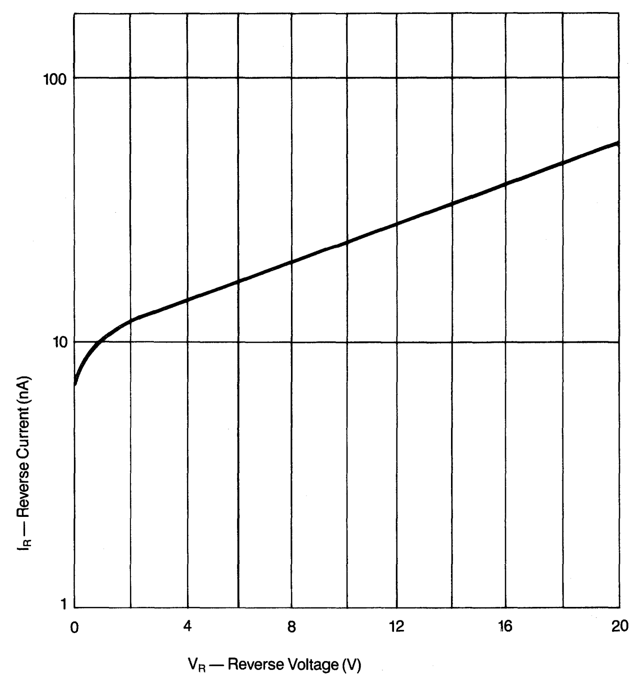


Figure 3. Typical Reverse Current vs. Reverse Voltage at $T_A = 25°C$ (DSH4787-40)

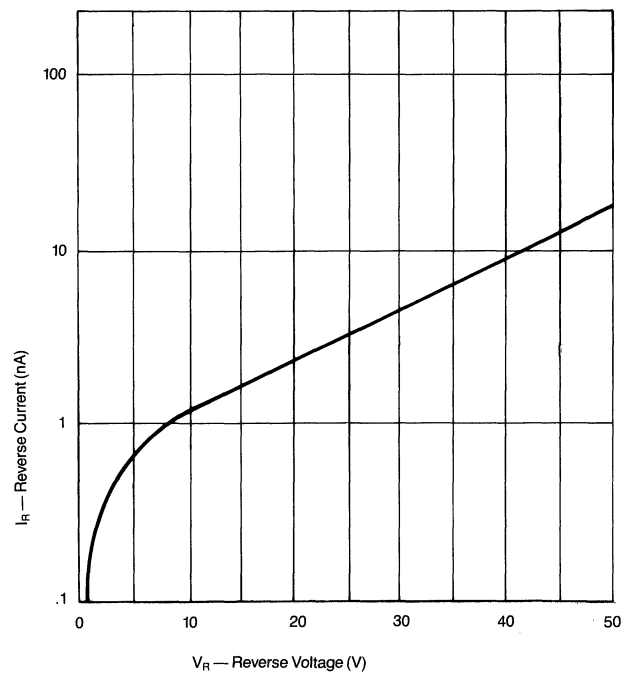
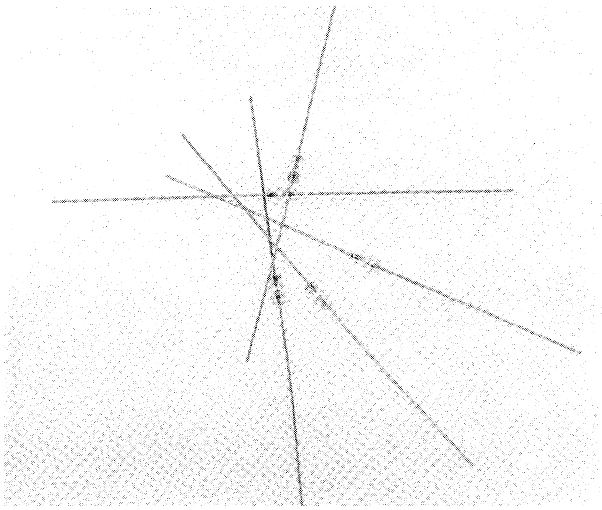


Figure 2. Typical Reverse Current vs. Reverse Voltage at $T_A = 25°C$ (DSN6566-50)

Bonded Contact Schottky Barrier Switching Diodes



Features

- Metallurgical Bonds
- Hermetically Sealed
- High Reliability
- High Breakdown Voltage
- Fast Switching Time

Types

- DSN6560
- DSH4785

Description

The Alpha DSN6560 and DSH4785 are high reliability Schottky barrier diodes for applications involving switching times in the picosecond range. The devices are packaged in a miniature glass axial lead package utilizing eutectic die mounting and metallurgical junction bonding.

The devices are designed primarily for applications where requirements mandate performance capability with high reliability over a wide range of operational and environmental service conditions.

CAUTION
SENSITIVE ELECTRONIC DEVICES

These Schottky barrier diodes are made by deposition of a suitable metal on an epitaxial silicon substrate to form the junction. The process and choice of materials result in low series resistance along with a narrow spread of capacitance values for close parameter control.

The devices are for high speed switching, clamping, pulse shaping, and other applications where switching times in the picosecond range are desired.

Breakdown voltage ranges other than those specified are available on request from Alpha Industries.

Maximum Ratings

	DSN Series	DSH Series
Operating Temperature	−65°C to +200°C	−65°C to +150°C
Storage Temperature	−65°C to +200°C	−65°C to +150°C
Power Dissipation DC	250 mW[1]	150 mW[2]

[1]Derate linearly above 25°C at 1.43 mW/°C
[2]Derate linearly above 25°C at 1.2 mW/°C

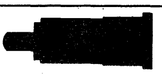
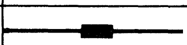
Electrical Characteristics

Type Number	Breakdown Voltage Vdc (Min.)		Forward Voltage Vdc (Max.)				Reverse Current nA (Max.)			Capacitance pF (Max.)
Polarity Reversible	V_B @ 10 μA	V_B @ 100 μA	V_F @ 1 mA	V_F @ 10 mA	V_F @ 15 mA	V_F @ 50 mA	I_R @ 1V	I_R @ 15V	I_R @ 50V	C_T @ V_R = 0V @ f = 1.0 MHz
DSN 6560-50	70	—	0.55	—	1.0	—	—	—	200	2
DSH 4785-40	30	—	0.40	—	—	1.0	—	300	—	1
DSH 4785-10	—	5	0.34	0.45	—	—	100	—	—	1

Silicon Point Contact Mixer and Detector Diodes Quick Reference Chart

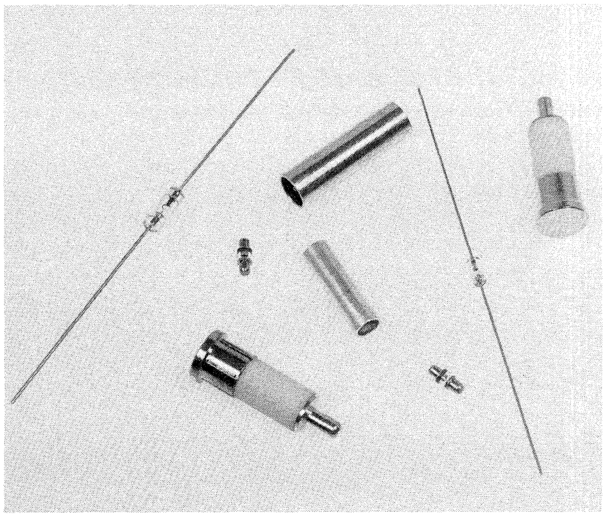
Description

This selection chart identifies the standard line of Alpha microwave point contact mixer and detector diodes by basic construction, package style and frequency band. If you require detailed specifications on device packages and electrical parameters, please refer to Alpha's Semiconductor Division Microwave Diode catalog. Catalogs and product line data sheets are available on request through the Alpha representative in your area or by contacting: Alpha's Semiconductor Division, 20 Sylvan Road, Woburn, Mass. 01801.

Type	Actual Size	Alpha Package	MIXERS					
			S-Band	S-X-Band	X-Band	Ku-Band	K-Band	Ka-Band
CERAMIC		005-801	IN21W 1N416 1N3655 DMA4148		1N23W 1N415 DMA6498 1N3747W 1N3746 1N3745			
CERAMIC		005-802	1N21		1N23 DMA6497 1N149			
MQM		013-001	DMA5221		DMA5223	DMA5278		DMA5253
GLASS		062-001	1N831		1N832			
GLASS		075-001	DMA5091		DMA5092			
COAXIAL		002-001			DMA5392 1N2510	1N78 DMA5282 1N4603 1N4604 1N4605 DMA6499 1N3205	1N26 DMA5326	
COAXIAL		007-001		DMA5632 1N1132				
COAXIAL		003-001						1N53 DMA5353

Alpha Package	DETECTORS							
	UHF	L-X-Band	X-Band	Ku-Band	K-Band	Ka-Band	B-Band	U-Band
005-801			DDA4072					
005-802			1N1611					
013-001			DDA5233 DDA5236	DDA6797	DDA5362	DDA5364	DDA5366	DDA5368
062-001	1N830		1N833 DDA5012					
075-001	DDA5090		DDA5093 DDA5036					
002-001				DDA5360	DDA5361			
007-001		DDA5638 1N358						
003-001						DDA5363	DDA5365	DDA5367

Silicon Point Contact Mixer Diodes



Features

- High Burnout Resistance
- Low Noise Figure, even in the Starved L.O. Mode
- Hermetically Sealed

Description

Alpha's point contact mixer diodes are designed for applications through Ka-band (40 GHz). These diodes employ epitaxial silicon optimized for low noise figure and uniformity. Since they are point contact devices, they can be used in mixers operating in the low, or starved, local oscillator condition as well as in the normal mode, where the local oscillator level is nominally one milliwatt.

They are available in a variety of packages which make them suitable for use in waveguide, coaxial and stripline applications.

For those applications requiring guaranteed power handling capability, Alpha has diodes that are screened 100% using narrow RF pulses ($\approx$ 5 nanoseconds). This screening insures reliable operation at power levels up to the screened value. These diodes are particularly useful in applications where the mixer follows a TRL or solid state limiter. Diodes in packages other than those shown are also available.

Applications

These diodes are categorized by noise figure at frequencies up through 40 GHz.

Matched pairs of mixer diodes are used in conjunction with a hybrid or magic-tee primarily for suppressing noise originating in the local oscillator. They are also used to isolate the local oscillator arm from the signal arm, thus minimizing radiation and absorption of signal power. Other uses are for specific reflection of signals through the hybrid and for balanced modulators and discriminators.

The matching criteria for mixer diodes are as follows:

a) Conversion loss (within 0.3 dB of each other)
b) IF impedance (within 25 ohms of each other)
c) The VSWR of individual diodes, when not otherwise restricted (such as 1.3 on premium units), is limited to 1.6 Max.

These specifications allow the noise figure of the receiver to deteriorate no greater than 0.1 dB due to local oscillator noise. The VSWR limit allows a maximum of 5% leakage. In practice, this leakage is generally less than 2%.

Matched diodes are supplied in either forward pairs (M) or forward/reverse pairs (MR). The forward/reverse pair allows for a simpler IF circuit design.

Figure 1 is a plot of a typical X-band point contact diode's E-I characteristic.

Figure 2 shows the behavior of a typical X-band single diode's noise figure versus local oscillator drive level. Because of the point contact diode's low turn-on as seen in Figure 1, it can operate efficiently as a mixer at local oscillator drive levels as low as 0.1 milliwatts, as can be seen in Figure 2.

Figure 3 depicts the circuit configuration of a balanced mixer using two diodes of the same polarity for L.O. noise suppression. In order to attain local oscillator noise suppression, the IF outputs of the two diodes must differ by 180°. In this circuit the phase reversal is accomplished in the IF combining network as shown.

A much easier method of obtaining the 180° phase reversal is to use one forward and one reverse diode as shown in Figure 4. This substantially simplifies the mixer-IF amplifier interface design.

Typical X-Band Mixer Diode

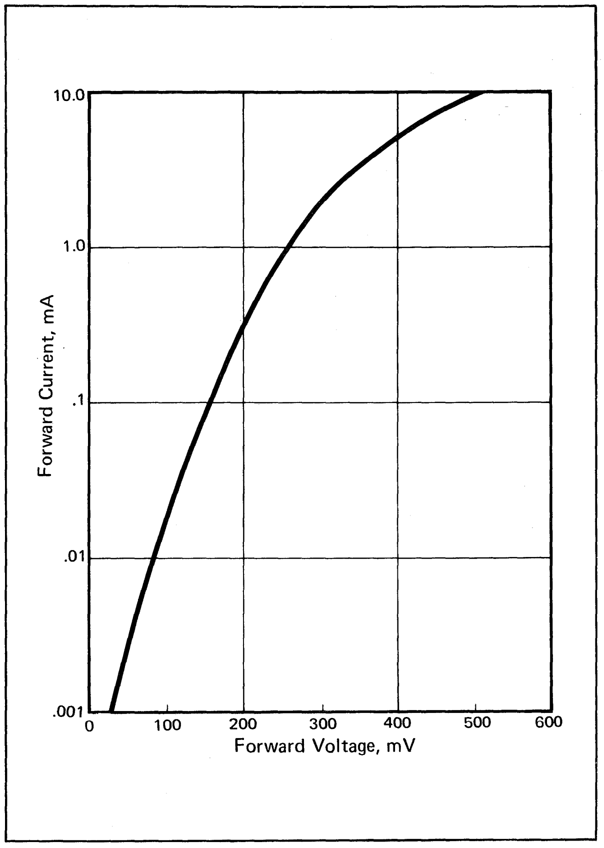


Figure 1. Typical Forward DC Characteristic Curve (Voltage vs Current)

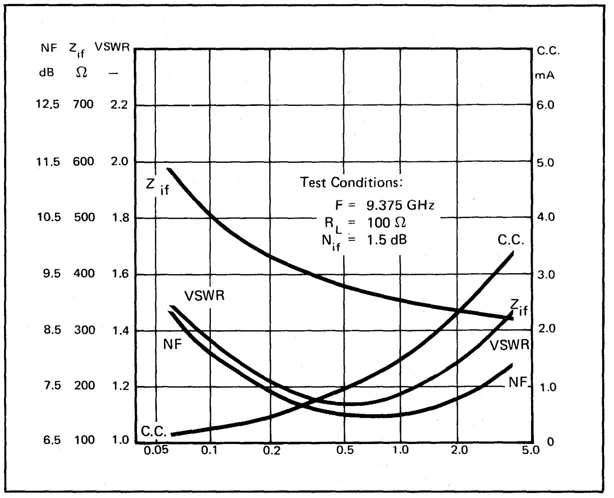


Figure 2. RF Parameters vs Local Oscillator Drive

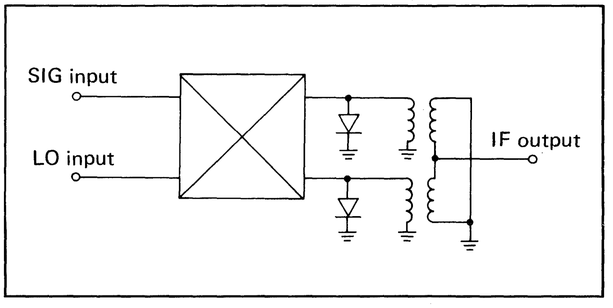


Figure 3. Balanced Mixer Using Diode Pairs With Suffix "M"

FREQUENCY TABLE

Band	Frequencies (GHz)
UHF	Up to 1
L	1 to 2
S	2 to 4
C	4 to 8
X	8.2 to 12.4
Ku	12.4 to 18.0
K	18.0 to 26.5
Ka	26.5 to 40.0

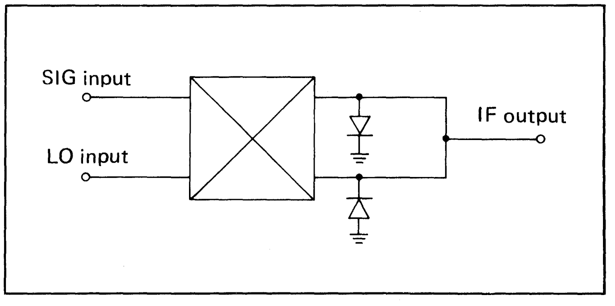


Figure 4. Balanced Mixer Using Diode Pairs With Suffix "MR"

Silicon Point Contact Mixer Diodes

S-Band

Frequency Band	TYPE NUMBER: POLARITY: Forward	POLARITY: Reverse	Reversible	MATCHED PAIRS: Two Forward-Polarity Diodes	MATCHED PAIRS: One Forward, One Reverse-Polarity Diodes	NF(3) dB Max.	Package Outline	ELECTRICAL CHARACTERISTICS: Proof Burnout Ergs	Z_{if} OHMS Min.	Z_{if} OHMS Max.	VSWR Max.	TEST CONDITIONS: Frequency MHz	L.O. Power mW	Holder	Basic Type
S	1N21G	1N21GR		1N21GM	1N21GMR	5.5	005-802	5.0	350	450	1.3	3060	0.5	264-JAN	1N21G
S			1N21WG(1)	1N21WGM(1)	1N21WGMR(1)	5.5	005-801	5.0	350	450	1.3	3060	0.5	264-JAN	1N21WG(1)
S			1N416G	1N416GM	1N416GMR	5.5	005-801	5.0	350	450	1.3	3060	0.5	264-JAN	IN416G
S			DMA5221G	DMA5221GM		5.5	013-001	5.0	300	600	1.6	3060	0.5	P-049	DMA5221G
S			DMA4148G	DMA4148GM	DMA4148GMR	5.5	005-801	10.0	350	450	1.3	3060	0.5	264-JAN	DMA4148G
S	1N21F	1N21FR		1N21FM	1N21FMR	6.0	005-802	5.0	350	450	1.3	3060	0.5	246-JAN	1N21F
S			1N416F	1N416FM	1N416FMR	6.0	005-801	5.0	350	450	1.3	3060	0.5	246-JAN	1N416F
S			1N3655B	1N3655BM	1N3655BMR	6.0	005-801	10.0	350	450	1.3	3060	0.5	264-JAN	1N3655B
S			DMA5221F	DMA5221FM		6.0	013-001	5.0	300	600	1.6	3060	0.5	P-049	DMA5221F
S			1N831C	1N831CM		6.0	062-001	5.0	300(2)	500(2)	–	3060	0.5	P-050	1N831C
S			1N831B	1N831BM		6.5	062-001	5.0	300(2)	500(2)	–	3060	0.5	P-050	1N831B
S			DMA5091A	DMA5091AM		6.5	075-001	5.0	300(2)	500(2)	–	3060	0.5	P-028	DMA5091A
S	1N21E	1N21ER		1N21EM	1N21EMR	7.0	005-802	5.0	350	450	1.3	3060	0.5	264-JAN	1N21E
S			1N21WE(1)	1N21WEM(1)	1N21WEMR(1)	7.0	005-801	5.0	350	450	1.3	3060	0.5	264-JAN	1N21WE(1)
S			1N416E	1N416EM	1N416EMR	7.0	005-801	5.0	350	450	1.3	3060	0.5	264-JAN	1N416E
S			1N831A	1N831AM		7.0	062-001	5.0	300(2)	500(2)	–	3060	0.5	P-050	1N831A
S			1N3655A(1)	1N3655AM(1)	1N3655AMR(1)	7.0	005-801	10.0	350	450	1.3	3060	0.5	264-JAN	1N3655A(1)
S			DMA5091	DMA5091M		7.0	075-001	5.0	300(2)	500(2)	–	3060	0.5	264-JAN	DMA5091
S			DMA5221E	DMA5221EM		7.0	013-001	5.0	300	600	1.8	3060	0.5	P-049	DMA5221E
S	1N21D	1N21DR		1N21DM	1N21DMR	7.3	005-802	5.0	325	425	1.5	3060	0.5	264-JAN	1N21D
S			1N416D	1N416DM	1N416DMR	7.3	005-801	5.0	325	475	1.5	3060	0.5	264-JAN	1N416D
S	1N21C	1N21CR		1N21CM	1N21CMR	8.3	005-802	5.0	300(2)	500(2)	–	3060	0.5	264-JAN	1N21C
S			1N416C	1N416CM	1N416CMR	8.3	005-801	5.0	300(2)	500(2)	–	3060	0.5	264-JAN	1N416C
S			1N831	1N831M		8.3	062-001	5.0	300(2)	500(2)	–	3060	0.5	P-050	1N831
S			1N3655	1N3655M	1N3655MR	8.3	005-801	10.0	300(2)	500(2)	–	3060	0.5	264-JAN	1N3655
S			DMA5221C	DMA5221CM		8.3	013-001	5.0	300	600	2.3	3060	0.5	P-049	DMA5221C
S-X	DMA5632A(4)	DMA5632AR(4)		DMA5632AM	DMA5632AMR	8.0	007-001	1.0	100	200	2.0	3000–12000	1.0	P-009	DMA5632A
S-X	DMA5632(4)	DMA5632R(4)		DMA5632M	DMA5632MR	9.0	007-001	1.0	100	200	2.0	3000–12000	1.0	P-009	DMA5632
S-X	1N1132(1, 4)	1N1132R(1, 4)		1N1132M	1N1132MR	9.5	007-001	1.0	100	200	2.0	3000–12000	1.0	P-009	1N1132(1)

Notes:

1. Available as JAN or single service types which meet all applicable requirements of MIL-S-19500.
2. Nominal range.
3. N_{if} = 1.5 dB.
4. Broadband device.
5. For stripline applications, all diodes in the 062-001 and 075-001 packages are available with flattened leads.
6. These diodes are designed for those applications requiring guaranteed RF burnout resistance. They are direct replacements for the 1N23/1N415 and 1N78 families. They are 100% screened under the following conditions and at the RF burnout level shown in the table.
   t_p = 3 ns min.
   Exposure = 15,000 pulses min.
   R_L = 22 ohms.
7. Maximum operating temperature = 150°C.
8. Calculated noise figure.

Silicon Point Contact Mixer Diodes

X-Band

Frequency Band	TYPE NUMBER: POLARITY: Forward	POLARITY: Reverse	POLARITY: Reversible	MATCHED PAIRS: Two Forward-Polarity Diodes	MATCHED PAIRS: One Forward, One Reverse-Polarity Diodes	NF[3] dB Max.	Package Outline	RF[6] Burnout Level W Min.	ELECTRICAL CHARACTERISTICS: Proof Burnout Ergs	Z_{if} OHMS Min.	Z_{if} OHMS Max.	VSWR Max.	TEST CONDITIONS: Frequency MHz	L.O. Power mW	Holder	Basic Type
X	1N23H	1N23HR		1N23HM	1N23HMR	6.0	005-802	–	2.0	335	465	1.3	9375	1.0	105-JAN	1N23H
X	DMA6497C	DMA6497CR		DMA6497CM	DMA6497CMR	6.0	005-802	20	–	335	465	1.3	9375	1.0	105-JAN	DMA6497C
X			1N415H	1N415HM	1N415HMR	6.0	005-801	–	2.0	335	465	1.3	9375	1.0	105-JAN	1N415H
X			DMA6498C	DMA6498CM	DMA6498CMR	6.0	005-801	20	–	335	465	1.3	9375	1.0	105-JAN	DMA6498C
X	1N23G	1N23GR		1N23GM	1N23GMR	6.5	005-802	–	2.0	335	465	1.3	9375	1.0	105-JAN	1N23G
X	DMA6497B	DMA6497BR		DMA6497BM	DMA6497BMR	6.5	005-802	20	–	335	465	1.3	9375	1.0	105-JAN	DMA6497B
X			1N23Wg	1N23WGM	1N23WGMR	6.5	005-801	–	2.0	335	465	1.3	9375	1.0	105-JAN	1N23WG
X			1N23WG[1]	1N23WGM[1]	1N23WGMR[1]	6.5	005-801	20	–	335	465	1.3	9375	1.0	105-JAN	1N23WG[1]
X			1N415G	1N415GM	1N415GMR	6.5	005-801	–	2.0	335	465	1.3	9375	1.0	105-JAN	1N415G
X			1N832C	1N832CM		6.5	062-001	–	2.0	250[2]	550[2]	–	9375	1.0	P-062	1N832C
X			DMA5092C	DMA5092CM		6.5	075-001	–	2.0	250[2]	550[2]	–	9375	1.0	P-075	DMA5092C
X			DMA5223G	DMA5223GM		6.5	013-001	–	2.0	250	500	1.5	9375	1.0	P-017	DMA5223G
X	DMA6497A	DMA6497AR		DMA6497AM	DMA6497AMR	7.0	005-802	20	–	335	465	1.3	9375	1.0	105-JAN	DMA6497A
X			DMA6498A	DMA6498AM	DMA6498AMR	7.0	005-801	20	–	335	465	1.3	9375	1.0	105-JAN	DMA6498A
X	1N23F	1N23FR		1N23FM	1N23FMR	7.0	005-802	–	2.0	335	465	1.3	9375	1.0	105-JAN	1N23F
X			1N415F	1N415FM	1N415FMR	7.0	005-801	–	2.0	335	465	1.3	9375	1.0	105-JAN	1N415F
X			1N832B	1N832BM		7.0	062-001	–	2.0	250[2]	550[2]	–	9375	1.0	P-062	1N832B
X			DMA5092B	DMA5092BM		7.0	075-001	–	2.0	250[2]	550[2]	–	9375	1.0	P-075	DMA5092B
X			DMA5223F	DMA5223FM		7.0	013-001	–	2.0	250	500	1.6	9375	1.0	P-017	DMA5223F
X	DMA5392B[4]	DMA5392BR[4]		DMA5392BM	DMA5392BMR	7.0	002-001	–	2.0	200	350	1.7	9375	1.0	P-056	DMA5392B
X	1N23E	1N23ER		1N23EM	1N23EMR	7.5	005-802	–	2.0	335	475	1.3	9375	1.0	105-JAN	1N23E
X	DMA6497	DMA6497R		DMA6497M	DMA6497MR	7.5	005-802	20	–	335	465	1.3	9375	1.0	105-JAN	DMA6497
X			1N23WE	1N23WEM	1N23WEMR	7.5	005-801	–	2.0	335	465	1.3	9375	1.0	105-JAN	1N23WE
X			1N23WE[1]	1N23WEM[1]	1N23WEMR[1]	7.5	005-801	20	–	335	465	1.3	9375	1.0	105-JAN	1N23WE[1]
X			1N415E	1N415EM	1N415EMR	7.5	005-801	–	2.0	335	465	1.3	9375	1.0	105-JAN	1N415E
X			1N832A	1N832AM		7.5	062-001	–	2.0	250[2]	550[2]	–	9375	1.0	P-062	1N832A
X			1N3747	1N3747M	1N3747MR	7.5	005-801	–	5.0	335	465	1.3	9375	1.0	105-JAN	1N3747
X			DMA5092A	DMA5092AM		7.5	075-001	–	2.0	250[2]	550[2]	–	9375	1.0	P-075	DMA5092A
X			DMA5223E	DMA5223EM		7.5	013-001	–	2.0	250	500	1.8	9375	1.0	P-017	DMA5223E
X	DMA5392A[4]	DMA5392AR[4]		DMA5392AM	DMA5392AMR	7.5	002-001	–	2.0	200	350	1.8	9375	1.0	P-056	DMA5392A
X	1N23D	1N23DR		1N23DM	1N23DMR	7.8	005-802	–	2.0	350	450	1.3	9375	1.0	105-JAN	1N23D
X			1N415D	1N415DM	1N415DMR	7.8	005-801	–	2.0	350	450	1.3	9375	1.0	105-JAN	1N415D
X	1N149	1N149R		1N149M	1N149MR	8.3	005-802	–	2.0	325	475	–	9375	1.0	105-JAN	1N149
X			1N3746	1N3746M	1N3746MR	8.5	005-801	–	5.0	335	465	1.3	9375	1.0	105-JAN	1N3746
X	DMA5392	DMA5392R[4]		DMA5392M	DMA5392MR	8.5	002-001	–	2.0	200	350	–	9375	1.0	P-056	DMA5392
X	1N23C	1N23CR		1N23CM	1N23CMR	9.5	005-802	–	2.0	325	475	1.5	9375	1.0	105-JAN	1N23C
X			1N415C	1N415CM	1N415CMR	9.5	005-801	–	2.0	325	475	1.5	9375	1.0	105-JAN	1N415C
X			1N832	1N832M		9.5	062-001	–	2.0	250[2]	550[2]	–	9375	1.0	P-062	1N832
X	1N2510	1N2510R		1N2510M	1N2510MR	9.5	002-001	–	2.0	300[2]	500[2]	–	10000	1.0	P-005	1N2510
X			1N3745	1N3745M	1N3745MR	9.5	005-801	–	5.0	325	475	1.5	9375	1.0	105-JAN	1N3745
X			DMA5092	DMA5092M		9.5	075-001	–	2.0	250[2]	550[2]	–	9375	1.0	P-075	DMA5092
X			DMA5223C	DMA5223CM		9.5	013-001	–	2.0	250	500	2.3	9375	1.0	P-017	DMA5223C

Silicon Point Contact Mixer Diodes

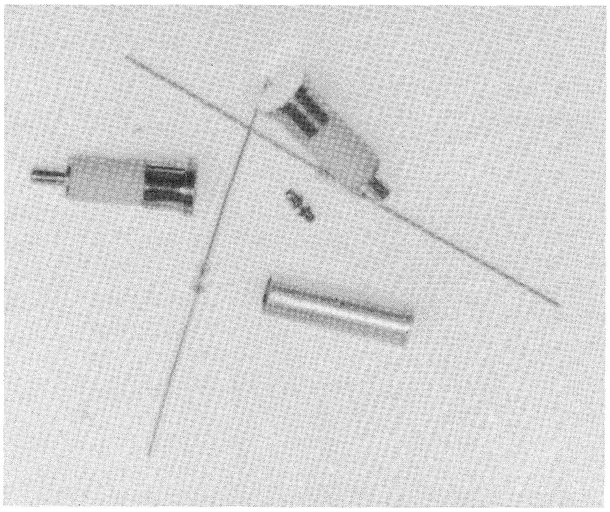
Ku, K, Ka-Band

Frequency Band	TYPE NUMBER — POLARITY — Forward	Reverse	Reversible	MATCHED PAIRS — Two Forward-Polarity Diodes	One Forward, One Reverse-Polarity Diodes	NF[3] dB Max.	Package Outline	RF[6] Burnout Level W Min.	ELECTRICAL CHARACTERISTICS — Proof Burnout Ergs	Z_{if} OHMS Min.	Z_{if} OHMS Max.	VSWR Max.	TEST CONDITIONS — Frequency MHz	L.O. Power mW	Holder	Basic Type
Ku	1N78G	1N78GR		1N78GM	1N78GMR	7.0	002-001	–	1.0	400	565	1.5	16000	1.0	201-JAN	1N78G
Ku	DMA5282G[4]	DMA5282GR[4]		DMA5282GM	DMA5282GMR	7.0	002-001	–	1.0	400	565	1.5	16000	1.0	201-JAN	DMA5282G
Ku	1N78F	1N78FR		1N78FM	1N78FMR	7.5	002-001	–	1.0	400	565	1.5	1600	1.0	201-JAN	1N78F
Ku	1N78F[1]	1N78FR[1]		1N78FM[1]	1N78FMR[1]	7.5	002-001	10	–	400	565	1.5	16000	1.0	201-JAN	1N78F[1]
Ku	DMA6499B	DMA6499BR		DMA6499BM	DMA6499BMR	7.5	002-001	10	–	400	565	1.5	16000	1.0	201-JAN	DMA6499B
Ku	DMA5282F[4]	DMA5282FR[4]		DMA5282FM	DMA5282FMR	7.5	002-001	–	1.0	400	565	1.5	16000	1.0	201-JAN	DMA5282F
Ku	1N78E	1N78ER		1N78EM	1N78EMR	8.0	002-001	–	1.0	400	565	1.5	16000	1.0	201-JAN	1N78E
Ku	1N4605[4]	1N4605R[4]		1N4605M	1N4605MR	8.0	002-001	–	1.0	400	565	1.5	1600	1.0	201-JAN	1N4605
Ku			DMA5278E	DMA5278EM		8.0	013-001	–	1.0	–	–	–	16000	1.0	P-041	DMA5278E
Ku	DMA6499A	DMA6499AR		DMA6499AM	DMA6499AMR	8.0	002-001	10	–	400	565	1.5	16000	1.0	201-JAN	DMA6499A
Ku	1N78D	1N78DR		1N78DM	1N78DMR	8.8	002-001	–	1.0	400	565	1.5	16000	1.0	201-JAN	1N78D
Ku	1N4604[4]	1N4604R[4]		1N4604M	1N4604MR	8.8	002-001	–	1.0	400	565	1.5	16000	1.0	201-JAN	1N4604
Ku			DMA5278D	DMA5278DM		8.8	013-001	–	1.0	–	–	–	16000	1.0	P-041	DMA5278D
Ku	DMA6499	DMA6499R		DMA6499M	DMA6499MR	8.8	002-001	10	–	400	565	1.5	16000	1.0	201-JAN	DMA-6499
Ku	1N78C	1N78CR		1N78CM	1N78CMR	9.5	002-001	–	1.0	400	565	1.5	16000	1.0	201-JAN	1N78C
Ku	1N78C[1]	1N78CR[1]		1N78CM[1]	1N78CMR[1]	9.5	002-001	10	–	400	565	1.5	16000	1.0	201-JAN	1N78C[1]
Ku	1N4603[4]	1N4603R[4]		1N4603M	1N4603MR	9.5	002-001	–	1.0	365	565	1.5	16000	1.0	201-JAN	1N4603
Ku			DMA5278C	DMA5278CM		9.5	013-001	–	1.0	–	–	–	16000	1.0	P-041	DMA5278C
Ku	1N3205	1N3205R		1N3205M	1N3205MR	9.8	002-001	–	1.0	365	565	1.6	16000	1.0	201-JAN	1N3205
Ku	1N78B	1N78BR		1N78BM	1N78BMR	10.0	002-001	–	1.0	365	565	1.6	16000	1.0	201-JAN	1N78B
Ku			DMA5278B	DMA5278BM		10.0	013-001	–	1.0	–	–	–	16000	1.0	P-041	DMA5278B
K	DMA5326B[4]	DMA5326BR[4]		DMA5326BM	DMA5326BMR	9.0	002-001	–	0.3	400	600	1.5	23984	1.0	107-JAN	DMA5326B
K	1N26C	1N26CR		1N26CM	1N26CMR	9.5	002-001	–	0.3	400	600	1.5	23984	1.0	107-JAN	1N26C
K	DMA5326A[4]	DMA5326AR[4]		DMA5326AM	DMA5326AMR	10.0	002-001	–	0.3	400	600	1.5	23984	1.0	107-JAN	DMA5326A
K	1N26B[1]	1N26BR[1]		1N26BM[1]	1N26BMR[1]	11.0	002-001	–	0.3	400	600	1.5	23984	1.0	107-JAN	1N26B[1]
K	DMA5326[4]	DMA5326R[4]		DMA5326M	DMA5326MR	11.0	002-001	–	0.3	400	600	1.5	23984	1.0	107-JAN	DMA5326
K	1N26A	1N26AR		1N26AM	1N26AMR	11.3	002-001	–	0.3	300	600	1.6	23984	1.0	107-JAN	1N26A
K	1N26	1N26R		1N26M	1N26MR	13.1	002-001	–	0.3	300	600	–	23984	1.0	107-JAN	1N26
Ka			DMA5253E	DMA5253EM		7.0[8]	013-001	–	0.1	–	–	–	34860	1.0	P-041	DMA5253E
Ka	DMA5353F[4]	DMA5353FR[4]		DMA5353FM	DMA5353FMR	7.0[8]	003-001	–	0.1	400	800	1.6	34860	1.0	174-JAN	DMA5353F
Ka	DMA5353E[4]	DMA5353ER[4]		DMA5353EM	DMA5353EMR	7.5[8]	003-001	–	0.1	400	800	1.6	34860	1.0	174-JAN	DMA5353E
Ka	DMA5353D[4]	DMA5353DR[4]		DMA5353DM	DMA5353DMR	8.0[8]	003-001	–	0.1	400	800	1.6	34860	1.0	174-JAN	DMA5353D
Ka			DMA5253D	DMA5253DM		8.0[8]	013-001	–	0.1	–	–	–	34860	1.0	P-041	DMA5253D
Ka	1N53D	1N53DR		1N53DM	1N53DMR	9.0[8]	003-001	–	0.1	400	800	1.6	34860	1.0	174-JAN	1N53D
Ka	DMA5353C[4]	DMA5353CR[4]		DMA5353CM	DMA5353CMR	9.0[8]	003-001	–	0.1	400	800	1.6	34860	1.0	174-JAN	DMA5353C
Ka			DMA5253C	DMA5253CM		9.0[8]	013-001	–	0.1	–	–	–	34860	1.0	P-041	DMA5253C
Ka	1N53B	1N53BR		1N53BM	1N53BMR	10.0[8]	003-001		0.1	400	800	1.6	34860	1.0	174-JAN	1N53B
Ka	1N53B[1]	1N53BR[1]		1N53BM[1]	1N53BMR[1]	10.0[8]	003-001	–	0.1	500	700	1.6	34860	1.0	174-JAN	1N53B[1]
Ka	DMA5353B[4]	DMA5353BR[4]		DMA5353BM	DMA5353BMR	10.0[8]	003-001	–	0.1	400	800	1.6	34860	1.0	174-JAN	DMA5353B
Ka			DMA5253B	DMA5253BM		10.0[8]	013-001	–	0.1	–	–	–	34860	1.0	P-041	DMA5253B
Ka	1N53A	1N53AR		1N53AM	1N53AMR	11.1[8]	003-001	–	0.1	400	800	1.6	34860	1.0	174-JAN	1N53A
Ka	1N53	1N53R		1N53M	1N53MR	13.1[8]	003-001	–	0.1	400	800	1.6	34860	1.0	174-JAN	1N53

Notes:
1. Available as JAN or single service types which meet all applicable requirements of MIL-S-19500.
2. Nominal range.
3. N_{if} = 1.5 dB.
4. Broadband device.
5. For stripline applications, all diodes in the 062-001 and 075-001 packages are availabe with flattened leads.
6. These diodes are designed for those applications requiring guaranteed RF burnout resistance. They are direct replacements for the 1N23/1N415 and 1N78 families. They are 100% screened under the following conditions and at the RF burnout level shown in the table.
   t_p = 3 ns min.
   Exposure = 15,000 pulses min.
   R_L = 22 ohms.
7. Maximum operating temperature = 150°C.
8. Calculated noise figure.

CAUTION
SENSITIVE ELECTRONIC DEVICES

Silicon Point Contact Detector Diodes



Features

- Broadband Operation
- Bias Not Required

Description

Alpha's point contact detector diodes are designed for applications through mm-band (60.0 GHz). These diodes employ epitaxial silicon optimized for high tangential signal sensitivity. Since they are point contact diodes, they are efficient detectors not requiring the use of bias.

They are available in a variety of packages, which make them suitable for use in waveguide, coaxial and stripline applications.

Applications

These diodes are categorized by TSS (Tangential Signal Sensitivity) for detector applications in eight frequency ranges: L, S, X, Ku, K, Ka, and mm-bands. TSS is the one parameter that best describes a diode's use as a video detector. It is defined as the amount of signal power, below a one milliwatt reference level, required to produce an output pulse whose amplitude is sufficient to raise the noise fluctuations by an amount equal to the average noise level. TSS is approximately 4 dB above the Minimum Detectable Signal.

Since the point contact diode has a turn-on voltage of essentially zero, it exhibits a typical video impedance of 10 K ohms without the use of bias and is an efficient detector under these conditions. The use of a small forward bias will increase sensitivity and greatly reduce parameter variation due to temperature change. Video impedance is a direct function of bias and closely follows the 28/I (mA) relationship. This is important to pulse fidelity, since the video impedance in conjunction with the detector output capacitance and video amplifier input capacitance affects the effective amplifier bandwidth. Bias does, however, increase noise, particularly in the 1/f region. Therefore, it should be kept at as low a level as possible (typically 5–50 microamps).

Matched Pairs

Matched pairs of detector diodes are used when near equal sensitivities are required. This is achieved by matching the voltage outputs at a point in the square law region.

The voltage outputs are matched within 1 dB as follows:

$$\triangle dB = 10 \log \frac{M1}{M2} = 1 \text{ dB}$$

where M1 is the higher Figure of Merit of the two diodes.

The video impedances are also matched:

$\triangle Z_V = 20\%$ Max.

Custom matching may be performed to other tolerances or as a function of frequency, power level and load resistance.

Silicon Point Contact Detector Diodes

	Type Number			Electrical Characteristics					Test Conditions		
	Polarity					Zv K ohms					
Frequency Band	Forward	Reverse	Reversible	TSS(3) –dBm Min.	FM Min.	Min.	Max.	Package Outline	Frequency MHz	Holder	Basic Type
UHF			1N830		Efficiency 65% min.			062-001	100		1N830
UHF			1N830A(4)		Efficiency 65% min. BV = 5.0 Vmin.			062-001	100		1N830A
UHF			DDA5090		Efficiency 65% min.			075-001	100		DDA5090
UHF			DDA5090A		Efficiency 65% min. BV = 5.0 V min.			075-001	100		DDA5090A
L-X	1N358(4)	1N358R(4)		40	15	4.5	18.0	007-001	1000-12400	P-009	1N358
L-X	1N358A(4)	1N358AR(4)		45	30	4.5	18.0	007-001	1000-12400	P-009	1N358A
L-X	DDA5638	DDA5638R		45	30	4.5	18.0	007-001	1000-12400	P-009	DDA5638
X			1N833	40	15	4.5	18.0	062-001	9375	105-JAN	1N833
X			DDA5093	40	15	4.5	18.0	075-001	9375	105-JAN	DDA5093
X			DDA5233	40	15	4.5	18.0	013-001	8375	P-017	DDA5233
			DDA6797 See Note 5 below			—	10.0	013-001			DDA6797
X			1N833A	45	30	4.5	18.0	062-001	9375	105-JAN	1N833A
X			DDA5093A	45	30	4.5	18.0	075-001	9375	105-JAN	DDA5093A
X	1N1611	1N1611R		51(2)	130(2)	0.6(2)	0.8(2)	005-802	9000	P-007	1N1611
X			DDA4072	51(2)	130(2)	0.6(2)	0.8(2)	005-801	9000	P-007	DDA4072
X	1N1611A	1N1611AR		53(2)	220(2)	0.6(2)	0.8(2)	005-802	9000	P-007	1N1611A
X			DDA4072A	53(2)	220(2)	0.6(2)	0.8(2)	005-801	9000	P-007	DDA4072A
X	1N1611B	1N1611BR		53(2)	220(2)	0.6(2)	0.8(2)	005-802	9000	P-007	1N1611B
X			DDA4072B	53(2)	220(2)	0.6(2)	0.8(2)	005-801	9000	P-007	DDA4072B
X			DDA5012	53(2)	220(2)	0.6(2)	0.8(2)	062-001	9000	105-JAN	DDA5012
X			DDA5036	53(2)	220(2)	0.6(2)	0.8(2)	075-001	9000	105-JAN	DDA5036
X			DDA5236	53(2)	220(2)	0.6(2)	0.8(2)	013-001	9000	P-017	DDA5236

Notes:
1. Maximum operating temperature = 150°C.
2. With 50μA bias.
3. Bandwidth = 10 MHz.
4. Available as JAN or single service types which meet all applicable requirements of MIL-S-19500.
5. This diode has a high self resonant frequency and is specifically designed for broadband, flat detector applications up to 18GHz.
6. Diodes are available in other configurations, consult factory with your specific requirements.
7. Diodes can be supplied with TX type screening. Details of recommended screening procedures will be supplied on request.
8. For stripline applications, all diodes in the 062-001 and 075-001 packages are available with flattened leads.

	Type Number			Electrical Characteristics			Test Conditions		
	Polarity								
Frequency Band	Forward(9)	Reverse	Reversible	TSS(10) –dBm Min.	Video Sensitivity(12) mv/mw Min.	Package Outline	Frequency Range GHz	Holder	Basic Type
Ku	DDA5360	DDA5360R		58(11)	500	002-001	12.0–18.0	Optimized	DDA5360
K	DDA5361	DDA5361R		58(11)	450	002-001	18.0–26.5	Optimized	DDA5361
K			DDA5362	58(11)	450	013-001	18.0–26.5	Optimized	DDA5362
Ka	DDA5363	DDA5363R		55(11)	400	003-001	26.5–40.0	Optimized	DDA5363
Ka			DDA5364	55(11)	400	013-001	26.5–40.0	Optimized	DDA5364
mm	DDA5365	DDA5365R		50(11)	200	003-001	33.0–50.0	Optimized	DDA5365
mm			DDA5366	50(11)	200	013-001	33.0–50.0	Optimized	DDA5366
mm(14)	DDA5367	DDA5367R		45(11)	200(13)	003-001(14)	40.0–60.0	Optimized	DDA5367
mm			DDA5368	50(11)	200(13)	013-001	40.0–60.0	Optimized	DDA5368

Notes:
9. Positive Output (Negative Output available using reverse type).
10. Measured at a 40 Hz video bandwidth.
11. Increased TSS levels of up to 10 dBm attainable with 10μA bias.
12. Measured with a 1 megohm video load.
13. To 55 GHz, 100 mv/mw to 60 GHz.
14. Package type usable up to 100 GHz with reduced performance characteristics.

CAUTION

SENSITIVE ELECTRONIC DEVICES

Typical X-Band Detector Diode

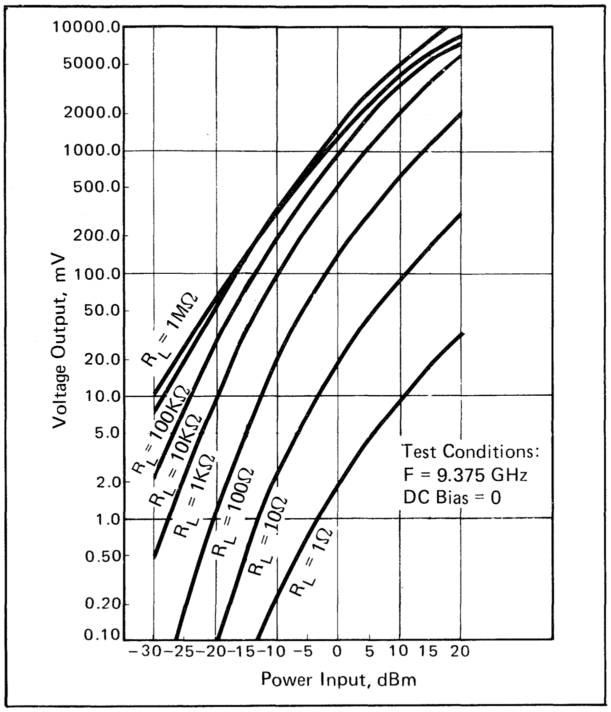


Figure 1a. Voltage Output vs Power Input as a Function of Load Resistance

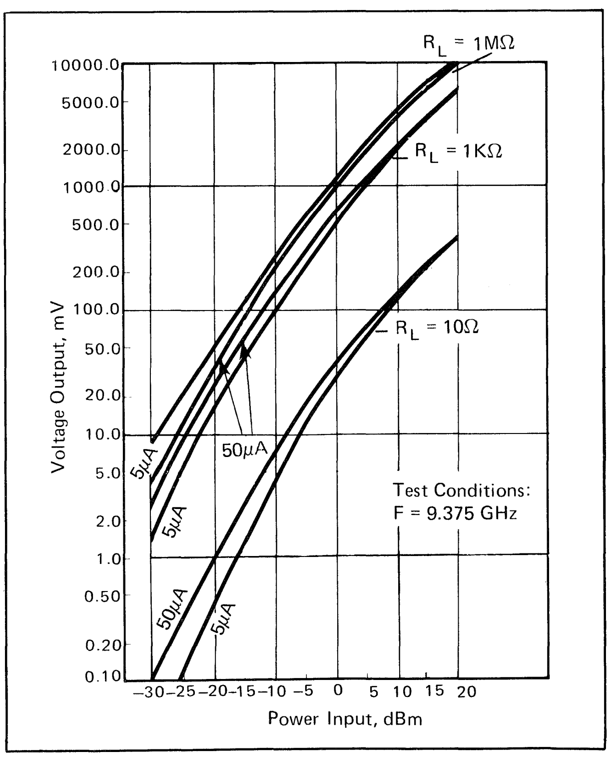


Figure 1b. Voltage Output vs Power Input as a Function of Load Resistance and Bias

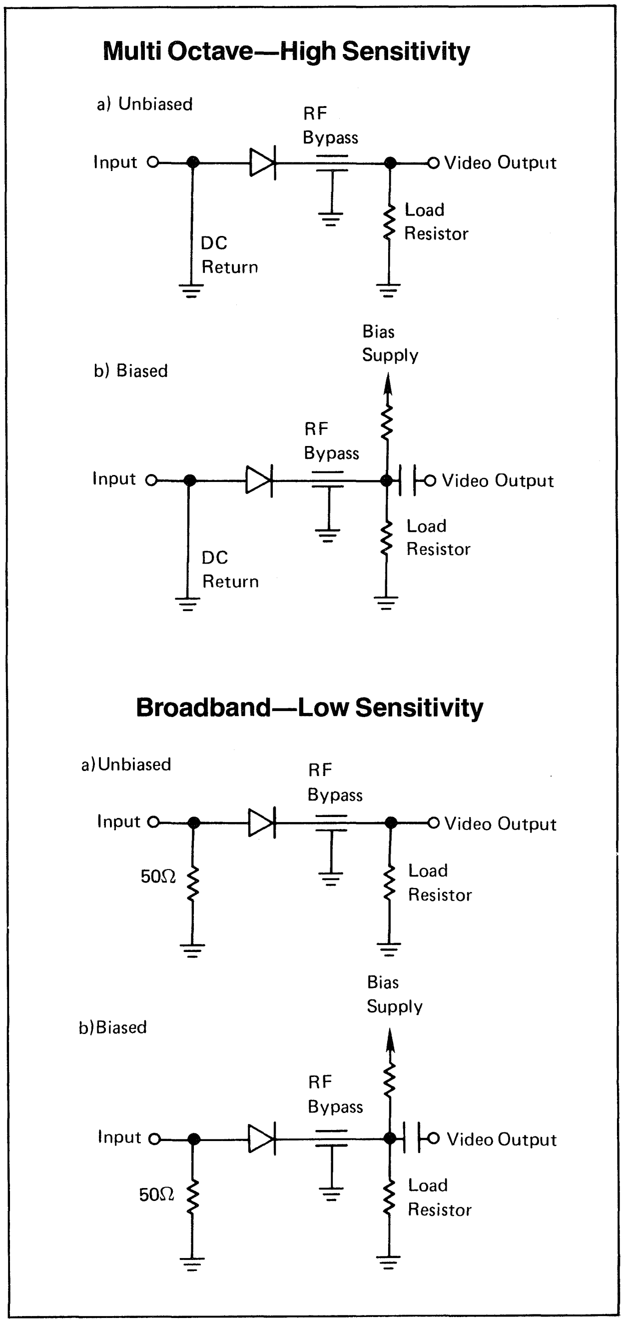


Figure 2. Typical Video Detector Circuits

Band	Frequencies (GHz)
UHF	Up to 1
L	1 to 2
S	2 to 4
C	4 to 8
X	8.2 to 12.4
Ku	12.4 to 18.0
K	18.0 to 26.5
Ka	26.5 to 40.0
mm	40.0 to 100.0

Application Note 80800: Mixer and Detector Diodes

I. Introduction: Surface Barrier Diodes

Most people who use diodes are more familiar with junction devices than with the surface barrier diodes commonly used in mixer and detector circuits. In a junction diode the rectifying junction is formed by contact between a p-type region and an n-type region of a semiconductor. In a surface barrier diode the rectifying junction is formed by contact between a metal and the semiconductor, which may be either n-type or p-type.

Two basic types of surface barrier devices are manufactured for use as microwave mixer and detector diodes — "point contact" and "Schottky barrier" ("hot carrier") devices. The physics of operation of both types is the same, the difference being in their construction. In the case of the Schottky barrier type of diode the barrier metal is brought into contact with the semiconductor as part of the chip fabrication process, whereas in the point contact type of construction the barrier metal is the pointed end of a whisker, which is brought into contact with the semiconductor chip (usually p-type epitaxial silicon) during final assembly of the device. Both constructions result in high quality microwave mixer diodes with excellent noise figures. The Schottky barrier type is available with a wider range of electrical properties and package types for more advanced circuits. In this application note we go into the details of the physics, construction, and applications of Schottky diodes. Much of this applies to point contact diodes as well.

II. Types of Construction

Schottky diodes can be divided into five main classifications, depending on package and chip construction. They are also available from Alpha in two semiconductor materials — silicon and gallium arsenide. Silicon Schottky diodes are available in either p-type or n-type polarity.

The major classifications are:

PRESSURE CONTACT

(This is also used for point contact diodes.) The Schottky chip has a close array of identical junctions. During construction a tungsten or molybdenum whisker is brought into contact with one of the metal pads on the chip and held in place by pressure. The whisker provides the required inductance when self-resonant operation is needed; for example, in high output detector applications. Examples are package styles 005 and 075 shown in Figs. 2-1 and 2-2:

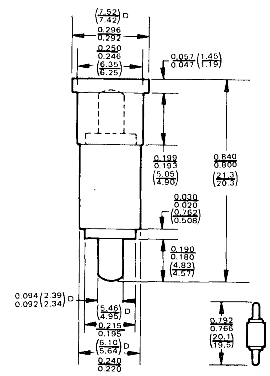


Figure 2-1

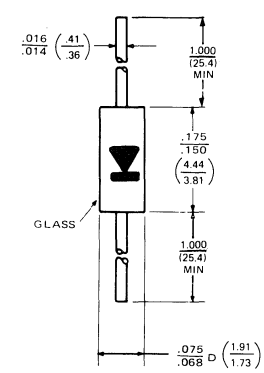
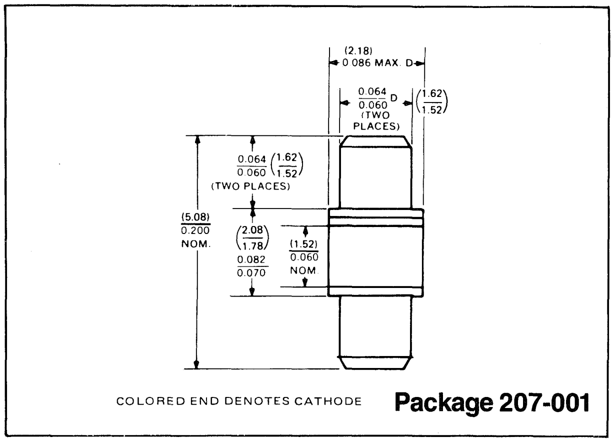


Figure 2-2

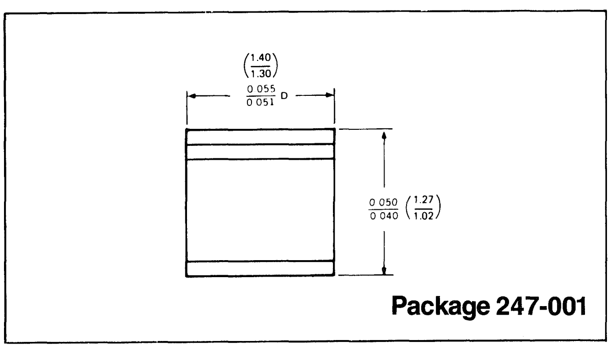
BONDED CONTACT

This construction features a gold wire bonded from the rim of the package to a bonding pad on the chip and then to the rim opposite the first bond. A cap is then soldered to this rim thus completing the assembly and resulting in a hermetic diode with lower inductance and better mechanical ruggedness than its pressure contact counterpart. Package styles 207 and 247 are of this construction (Figs. 2-3 and 2-4):



Package 207-001

Figure 2-3

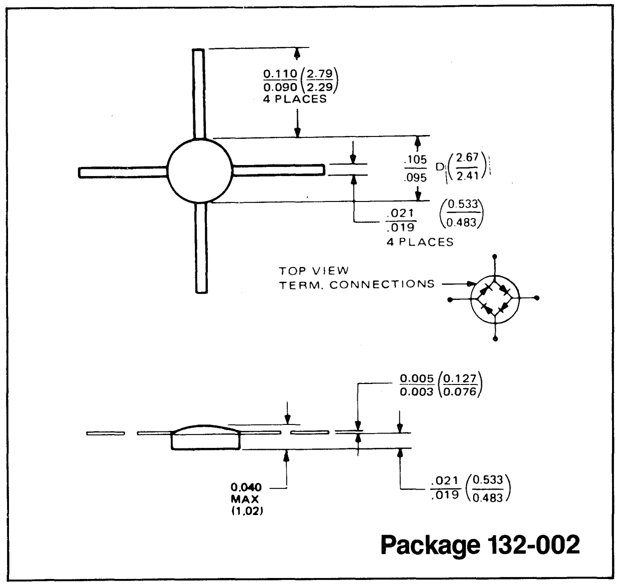


Package 247-001

Figure 2-4

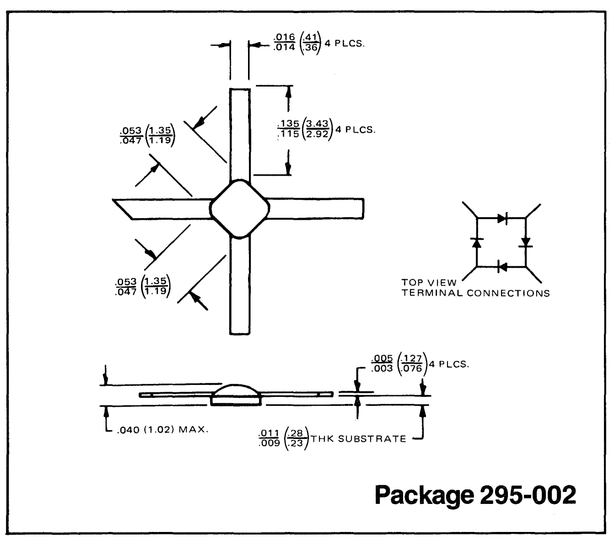
MOUNTED BEAM-LEAD

In this type, one or more beam-lead Schottky diodes with coplanar leads are bonded onto a ceramic, fiberglass, or plastic substrate. This construction is mechanically rugged, has very low inductance, and is particularly convenient for double-balanced mixers. For example, package styles 132, 295 and 364 (Figures 2-5, 2-6, and 2-7):



Package 132-002

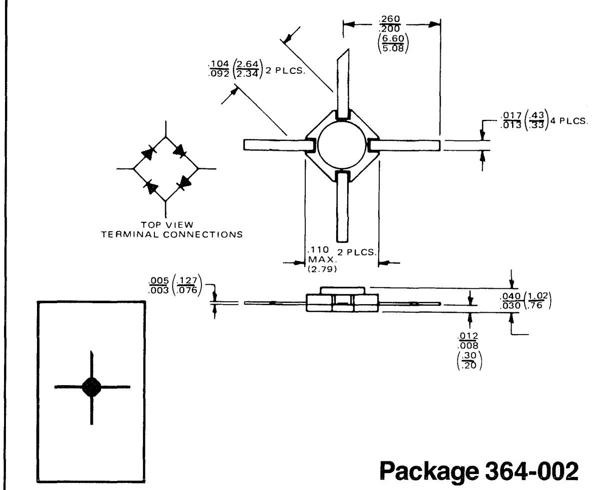
Figure 2-5



Package 295-002

Figure 2-6

Application Note 80800: Mixer and Detector Diodes



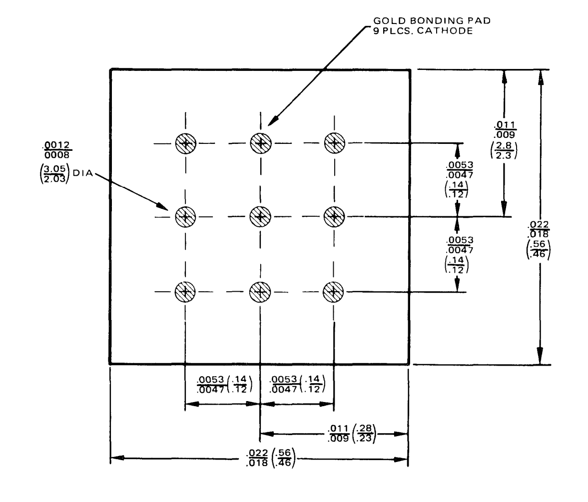
Package 364-002

Figure 2-7

UNMOUNTED CHIP

For those who prefer to use chips, they are available in several different sizes and bonding pad arrays. For example, chip style 270-804 (Fig. 2-8):

Note: Millimeters in parentheses.

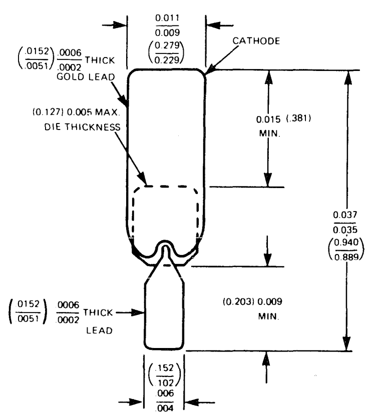


Chip 270-804

Figure 2-8

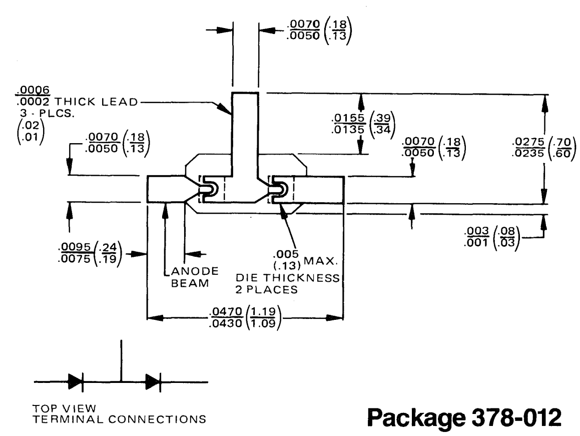
UNMOUNTED BEAM-LEAD DIODES

For use in MIC circuits or other special constructions, where minimum inductance or minimum size are important. Available as single diodes (174), pairs (378), and quads (294), and other monolithic arrangements (Figs. 2-9, 2-10, and 2-11):



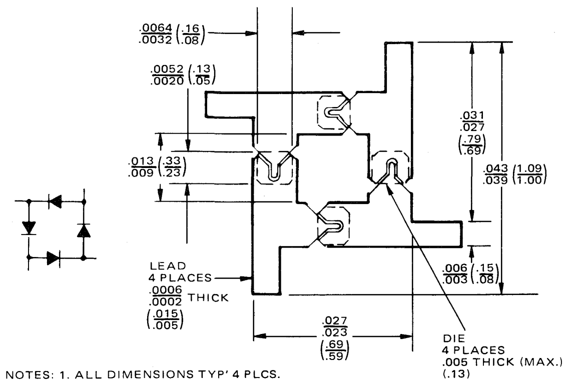
Package 174-001

Figure 2-9



Package 378-012

Figure 2-10



Package 294-003

Figure 2-11

III. Low Frequency and RF Parameters of Schottky Diodes

MIXER DIODES COMPARED TO DETECTOR DIODES

Mixer diodes are designed to convert radio frequency (RF) energy to an intermediate frequency (IF) as efficiently as possible. (In practice, the conversion efficiency should be at least 20%). The reason for doing this is that selective amplifiers at the RF frequency are expensive, so the signal is converted to a lower frequency where high gain and good selectivity can be more easily achieved.

The frequency conversion is obtained by operating a diode with fast response and high cutoff frequency as a switch, turning it on and off at a rate determined by a local oscillator (LO). The output frequency (IF) is then the difference between the LO frequency and the RF frequency.

A good mixer diode with a high cutoff frequency will be capable of low conversion loss (L_C). This, combined with a low noise figure in the IF amplifier, will result in a low overall noise figure, unless the diode itself generates noise (other than normal thermal noise). Ideally, the mixer diode should accomplish this with a minimum of LO power and no DC bias.

Detector diodes are designed to rectify very low levels of RF power to produce a DC output voltage proportional to the RF power. The diode may be operated at a small DC bias (typically 50 µA) which results in a relatively high RF impedance (typically 600Ω). As a result, very low capacitance is required to achieve high sensitivity. Since the output is at a very low level, the low frequency, audio frequency excess noise ("1/f noise") is an important consideration.

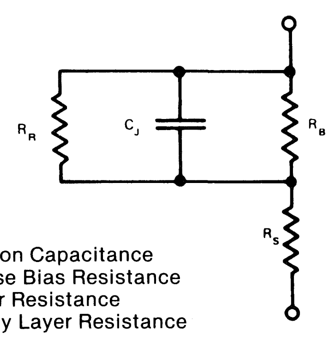
SMALL SIGNAL IMPEDANCE

Chip Equivalent Circuit

The small signal impedance of a Schottky diode chip can be obtained directly from low frequency measurements, if you take into account the physical locations of the various elements.

The relationship between the small signal parameters and the physics of the semiconductor barrier is discussed in the Appendix. In particular, equation (A-2) gives the I-V characteristic, equations (A-9) and (A-10) give the small signal resistances for forward and reverse bias, and equation (A-15) gives the C-V characteristic. These form the basis for the following microwave equivalent circuit for the diode.

The depletion layer, with a low current flowing across it, acts as a parallel RC circuit and the epitaxial layer acts as a series resistor, R_S. Therefore, the chip can be represented by the equivalent circuit shown in Figure 3-1:



C_J = Junction Capacitance
R_R = Reverse Bias Resistance
R_B = Barrier Resistance
R_S = Epitaxy Layer Resistance

Figure 3-1. Chip Equivalent Circuit

where,

$$R_B = \frac{28}{I + I_S} \qquad (I \text{ in mA})$$

$$C_J = \frac{C_{BO}}{\sqrt{1 - \frac{V}{\phi_C}}} + C_O \qquad (3\text{-}1)$$

$$R_R = \frac{V_B}{KI_S}$$

The admittance of this circuit is

$$Y = \frac{1}{Z} = \frac{1}{R_S + \cfrac{1}{j\omega C_J + \cfrac{1}{R_B} + \cfrac{1}{R_R}}} \qquad (3\text{-}2)$$

This can be written in terms of its real and imaginary parts, but the results are complicated. Diodes are usually used under special conditions that simplify the equations. First, they are chosen to have a cutoff frequency that is usually 10 times higher than the operating frequency.

$$f_C = \frac{1}{2\pi R_S C_J} > 10\,f \qquad (3\text{-}3)$$

or $\omega R_S C_J < .1\ R_S C_J$

so terms involving $\omega^2 R_S^2 C_J^2$ can be eliminated.

Second, mixer diodes spend most of the time either heavily forward biased ($I_F > 5mA$, so $R_B < R_S$) or reverse biased ($R_B \rightarrow \infty$) with very little time in between. Only the admittance of the diode at the extremes needs to be known. Detector diodes, on the other hand, are operated at low bias current, typically $< 50\ \mu A$, so $R_B >> R_S$.

Therefore, the important cases are:

Heavy forward bias (mixer):

$$Y \cong \frac{1}{R_B + R_S} + j\omega C_J \left(\frac{R_B}{R_S}\right)^2 \qquad (3\text{-}4)$$

Reverse bias (mixer):

$$Y = \frac{1}{R_R} + \frac{R_S}{X_C^2} + j\omega C_J \qquad (3\text{-}5)$$

Low forward bias (detector):

$$Y = \frac{1}{R_B} \mp \frac{R_S}{X_C^2} + j\omega C_J \qquad (3\text{-}6)$$

Packaged Diode Equivalent Circuit

The package has the same effect in the case of a mixer diode as it does in the case of a junction diode. The package is represented by an inductance and a capacitance (Fig. 3-2).

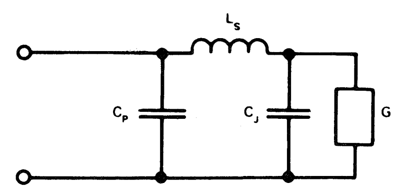


Figure 3-2. Packaged Diode Equivalent Circuit

Here, C_P is the capacitance of the ceramic, glass, or plastic insulator; L_S is the inductance due to the package, bond wires, and mounting pedestal; and C_J is the junction capacitance.

It is useful to consider C_J (together with the package elements) as part of a low-pass matching network that couples the real part of the chip admittance to the circuit.

$$G \cong \begin{cases} \dfrac{1}{R_S + R_B} & \text{for heavy forward bias} \\ \dfrac{1}{R_R} + \dfrac{R_S}{X_C^2} & \text{for reverse bias} \\ \dfrac{1}{R_B} + \dfrac{R_S}{X_C^2} & \text{for low forward bias} \end{cases} \qquad (3\text{-}7)$$

The low pass filter consisting of C_P, L_P, and C_J, transforms the line impedance Z_0 to another value, Z'_0, which can be calculated by standard circuit analysis techniques.

Application Note 80800: Mixer and Detector Diodes

The following table lists C_P and L_P for some standard single diode packages.

Package	C_P (pF)	L_P (nH)
005–801	.15	2.0
013–001	.12	0.8
075–001	.04	1.0
130–011	.10*	0.6
173–001	.15	0.6
207–001	.13	0.6
247–001	.15	0.3
295–011	.06	0.5
325–011	.14	0.6
364–011	.08	0.5
404–011	.09	0.5

*Can be .04 pF less if no epoxy is used.

MIXER PARAMETERS

The quality of a mixer diode is generally controlled by either low frequency parameters or RF operating parameters.

Low frequency parameters customarily specified are (in order of importance):

Junction Capacitance	(C_{J0}) at zero bias
Series Resistance	(R_S) or cutoff frequency (f_{CO})
Reverse Voltage	(V_B) at 10 µA or 100 µA
Forward Voltage	(V_F) at 1 mA
Excess Noise Voltage	(1/f noise)

Reverse resistance, R_B, does not strongly affect the diode's RF impedance, and is not usually specified. For the same reason, leakage current is not usually specified. Series resistance is sometimes controlled by specifying dynamic resistance, R_T, at some particular forward current, such as 10 mA. The excess noise voltage need not be specified unless the IF frequency is less than 1.0 MHz (such as for doppler radars or autodyne mixers).

Some people prefer to specify RF parameters *instead* of the above low frequency parameters. In order of importance, the customary parameters are:

Noise Figure (NF in dB)	specified in a particular mixer circuit at a particular RF frequency and LO power level.
Conversion Loss (L_C in dB)	specified in a particular mixer circuit at a particular RF frequency and LO power level.
RF Impedance (VSWR)	expresses how well the diode and circuit are matched to the LO source at a particular LO power.
IF Impedance (Z_{if})	expresses the low frequency impedance of the driven diode, considered as a source of IF voltage. The IF amplifier should be designed to have its optimum noise figure for this source impedance. This parameter is dependent on LO power, as well as RF and harmonic impedance presented to the diode.

DETECTOR PARAMETERS

As with mixers, a detector diode can be specified by its low frequency parameters, the same ones that apply to the mixer diodes, with the exception that 1/f noise is now second in importance instead of fifth.

Alternatively, the diode can be specified by RF parameters, the customary ones being:

Voltage Sensitivity (V/mW)	the ratio of DC voltage output to RF power input at a particular frequency and power level. Depends on bias current and C_{J0}.
Tangential Signal Sensitivity (TSS, in – dBm)	the minimum RF signal level, in dB below 1 mW, that produces a tangential indication on a low frequency oscilloscope. See Figure 3-3:

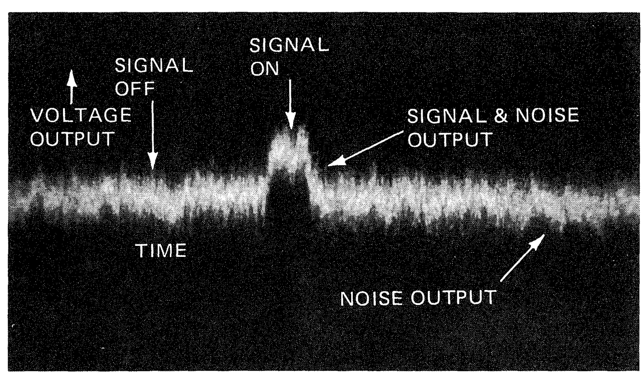


Figure 3-3. Measurement of Tangential Signal Sensitivity

Application Note 80800: Mixer and Detector Diodes

(Tangential sensitivity depends on voltage sensitivity, diode excess noise voltage, and both RF and video bandwidth).

Video Impedance (Z_V, in ohms)	the low frequency impedance of the diode, considered as a source of audio-frequency voltage. It is the same as R_T at the bias current used (about 600 Ω for any diode with 50 μA bias).
Figure of Merit (FM)	This parameter combines voltage output and Z_V to give a convenient bandwidth-independent measure of TSS.

IV. Mixers and Mixer Diodes

THEORY OF MIXERS

The simplest way to think about the action of a mixer diode is to consider a single ended mixer consisting of a single diode at the end of a transmission line. The RF signal and the local oscillator drive power are coupled into the same line by filters or hybrids. The local oscillator drives the diode into heavy forward conduction for nearly half a cycle and into reverse bias for the other half cycle. The reflection coefficient of the diode, Γ, then varies periodically as a function of time.

In this model, the only effect of the junction capacitance and package parasitics is to transform the source impedance from its actual value to some other number, Z'_0, at the semiconductor junction. If the instantaneous junction conductance is G(t), then you have the situation indicated in Figure 4-1:

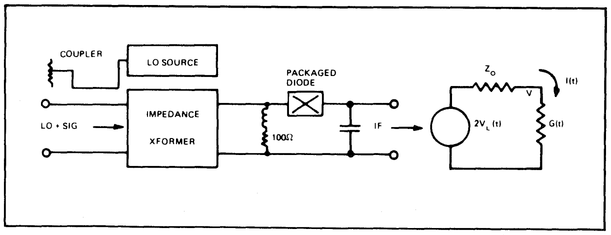


Figure 4-1. Mixer and Equivalent Circuit

For available LO power, P_L, the generator voltage is:

$$2V_L(t) = 2V_L \cos \omega_L t \tag{4-1}$$

where $V_L = \sqrt{2Z'_0 P_L}$

DIODE I-V APPROXIMATION

The forward diode characteristic is given by the equation

$$I(t) = I_S \exp[(V(t) - IR_S)/.028] \tag{4-2}$$

This equation can be approximated by a two-piece linear approximation, which has the diode conducting only if the voltage exceeds a forward voltage, V_F:

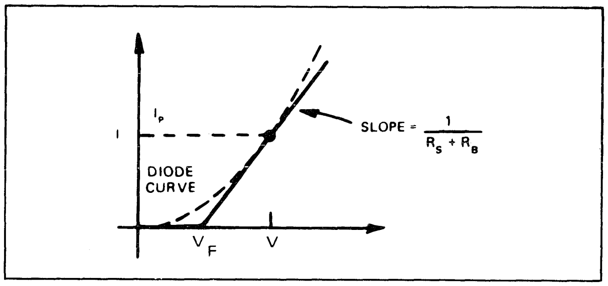


Figure 4-2. Diode Forward Characteristic

The barrier resistance, R_B should be evaluated at the peak current using $R_B = .028/I_P$. The equation for I_P is:

$$I_P = \frac{2V_L - V_F}{Z'_0 + R_S + R_B} \tag{4-3}$$

This approximation can be justified by graphing the equation or by looking at an actual diode on a curve tracer (1 mA/cm). (In practice, V_{F1}, the forward voltage at 1 mA, can be used for V_F).

Therefore, the low frequency diode conductance, G is

$$G(t) = \begin{cases} \frac{1}{R_S + R_B}, & \text{if } 2V_L(t) > V_F \\ \omega^2 C_J^2 R_S, & \text{otherwise} \end{cases} \tag{4-4}$$

If you use this reasoning to compute the time-dependent reflection coefficient, the result is a rectangular waveform (Figure 4-3).

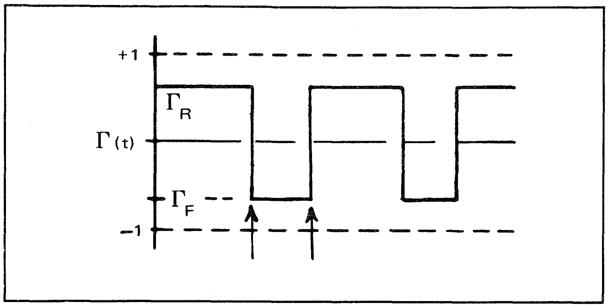


Figure 4-3. Time Dependent Reflection Coefficient

$$\Gamma_F = \frac{R_S + R_B - Z'_0}{R_S + R_B + Z'_0} \approx -1 + \frac{2(R_B + R_S)}{Z'_0} \quad (4\text{-}5)$$

$$\Gamma_R = \frac{1 - Z'_0\omega^2 C_J^2 R_S}{1 + Z'_0\omega^2 C_J^2 R_S} \approx 1 - 2Z'_0\omega^2 C_J^2 R_S \quad (4\text{-}6)$$

The angle, θ, is the conduction angle, i.e. the number of electrical degrees of the LO waveform during which the diode is conducting.

$$\theta = 2 \text{ arc cos}\left(\frac{V_F}{V_t}\right)$$

$$= 2 \text{ arc cos}\left(\frac{V_F}{\sqrt{8Z'_0 P_L}}\right) \quad (4\text{-}7)$$

Typically the conduction angle is between 120° and 170°.

CONVERSION LOSS

In order to handle the mathematics of the mixer, the Γ-waveform must be expressed as a Fourier series

$$\Gamma(t) = \Gamma_0 + \Gamma_1 \cos\omega_L t + \Gamma_2 \cos 2\omega_L t + \ldots$$

where

$$\Gamma_1 = \frac{2}{\pi}(\Gamma_F - \Gamma_R)\sin\frac{\theta}{2} \quad (4\text{-}8)$$

$$\approx -\frac{2}{\pi}\left(2 - 2Z'_0\omega_L^2 C_J^2 R_S - 2\frac{R_S + R_B}{Z'_0}\right)\sin\frac{\theta}{2}$$

When there is an incident RF signal voltage $V_s \cos\omega_{st}$ in addition to the LO voltage, the voltage of the reflected wave is

$$V_R(t) = \Gamma(t)V_S \cos\omega t$$

$$= \Gamma_0 V_S \cos\omega t + \Gamma_1 V_S \cos\omega_L t \cos\omega_S t + \ldots$$

$$= \Gamma_0 V_S \cos\omega_S t + \frac{1}{2}\Gamma_1 V_S [\cos(\omega_L - \omega_S)t + \cos(\omega_L + \omega_S)t] + \ldots \quad (4\text{-}9)$$

The important term is the one involving $\omega_L - \omega_S$, because this is the difference frequency (IF). The ratio of reflected power at this frequency to the incident power at ω_S is the conversion efficiency, η.

$$\eta = \frac{P_{IF}}{P_S} = \frac{(.5\Gamma_1 V_S)^2}{V_S^2} = \frac{\Gamma_1^2}{4}$$

$$= \frac{4}{\pi^2}\left[1 - Z'_0\omega_L^2 C_J^2 R_S - \frac{(R_S + R_B)}{Z'_0}\right]^2 \sin^2\frac{\theta}{2} \quad (4\text{-}10)$$

Conversion loss is η expressed in dB:

$$L_C = -10\log_{10}\eta \quad (4\text{-}11)$$

To optimize the conversion efficiency, you clearly want R_S to be zero; however, nature won't allow you to do this. In practice, low R_S means large junction diameter and thus high C_J (and vice versa), so diode manufacturers introduce a parameter, the "cutoff frequency," which is essentially independent of junction diameter:

$$f_C = \frac{1}{2\pi R_S C_J} \quad (4\text{–}12)$$

where f_C = cutoff frequency.

It is useful to express conversion loss in terms of f_C instead of R_S, leaving C_J as the free parameter, since the range of variation of f_C in actual products is limited by material properties, whereas C_J can be designed for almost any value.

$$R_S = \frac{1}{\omega_C C_J}$$

$$\eta = \frac{4}{\pi^2}\sin^2\frac{\theta}{2}\left[1 - \left(\frac{Z'_0}{X_C} + \frac{X_C}{Z'_0}\right)\frac{f}{f_C} - \frac{R_B}{Z'_0}\right]^2 \quad (4\text{-}13)$$

The quantity in parenthesis is close to 2, if the reactance of C_J is between $Z'_0/2$ and $2Z'_0$. So, for a large range of C_J, the conversion efficiency is determined almost entirely by the ratio of LO frequency to the cutoff frequency of the junction, by the peak current which determines R_B, and by the conduction angle.

For this reason, the capacitive reactance should be chosen to be Z'_0 or typically 100 ohms. The exact value is not critical for conversion loss unless very wide bandwidth is desired. Cutoff frequency should clearly be as high as possible. Conduction angle and R_B are determined by LO power and forward voltage. Therefore, LO power should be high and forward voltage should be low.

For high drive levels, θ is close to 180°, sin θ/2 is nearly one and $R_B \to 0$ so the best conversion efficiency is:

$$\eta = \frac{4}{\pi^2}\left(1 - 2\frac{f}{f_C} - \frac{R_B}{Z'_0}\right)^2 \qquad (4\text{-}14)$$

and the conversion loss, in dB, is:

$$L_C \approx 3.9\,\text{dB} + 17\frac{f}{f_C} + 9\frac{R_B}{Z'_0} \qquad (4\text{-}15)$$

Actual single-ended mixers, such as the ones used at Alpha to test Schottky diodes, give results similar to this equation, or slightly better. Theoretically, an actual mixer can be 0.9 dB better than this because of harmonic suppression. That is, instead of the sum frequency and other harmonics being absorbed in the source resistance, they are reflected back into the diode to be remixed with harmonics of the Γ-waveform to produce more IF output. In actual diodes this happens automatically if the package is designed to have a low-pass characteristic that cuts off between the operating frequency and the harmonics. In any case, the circuit can be designed to reflect all harmonics back into the diode, and if these reflections are phased properly, you get the full 0.9 dB improvement.

The conversion loss actually measured on production diodes is in general agreement with the previous equations, as indicated in the following figure. The conversion loss points are from a large number of production lots measured at Alpha over the last several years, including silicon, GaAs, n-type and p-type at frequencies 3 to 16 GHz, in various packages. As can be seen in Figure 4-4, the results follow Eq. (4-15) if 0.9 dB is subtracted for harmonic suppression, and the last term contributes about 0.5 dB.

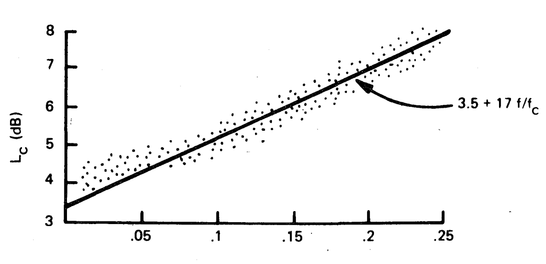


Figure 4-4. Conversion Loss as a Function of Normalized Frequency

NOISE FIGURE

Definitions and Formulas

In practice, not only the wanted signal comes into the diode to be converted to the IF frequency, but also random noise of various sorts. This noise is also converted to the IF frequency with the same conversion efficiency as the signal. In addition to this, the mixer adds other sources of noise:

1. *Image noise* — If the signal frequency is $f_L + f_{IF}$, then noise at the frequency $f_L - f_{IF}$ is also converted to the IF frequency with the same efficiency. This doubles the noise at the IF port.
2. *Diode thermal noise* — The parasitic resistance R_S generates thermal noise. The higher the R_S, the more the conversion loss and the higher this contribution is, in direct proportion. This noise source will increase if the diode is run at elevated temperatures.
3. *Shot noise* — Electron flow across the diode depletion layer generates shot noise. This noise turns out to be half what the thermal noise would be in an ordinary resistor equal to R_B, and will be directly proportional to the absolute temperature of the diode.
4. *Excess noise* — At low frequencies, the junction noise increases due to trapping of electrons. This noise often has a 1/f spectrum and is therefore called 1/f noise. At high current levels there is additional noise due to velocity saturation of the carriers and carrier trapping. This noise has a minor effect on mixers and is discussed in a later section.
5. *IF noise* — The input stage of the IF amplifier adds some noise of its own. Most mixer specifications assume that the IF amplifier has a noise figure of 1.5 dB.
6. *LO noise* — The sidebands of the noise from the local oscillator may overlap the signal and image frequencies, thus acting like an excess noise source. (This effect can be eliminated by filtering the LO or by using a balanced mixer.)
7. *Harmonic noise* — In the wide-open, single-ended mixer design we are talking about, noise at frequencies near harmonics of the LO frequency can also be converted to the IF frequency. This can be eliminated by using a harmonic enhanced design, or by making sure that the package parasitics isolate the junction from the circuit at the harmonic frequencies.

Noise factor is defined as the ratio of the signal-to-noise (S/N) ratio at room temperature at the signal input to the mixer to the S/N ratio at the output of the IF amplifier. Noise figure is the noise factor expressed in dB. For a moderately heavily driven mixer ($R_B \to 0$), the noise added from the image and the diode thermal noise (from R_S) exactly makes up for the noise lost in the conversion process, if the diode is at room temperature. Therefore, the noise power going into the IF amplifier is exactly equal to the noise coming in with the signal, but the signal is reduced, so the signal-to-noise ratio is reduced by exactly the amount of the conversion loss.

After adding in the IF noise figure, the result is:

$$NF = \text{noise figure (dB)} = L_C + N_{IF} \qquad (4\text{-}16)$$

However, the shot noise and the excess junction noise should be considered. The shot noise added by the junction is only half what would be expected from a resistor equal to R_B. For low drive the increase in noise figure is not as great as the increase in conversion loss. If enough LO power is absorbed to heat the diode significantly, one should take into account the temperature of the diode. Also, excess noise (1/f noise) should be taken into account if the IF frequency is low. This is usually accounted for by assigning an effective temperature to the diode, which may be either less or more than room temperature, T_0.

$$NF = L_C + 10\log_{10}(NTR) + N_{IF} \qquad (4\text{-}17)$$

where the NTR, in this model, is:

$$NTR = \frac{T_{eff}}{T_0} = 1 - 4\frac{f}{f_C}\left(\frac{T}{T_0} - 1\right) + \frac{R_B}{Z'_0}\left(2 - \frac{T}{T_0}\right) \qquad (4\text{-}18)$$

NTR = Noise Temperature Ratio

In most specifications, the IF amplifier noise figure is assumed to be 1.5 dB (if the actual amplifier has a different noise figure, the data are corrected to the nominal 1.5 dB). In addition, the diode is assumed to be operated at a junction temperature equal to room temperature.

Therefore, if the IF frequency is not too low the expected noise figure for the single-ended mixer, driven with a quiet local oscillator is:

$$NF \cong 5.4\text{ dB} + 17\frac{f}{f_C} + 10\log_{10}(NTR) + 9\frac{R_B}{Z'_0} \qquad (4\text{-}19)$$

For IF frequencies below 1.0 MHz the 1/f noise becomes important and the noise figure could be higher than this unless the diodes are selected for low 1/f noise. At high local oscillator drive levels, R_B decreases, but the high forward current activates additional noise due to traps and velocity saturation, as well as higher temperature. Thus the noise figure increases instead of approaching a constant. In addition, as the reverse swing from the LO approaches diode breakdown, the back resistance, R_R, decreases, and conversion loss will be degraded further.

Double Sideband (DSB) Noise Figure

When noise figure is actually measured, a hot source or broadband noise tube (or noise diode) is used as a "signal" source. Unless filtering is used, this kind of source provides "signal" both at the signal frequency and the image frequency. Therefore, when the noise source is switched on and off to determine the signal-to-noise ratio at the output of the IF amplifier, twice as much output is obtained with the noise source on than if a single frequency signal were used. Therefore, the measured noise figure (the so-called "double sideband" noise figure) will be 3 dB lower than the specified ("single sideband") noise figure. Nevertheless, this kind of measurement is more convenient to do, and usually the measurement consists of measuring the DSB noise figure and adding 3 dB to obtain the SSB noise figure.

There are many other factors, such as line losses, coupler losses, the loss in signal — LO combiner or filter, and the deviation of the IF noise figure from 1.5 dB which must be taken into account as part of the calibration in order to get the correct noise figure for the single-diode mixer alone.

CRYSTAL CURRENT

The diode produces DC current as a result of rectifying the local oscillator current. The total current is

$$I(t) = \begin{cases} \dfrac{2V_L \cos\omega_L t - V_T}{Z'_0} & \text{if } 2V_L(t) > V_T \\ \omega^2 C_J^2 R_S V_L \cos\omega_L t, & \text{(otherwise)} \end{cases} \qquad (4\text{-}20)$$

The average DC current, or "crystal current" ($\omega = \theta$) is:

$$\text{crystal current} = I_{DC} = \frac{2V_L\left[\sin\frac{\theta}{2} - \frac{\theta}{2}\cos\frac{\theta}{2}\right]}{\pi(Z'_0 + R_S + R_B)} \qquad (4\text{-}21)$$

If you compute the DC voltage by similar reasoning, you find that there is an apparent reverse DC voltage equal to

$$V_{DC} = -Z'_0 I_{DC} \qquad (4\text{-}22)$$

This is caused by the DC current through the DC circuit here assumed to be equal to Z'_0. (Actual single ended mixers typically use a 100 ohm resistor.)

VSWR

The VSWR expresses how well the RF diode impedance is matched to the LO source impedance. In terms of the LO current and voltage it is defined as:

$$VSWR = \frac{Z_{LO}}{Z_0} \text{ or } \frac{Z_0}{Z_{LO}}\text{; whichever is larger.} \qquad (4\text{-}23)$$

The large signal impedance, Z_{LO}, is the ratio of V_{LO} and I_{LO} which are the first order Fourier coefficients of the voltage and current waveforms:

Application Note 80800: Mixer and Detector Diodes

$$V(t) = V_{DC} + V_{LO}\cos\omega_L t + V_2\cos 2\omega_L t + \ldots$$

$$I(t) = I_{DC} + I_{LO}\cos\omega_L t + I_2\cos 2\omega_L t + \ldots$$

$$I_{LO} = \frac{2V_L(\theta - \sin\theta)}{2\pi(Z'_0 + R_S + R_B)} + 2\omega^2 C_J^2 R_S V_L \qquad (4\text{-}24)$$

$$V_{LO} = 2V_L - Z'_0 I_{LO} \qquad (4\text{-}25)$$

$$\frac{Z_{LO}}{Z'_0} = \frac{V_L}{Z'_0 I_{LO}} = \frac{2\pi\left(\frac{R_S + R_B}{Z'_0} + 1\right)}{\theta - \sin\theta + \pi\omega^2 C_J^2 R_S Z'_0} - 1 \qquad (4\text{-}26)$$

$$VSWR = \left[\frac{Z_{LO}}{Z'_0}\right]^{\pm 1}$$

In order to reduce radiation of the LO from the antenna, the VSWR should be less than 1.6. This corresponds to a reflection of less than 5% of the LO power.

IF IMPEDANCE

When the diode is considered as a source of IF voltage, it is important to know what its low frequency (IF) impedance is. The IF amplifier has to be designed to work optimally when driven from a source of this impedance, or diodes and circuit conditions should be chosen to provide an optimum impedance for the input of the IF amplifier.

If an external DC bias is applied to the diode, the crystal current will change, due to a change in the conduction angle. Applying a small reverse DC (or IF frequency) voltage is the same as increasing V_T by the same amount. The IF impedance is the ratio of the applied DC or IF voltage to the change in crystal current

$$Z_{IF} = \frac{\Delta V_F}{\Delta I_{DC}} = \frac{1}{\left(\frac{dI_{DC}}{dV_F}\right)} \qquad (4\text{-}27)$$

$$= \frac{2\pi}{\theta}(Z'_0 + R_S + R_B) \qquad (4\text{-}28)$$

This is always greater than $2Z'_0$ and typically ranges from 200 to 500 ohms.

As an example of the behavior of these parameters as LO power is varied, the following graph shows the noise figure, VSWR, crystal current and IF impedance of an X-band diode. The fixed parameters are: $V_F = .28V$, $R_S = 7\Omega$, $C_J = .20$ pf, and $Z_0 = 150$ ohms, values appropriate for low barrier diodes in a waveguide test holder, such as those used for testing mixer diodes at Alpha.

Performance is better at low LO power levels than these formulas indicate because actual diodes have a soft knee in the forward I-V characteristic. Also, the noise figure for actual diodes can be about 1 dB better due to harmonic suppression, but the noise figure goes up at high LO power due to heating and other effects. Nevertheless, these formula can give you some insight into the meaning of the various RF parameters and their relationship to the capacitance and I-V characteristics of an actual diode.

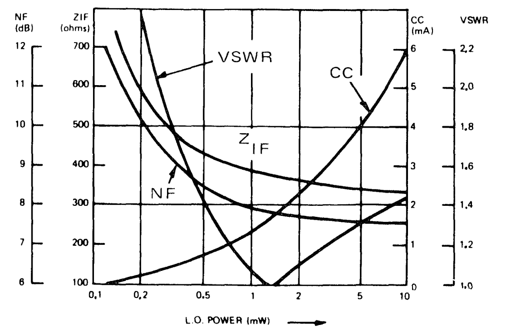


Figure 4-5. Mixer Parameters as a Function of LO Power

PRACTICAL MIXER CONFIGURATIONS

Single Ended Mixer

The single ended mixer used in the above analysis has some disadvantages which limit its usefulness.

1. Even with a low VSWR, too much LO power is reflected into the signal port.
2. To couple the LO and signal onto the same line with broad bandwidth requires a coupler which increases the conversion loss, noise figure and multiplies required LO power. (For example, a 6 dB coupler adds 1.2 dB to the conversion loss and noise figure and requires four times the LO power.)
3. If the coupler is unacceptable, a set of filters can be used, but if the IF and LO frequencies are close, the bandwidth will be restricted severely. However, no extra LO power is needed.
4. The mixer is very sensitive to amplitude variations (AM noise) in the LO power, which will increase the noise figure, if the AM noise spectrum overlaps the signal frequency.

Balanced Mixer

For many years, the solution to these problems was to use a balanced mixer containing two diodes driven in opposite phase. In this case, the reflected LO power cancels, but the IF output adds if the diodes are reversed. Conversion loss is the same as for the single ended mixer.

Twice the LO power is required as for a single diode mixer. The VSWR can be much lower, and the Z_{IF} depends on how the signals are combined. (For the transformer circuits it will be half that of a single diode.) The noise figure will be reduced dramatically compared to the single ended mixer because the AM noise from the local oscillator at the signal frequency is cancelled at the IF output, provided the diodes are well enough matched.

Figure 4-6 shows some of the common balanced mixer configurations, as well as a practical single ended mixer:

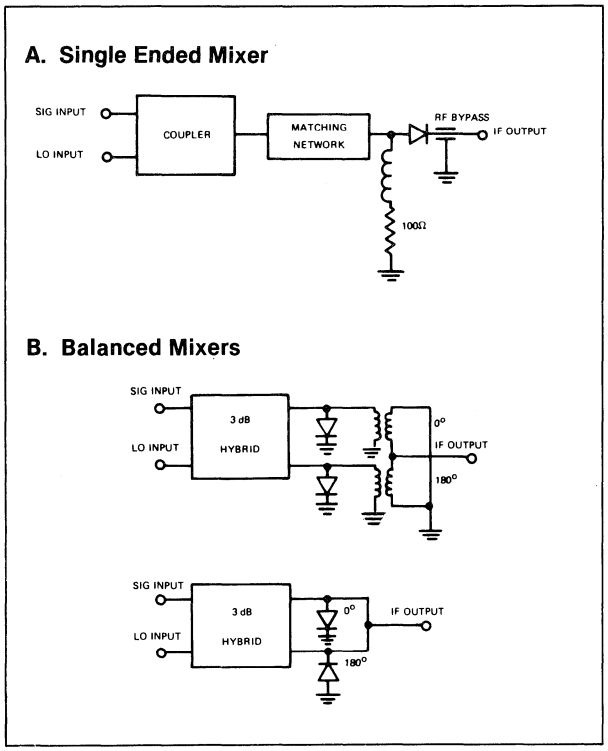


Figure 4-6. Single Ended and Balanced Mixers

Matched Pairs

The simplest of the above configurations require pairs of diodes that are identical except one diode is of opposite polarity. Since it is not practical to make complementary pairs (n-type and p-type), the packages are designed to be double ended, so that one diode can be mechanically reversed. This still requires that the two diodes used in the same mixer must be matched, so that a high order of cancellation of reflected LO power and LO noise results. Matching can be done in one of two ways:

1. The diodes can be matched for C_{JO}, R_S and V_{F1} (V at 1 mA forward).
2. The diodes can be individually tested in a single ended mixer and matched for L_0 and Z_{IF} and VSWR limited to a maximum value.

Both methods accomplish the same thing since the second set of parameters can be related to the first by equations similar to those in Section V. It has been customary for many years to use the second set of parameters, but many people prefer to specify the first set for diodes which are difficult to test 100% in mixers, for example beam-lead types.

Double Balanced Mixers

The use of four diodes in a ring, bridge, or star configuration makes it possible to cancel the LO reflections and noise at both the signal and IF ports, so no filtering is needed at the IF port. This requires the use of very broadband baluns or transformers. In recent years, several manufacturers have developed these double balanced mixers to the point where bandwidths over 8 GHz are possible. To do this requires that the diodes be physically very close together to avoid inductive parasitics, and requires good electrical matching of all four diodes.

The best solution is to make all four diodes simultaneously in a ring configuration using beam-lead technology. (These are available mounted on various carriers, or as unmounted beam-lead quads.) Figure 4-7 shows one of the most common circuit configurations.

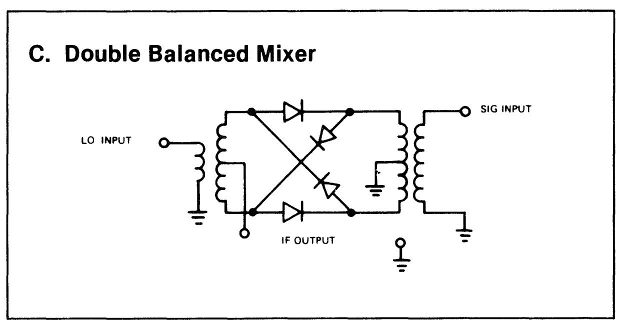


Figure 4-7. Ring Quad Configuration

If you know how to design broadband baluns or transformers, this kind of mixer circuit is a natural. However, you should remember that in circuits with the bandwidth over one octave, harmonic enhancement cannot be used, so there is a penalty in conversion loss.

The easiest way to understand the conversion action is to consider Figure 4-8:

Application Note 80800: Mixer and Detector Diodes

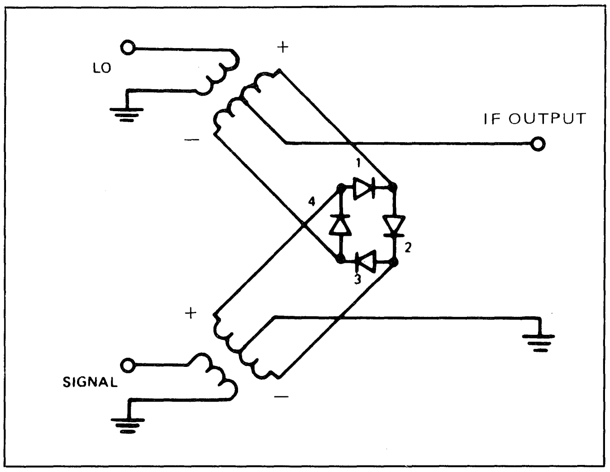


Figure 4-8. Ring Quad for Analysis

When the LO is in "positive" phase, diodes (2) and (3) conduct, and the negative arm of the signal transformer is connected to IF. When the LO phase is negative, diodes (1) and (4) conduct and connect the positive arm of the signal transformer to the IF output. The two pairs of diodes therefore act like a high speed SPDT switch. When one goes through the mathematics for the conversion loss (involving the transmission coefficient instead of the reflection coefficient) formulae for conversion loss and noise figure similar to the ones for the single ended mixer can be derived.

Image Enhancement

The introduction of noise from the image accounts for 3 dB of the total noise figure. Noise can be blocked from entering the mixer at the image frequency by filtering or by operating two mixers in such a way that the image noise cancels at the IF port. Such mixers can have a noise figure improvement of over 2 dB. Filtering reduces the bandwidth of the mixer, so the phase cancellation approach is preferred. However, in order to realize this advantage, image enhanced mixers must be very well built to maintain proper phasing over the band and the diodes used must have higher cutoff frequencies than for non-enhanced mixers. This favors the use of GaAs Schottky diodes in image enhanced mixers.

PARAMETER TRADEOFFS

Barrier Height

The barrier height of a Schottky diode is important because it directly determines the forward voltage. In order to get good noise figure the LO drive voltage, V_L, must be large compared to V_T, which is essentially V_{F1}. Normally, it is best to have a low forward voltage (low V_{F1}, or low drive) diode, to reduce the amount of LO power needed. However, if high dynamic range is important, high LO power is needed, and the diode can have a higher V_F and should also have a high V_B (see Table 1).

Table 1

Type	Typical V_{F1}	LO Power	Application
"zero bias"	.10–.25	<0.1 mW	mainly for detectors
low barrier	.25–.35	0.2–2 mW	low-drive mixers
medium barrier	.35–.50	.5-10 mW	general purpose
high barrier	.50–.80	>10 mW	high dynamic range

Noise Figure vs. LO Power

At low LO drive levels, noise figure is poor because of poor conversion loss, due to too low of a conduction angle. At very high LO drive levels, noise figure again increases due to diode heating, excess noise, and reverse conduction.

If high LO drive level is needed, for example, to get higher dynamic range, then high V_B should be specified (>5V). However, nature requires that you pay for this with higher R_S (lower f_c), so the noise figure will be degraded compared to what could be obtained with diodes designed for lower LO drive. Forward voltage and breakdown are basically independent parameters, but high breakdown is not needed or desirable unless high LO power is used.

Such a high breakdown diode will have low reverse current (which is important only if the diode has to run hot).

Silicon vs. GaAs

Typical silicon Schottky diodes have cutoff frequencies in the 80–200 GHz range, which is good enough through Ku-band.

At Ku-band and above or for image enhanced mixers, higher f_c may be needed, which calls for the use of GaAs diodes. These have lower R_S due to higher mobility, which translates to cutoff frequencies in the 400–1000 GHz range.

However, if your IF frequency is low, be careful; GaAs diodes have high 1/f noise. They also have high V_{F1}, so more LO power is required.

C_J vs. Frequency

There is quite a lot of latitude in choosing C_J. However, in general, the capacitive reactance should be a little lower than the transformed line impedance (Z_0). If Z_0 is not known, a good way to start is to use $X_C = 100\Omega$. Experience has shown that most practical mixers use an X_C near this value (a little higher in waveguide, and lower in 50Ω systems). This translates to the following "rule of thumb" for choosing the junction capacitance of a diode for operation at frequency f (in GHz):

$$C_{JO} \approx \frac{100}{\omega} \approx \frac{1.6}{f} \quad \text{(in pF)} \qquad (4\text{-}29)$$

MIXER DIODES

As an example of some of the parameters for state-of-the-art mixer diodes, Table 2 gives data on some of the X-band mixer diodes. NF is measured at 9.375 GHz.

Table 2

Material	Barrier	Typ. V_F (@1 mA)	Typ. F_{CO} (GHz)	Typ. R_S (ohms)	Typ. C_{J0} (pF)	Max. NF (dB)	Pkg.	Type #
n GaAs	high	.70	1000	—	.15	5.0*	207	DMK6600A
n GaAs (BL)	high	.70	500	—	.15	6.0*	174	DMK6604A
n GaAs (chip)	high	.70	1000	—	.15	5.3*	270	CMK7704A
n silicon (BL)	low	.28	150	6	.20	6.5	130	DMF5827A
n silicon (quad)	low	.28	150	6	.20	6.5	132	DMF5829A
p silicon (BL)	low	.28	150	12	.20	6.5	130	DMB6780A
n silicon (BL)	high	.60	100	8	.20	6.5	130	DMJ6786
n silicon (quad)	high	.60	100	8	.20	6.5	132	DMJ6788
n silicon	low	.28	200	6	.15	5.5	207	DMF6106C
p silicon	low	.28	200	18	.14	6.0	005	DMB5880C
p silicon	med	.40	150	12	.12	6.5	075	DMC5504C
n silicon	low	.28	150	8	.18	6.5	270	DMG6413A
p silicon	low	.28	150	12	.18	6.5	270	CMB7602A

*specified for N_{IF} = 1.0 dB

V. Detectors

GENERAL

Detectors are typically used to convert low levels of amplitude modulated RF power to modulated DC. The output can be used for retrieval of modulated information, or as a level sensor to determine or regulate the RF level.

Detector diodes act as square law detectors for low level signals. That is, the output voltage is proportional to the square of the RF voltage at the junction (i.e., proportional to the RF power). At higher signal levels, the detector will become linear, and at still higher levels, the voltage output will saturate, and not increase at all with increasing signal.

DETECTOR CIRCUITS

In general, a diode detector will require a single diode together with an RF impedance transformation circuit and some low frequency components. The configuration looks like:

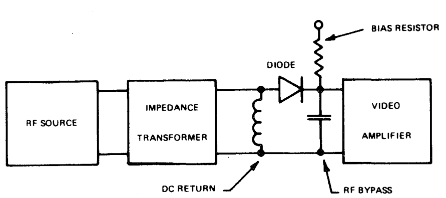


Figure 5-1. Typical Detector Circuit

The bias resistor generally has a very high impedance compared to the diode, to keep the total DC current through the diode constant, and bias the diode to a favorable impedance level.

THEORY OF DETECTION: LOW LEVEL (SQUARE-LAW)

Detection occurs because of the non-linear I-V characteristic of the diode junction. The I-V curve of the junction is the same at microwave frequencies as at DC.

If the junction capacitance is left out of consideration for the moment, the forward I-V curve of the diode (at room temperature) is:

$$I = I_S\left[\exp\left(\frac{V_J}{.028}\right) - 1\right] \quad (5\text{-}1)$$

Where $V_J = V - IR_S$ = junction voltage

If the DC current is held constant by a current regulator or a large resistor, then the total junction current, including RF, is:

$$I = I_0 + i\cos\omega t \quad (5\text{-}2)$$

and the I-V relationship can be written

$$V_J = .028\,\ell n\left(\frac{I_S + I_0 + i\cos\omega t}{I_S}\right) \quad (5\text{-}3)$$

$$= .028\,\ell n\left(\frac{I_0 + I_S}{I_S}\right) + .028\,\ell n\left(1 + \frac{i\cos\omega t}{I_0 + I_S}\right)$$

If the RF current, i, is small enough, the ℓn-term can be approximated in a Taylor series:

$$V_J \approx .028\,\ell n\left(\frac{I_O + I_S}{I_S}\right) + .028\left[\frac{i\cos\omega t}{I_O + I_S} - \frac{i^2\cos^2\omega t}{2(I_O + I_S)^2} + \ldots\right] \quad (5\text{-}4)$$

$$= V_{DC} + V_J\cos\omega t + \text{higher frequency terms}$$

If you use the fact that the average value of $\cos^2$ is .50, then the RF and DC voltages are given by the following equations:

$$V_J = \frac{.028}{I_O + I_S}\,i = R_B i \quad (5\text{-}5)$$

$$V_{DC} = .028\,\ell n\left(1 + \frac{I_O}{I_S}\right) - \frac{.028\,i^2}{4(I_O + I_S)^2} = V_O - \frac{V_J^2}{.112} \quad (5\text{-}6)$$

Therefore, the DC voltage decrease from the bias voltage, V_O, depends on the square of the RF junction voltage *only.* (Note, however, that the number ".112" is really $\frac{4nkT}{q}$ and is temperature dependent).

To get the maximum voltage sensitivity, it is clearly necessary to arrange the circuit to get the maximum possible RF voltage at the junction. That is, the impedance transformer should be designed to have the highest possible impedance at the diode, and the diode should be biased to a high enough impedance (low I_O) so the open circuit RF voltage will not be loaded down too much. In addition, C_J should be low for the same reason.

Voltage Output (Square-Law Region)

The output voltage of a detector will depend on the parasitics, and circuit impedances. Suppose the impedance transformer is designed to boost the source impedance to an impedance, Z'_O, at the diode. Then the relation between V_J and the available power of the source P_{RF} can be seen in Figure 5-2.

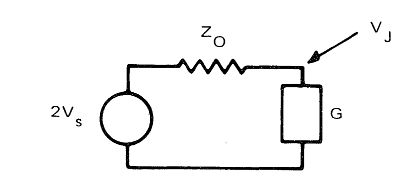


Figure 5-2.

$$V_S = \sqrt{2Z'_O P}$$

$$G = \frac{1}{R_B} + \frac{R_S}{X_C^2} \quad (5\text{-}7)$$

As before, the C_J is absorbed into the impedance transformation and the impedance, Z'_O, is assumed real at the junction (i.e., C_J has been "parallel-tuned" to get the highest possible V_J):

$$V_J^2 = \frac{(2\,V_S)^2}{(1 + Z'_O G)^2} = \frac{8\,Z'_O P_{RF}}{(1 + Z'_O G)^2} \quad (5\text{-}8)$$

The output voltage of the detector will be

$$V_{DC} - V_O = \frac{-8\,Z'_O P_{RF}}{.112(1 + Z'_O G)^2} = \frac{-71.4\,Z'_O P_{RF}}{(1 + Z'_O G)^2} \quad (5\text{-}9)$$

The impedance, Z'_O, is usually limited by bandwidth considerations or by the practical design of the impedance transformer. For a fixed Z'_O, R_J should be as high as possible (which results in a high VSWR). Most manufacturers specify the output voltage for one microwatt RF input power.

An important special case is $Z'_O = 50\Omega$, because many of the voltage sensitivity specifications are measured by placing the diode in the end of a 50 Ω line. If the C_J is small enough, the voltage output per unit power input for $Z'_O = 50\ \Omega$ is:

$$E_O = \frac{V_O - V_{DC}}{P_{RF}} = \frac{V_J^2}{.112} = \frac{3570}{1 + \left(\frac{100}{R_B}\right)}\ \mu V/\mu W \quad (5\text{-}10)$$

Remember

$$R_B = \frac{28}{I_O + I_S},\ (\text{for } I_O \text{ in mA})$$

So for $I_O = 50\ \mu A$; $R_B = 560$ ohms, and therefore:

$$E_O = 3000\ \mu V/\mu W \quad (5\text{-}11)$$

It should be pointed out that the VSWR will be very high for this kind of detector. In this case the VSWR is equal to $R_B/50$, which is over 11 if $I_O = 50\ \mu A$, a typical bias current.

Another important special case is when Z'_O is matched to the shunt conductance, $Z'_O = 1/G$. In this case the voltage output is:

$$E_O = \frac{18}{\frac{1}{R_B} + \left(\frac{R_S}{X_C^2}\right)}\ \mu V/\mu W = \frac{18\,R_B}{1 + \frac{R_S R_B}{X_C^2}}\ \mu V/\mu W \quad (5\text{-}12)$$

If the detector diodes are specified at a bias current of 50 μA (R_B = 560 Ω) and X_C is designed to be large, then the matched output voltage is:

$$E_O = 18\,R_B = 10{,}000\ \mu V/\mu W \quad (5\text{-}13)$$

From equation (5-12), the larger X_C, the higher the output voltage, but remember that practical diodes are limited by a finite cutoff frequency so a large X_C automatically means a large R_S.

In practice, it is usually sufficient to have $X_C > 200\ \Omega$ and $R_S < 40\ \Omega$ which results in no more than 2 dB degradation of the output voltage compared to equation (5-13).

SENSITIVITY

Tangential Signal Sensitivity (TSS)

At low power levels, sensitivity is specified by the "tangential signal sensitivity" (TSS). This is the power level that raises the DC voltage by an amount so the noise fluctuations do not drop below the level of the noise peaks with no signal. This is about 4 dB above the minimum detectable signal (MDS). Detection is so inefficient that even for wideband systems, the incoming noise (antenna noise) need not be considered. All the noise is produced in the diode and the video amplifier.

The open circuit noise of the diode involves three parts: 1) the thermal noise of R_S, 2) the shot noise of the junction, which is associated with R_J, and 3) the 1/f noise. Not counting 1/f noise, it can be shown that the open circuit low frequency noise voltage due to the diode is:

$$V_N^2 = 4kTBR_S + 2\,kTBR_B\left(1 + \frac{I_S}{I_O + I_S}\right) \qquad (5\text{-}14)$$

To this should be added the noise voltage due to the video amplifier, which can be expressed in terms of the fictitious noise resistance, R_a, of the amplifier:

$$V_{NA}^2 = 4kTBR_a \qquad (5\text{-}15)$$

The standard value of R_a is 1200 Ω.

The total noise voltage is

$$V_N^2 = 2kTB\left[R_B\left(1 + \frac{I_S}{I_O + I_S}\right) + 2R_a + 2R_S\right] \qquad (5\text{-}16)$$

Since the peak noise voltage is 1.4 times the rms noise voltage, (V_N), the condition for tangential voltage output is:

$$V_{DC} + 1.4\,V_N = V_O - 1.4\,V_N$$

or (5-17)

$$V_O - V_{DC} = 2.8\,V_N$$

For the biased diode measured in a 50 Ω circuit,

$$\text{Tangential Power} = \frac{2.8\,V_N}{V_{OUT}} = \frac{\left(1 + \frac{50}{R_B}\right)^2 (2.8\,V_N)}{3570} \qquad (5\text{-}18)$$

$$= .78\left(1 + \frac{50}{R_J}\right)^2 \sqrt{2kTB\,[R_B + 2R_a + 2R_S]}\ \text{mW}$$

The tangential sensitivity is the tangential power expressed in −dBm. For a diode with 50 µA bias ($R_J = 560\ \Omega$) measured with a video bandwidth of 10 MHz, this is:

$$\text{TSS} = 10\log_{10}(2828\,V_N/V_O)$$

$$= 10\log_{10}\left[.92\sqrt{2kTB\,[560 + 2R_a + 2R_S]}\right]$$

$$= -48.8\ \text{dBm for } R_a \sim 1200\ \Omega \qquad (5\text{-}19)$$

Note that if the diode has high 1/f noise, the tangential sensitivity will be reduced considerably.

If the circuit is matched to the diode, the tangential sensitivity will be significantly increased. In this case the TSS is:

$$\text{Tangential Power} = \left(\frac{1 + \frac{R_S R_B}{X_C^2}}{18\,R_B}\right) 2.8\,V_N \qquad (5\text{-}20)$$

$$= .157\left(1 + \frac{R_S R_B}{X_C^2}\right)\sqrt{\frac{2kTB}{R_B}\left[1 + \frac{I_S}{I_O + I_S} + 2\frac{R_a + R_S}{R_B}\right]}$$

For a zero bias detector diode, $I_O = 0$ and $R_B = R_O - R_S = Z_V - R_S$ so the tangential sensitivity is:

$$\text{TSS} = 10\log_{10}\left[.157\left(1 + \frac{R_S Z_V}{X_C^2}\right)\sqrt{\frac{4kTB}{Z_V}\left(1 + \frac{R_a}{Z_V}\right)}\right] \qquad (5\text{-}21)$$

If you assume typical values as $X_C = 200\ \Omega$, B = 10 MHz, $R_a = 1200\ \Omega$, and $R_S = 20\ \Omega$, then the result is:

$$\text{TSS} = 10\log_{10}\left[4.6 \times 10^{-5}(1 + .0005)\sqrt{\frac{1}{Z_V}\left(1 + \frac{1200}{Z_V}\right)}\right]$$

$$= -55\ \text{dBm for } Z_V = 2000\text{–}5000\ \Omega \qquad (5\text{-}22)$$

Figure of Merit (FM)

The measurement of TSS is complicated by the fact that the apparent peak noise voltage may not be exactly 1.4 V_N. Depending on the intensity setting of the oscilloscope, the apparent peak noise can be much larger than this, resulting in an error of several dB in the apparent TSS.

To take the operator dependence out of the TSS measurement, FM is introduced, which is defined by:

$$FM = \frac{E_O}{\sqrt{Z_V + R_N}} \qquad (5\text{-}23)$$

For diodes with zero bias the TSS is calculated from the FM by the formula:

$$TSS = 10 \log_{10} \frac{\sqrt{4kTB}}{FM} \qquad (5\text{-}24)$$

For biased diodes, the situation is slightly more complicated:

$$TSS = 10 \log_{10}\left(\frac{\sqrt{4kTB}}{FM}\right) + 5 \log_{10}\left(\frac{2Z_V + 2R_a}{Z_V + 2R_a}\right) \qquad (5\text{-}25)$$

The relationship is even more complicated if 1/f noise is considered which may be necessary if the diode is biased.

High Level Voltage Output

At high signal levels, the detector will begin to deviate from square law behavior. This begins to happen when $V_J = .028$ volts. For these signal levels, the sensitivity can be calculated from the same formulas as for the crystal current of a mixer if V_T is replaced by $V_{F1} - V_{DC}$. At high signal levels, the diode will develop enough reverse bias to keep the crystal current at the value I_O and the output voltage will approach twice the signal voltage, V_S. Therefore:

$$V_{DC} - V_F \cong 2V_S = -\sqrt{8Z'_O P_{RF}} \qquad (5\text{-}26)$$

This behavior is called linear detection because of the linear relationship between V_{DC} and V_S.

At higher power levels, the reverse bias behavior of the I-V curve becomes important; as the reverse voltage approaches V_B, the slope of the reverse characteristic becomes comparable to Z'_O, and begins to load down the circuit. At a little higher power, the diode starts rectifying in the reverse direction as well as in the forward direction, and this results in a limitation of the output voltage.

The whole input-output characteristic of a detector is illustrated in Figure 5-3.

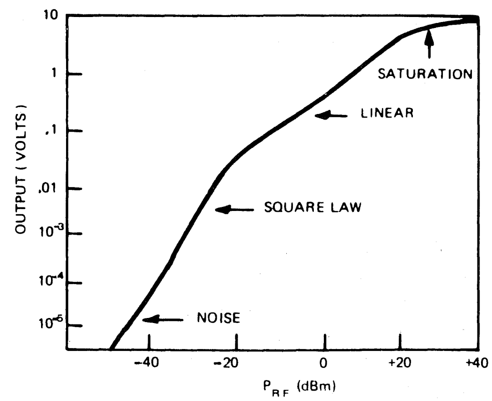


Figure 5-3. Detector Output Characteristic

1/f Noise

Excess noise due to surface static and traps often has a 1/f frequency spectrum instead of the uniform spectrum characteristic of thermal noise and shot noise. That is, the noise power per unit bandwidth has a behavior:

$$\Delta\ (V^2_{N1}) \sim \frac{A}{f} \Delta f \qquad (5\text{-}27)$$

To find the total noise voltage, the actual lower frequency limit, f_L, of the video amplifier must be known

$$V^2_{N1} = \int_{f_L}^{f_L + B} \frac{A}{f} df = A\ell n\left(\frac{f_L + B}{f_L}\right) \qquad (5\text{-}28)$$

Combining this with the thermal and shot noise expressions gives

$$V^2_{N1} = A\ell n\left(1 + \frac{B}{f_L}\right) + 2kTB\left[R_B\left(1 + \frac{I_S}{I_O + I_S}\right) + 2R_a + 2R_S\right] \qquad (5\text{-}29)$$

It is convenient to eliminate the constant A by defining a noise corner frequency f_N, the frequency at which the 1/f noise is equal to the shot noise.

$$f_N = \frac{A}{2kTR_J} \qquad (5\text{-}30)$$

In terms of noise corner,

$$V^2_{N1} = 2kTB\left\{R_B\left[1 + \frac{I_S}{I_O + I_S} + \frac{f_N}{B}\ell n\left(1 + \frac{B}{f_L}\right)\right] + 2R_a + 2R_S\right\} \qquad (5\text{-}31)$$

This noise corner can be specified for a diode, but this is complicated by the fact that for typical diodes the excess noise does not have an exact 1/f spectrum, and also because the noise corner can depend on bias conditions. At Alpha, the 1/f noise output is measured in a bandwidth of 60 kHz (with $f_L = 8$ Hz) as a measure of 1/f noise. This is sufficient as a qualitative measurement of noise corner frequency, since V_N^2 is proportional to f_N. It is interesting to note that for a 50 μA biased diode with a noise corner of less than 3 kHz, the noise output will be less than a 560 Ω resistor.

DETECTOR CONFIGURATION

High Sensitivity

In this type, an impedance transformer is used to raise the impedance to as high a value as practical. Ideally, this should be the zero-bias resistance of the diode, but this approach is limited by the R_S and C_J. It is also limited by bandwidth considerations and losses in the impedance transformer. Narrow band detectors with voltage outputs of 10–30 mV/μW can be achieved this way. Tangential sensitivity approaching −70 dBm (in a << 1 MHz video bandwidth) are achievable with good diodes, high Z_O (over 10 KΩ), and low noise video amplifiers. Even higher sensitivity can be obtained by reducing the video bandwidth. A schematic is shown in Figure 5-4.

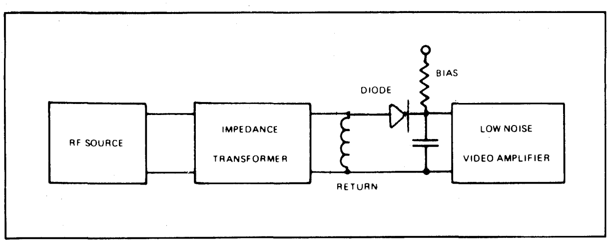


Figure 5-4. Typical Detector Circuit — High Sensitivity

Wideband

A detector circuit uses a wider band impedance transformer or balun and is limited to a much smaller impedance at the diode, usually 50–200 ohms. For the 50 ohm type, the best voltage sensitivity is 3600 μV/μW, (unless the diode package increases the impedance at the chip above 50 ohms), and tangential sensitivities are limited to about −54 dBm (in a 10 MHz band). The configuration is shown in Figure 5-5.

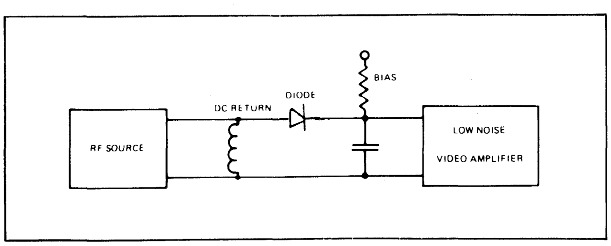


Figure 5-5. Typical Detector Circuit — Wideband

Flat Detector

The above configuration has a reasonably flat response if the RF source is well matched, but has a high VSWR. Therefore, it is sensitive to any mismatch in the source which will then reflect back some of the reflected signal. To avoid this, a 50 ohm resistor can be included to eliminate the reflections, but this halves the signal voltage available at the diode, and reduces the output to less than 1 mV/μW, and the TSS will not be more than −48 dBm. However, the extremely wide bandwidth and low VSWR of this type of detector makes it very useful. The circuit is shown in Figure 5-6.

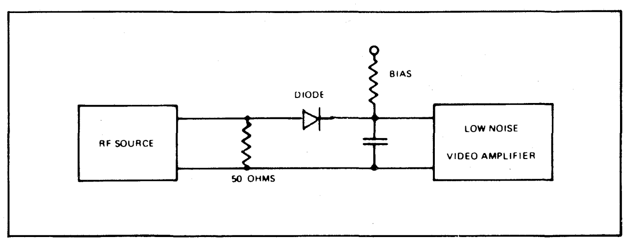


Figure 5-6. Typical Detector Circuit — Flat Response

Matched Pairs

Detectors that must operate over a temperature range, or must be insensitive to variations of bias supply voltage, must have the reference voltage, V_O, built into the detector. This can be done by using an identical diode as a reference. For this reason, detectors are often sold in matched pairs. A typical circuit might be as shown in Figure 5-7.

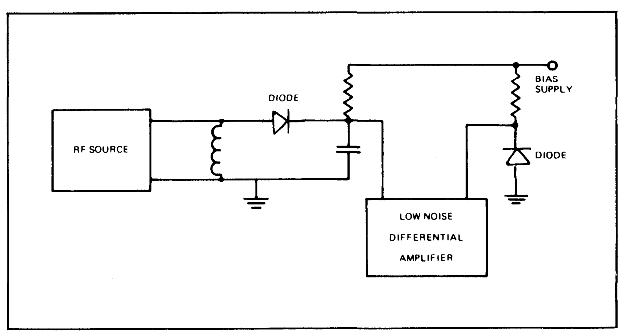


Figure 5-7. Temperature Compensated Detector

PARAMETER TRADEOFFS

Bias vs. No Bias

Although the zero bias detector diode looks like a good way to reduce circuit complexity, applying bias to a diode reduces the noise temperature of the resistance, R_B at video frequencies. In addition, the bias resistor can be chosen to compensate for the natural temperature variation of R_J (which is proportional to absolute temperature in °K for constant current). That is, if the resistance is inversely proportional to T, then R_B will be constant over temperature. The video impedance of a zero bias diode is very temperature dependent. However, a diode operated at zero bias has no 1/f noise. Therefore, this type of diode is the choice for audio frequency output, such as motion detectors. The lack of a bias resistor also simplifies the design of impedance matching networks for narrowband, high sensitivity detectors.

Caution should be used in selecting diodes for use in unbiased detector circuits because deviation from square-law behavior can occur at low levels. If a mixer diode or a detector diode not designed for zero-bias operation is used without bias, the small signal resistance, R_B (video impedance) will be too high. In this case, it will be impossible to get a good match to the diode, even over a narrow bandwidth, and the RF power will be dissipated in lossy circuit elements. Thus the RF voltage at the junction will be much less than it should be, resulting in lower TSS and voltage sensitivity at very low signal levels. When the signal level is increased, the diode self-biases to a lower resistance, R_B, and more of the power reaches the diode. Therefore, the voltage sensitivity increases. The net result is that the detected response is faster than square-law at very low signal levels, approaching fourth law or fifth law in many cases. This results in substantial error if a square law characteristic is assumed, as in many power level measurement applications. This effect does not happen if a zero-bias Schottky diode is used, properly matched, in a low loss detector mount. In particular, the 1N21 and 1N23 point contact diodes and the similar DMB5880 Schottky diode are not suitable for use in detectors without bias.

C_J vs. Frequency

For most purposes, it is sufficient to have $X_C > 150\ \Omega$ in a detector diode. This leads to the following "rule of thumb" (for C_{JO} in pF)

$$C_{JO} < \frac{1.1}{f} \text{ (f = signal frequency in GHz)} \qquad (5\text{-}33)$$

which is good for "typical" detectors. However, this is usually too stringent for 50 ohm detectors, especially flat detectors. Conversely, in the case of high output detectors, this C_J may not allow enough bandwidth. In this case, lower C_J should be traded for more R_S, since R_S matters less in detectors than in mixer diodes. Some detector designers use diodes with R_S as high as 100 ohms.

1/f Noise

Detector diodes are usually used in systems whose video bandwidth extends below 10 kHz. In this case 1/f noise voltage becomes much more important than for typical mixer diodes. It can be specified by a noise corner frequency, or by an upper limit or the noise output in a particular audio band. Alpha's diodes are screened using an audio amplifier with a response from 8 Hz to 60 kHz (at 50 µA bias) when low 1/f noise is specified.

Point Contact Detector vs. Pressure Contact Schottky

The point contact type of detector is similar in action to the zero bias Schottky. One feature that is built into many of them is self resonance which allows the construction of high output detectors without an impedance transformer other than the diode package itself. A disadvantage of point contact diodes is their high 1/f noise and microphonic behavior. Both of these problems are eliminated by using the pressure contact type of Schottky, while retaining the advantage of the high voltage output due to the self resonance of the whisker-type package. A good example of this is the DMC6224 Schottky in the 005 package (similar to the 1N23 point contact).

DETECTOR DIODES

As an example of some of the parameters for state-of-the-art detector diodes, Table 3 gives data on some X-band detector diodes.

Table 3

Material	Barrier	Min TSS (−dBm)	Min E_O (µV/µW)	Typ Z_V (ohms)	Bias (µA)	Pkg.	Type #
N Silicon	low	50[1]	2500[1]	600	50	207	DDB4517
N Silicon (BL)	low	50[1]	2500[1]	600	50	174	DDB4503
P Silicon	low	53[2]	9000[2]	600	50	005	DMC6224
P Silicon	Zero bias	56[2]	15000[2]	8000	0	207	DDC4563D
P Silicon (BL)	Zero bias	56[2]	15000[2]	8000	0	174	DDC4565D
P Silicon (Chip)	Zero bias	56[2]	15000[2]	8000	0	270	CDC7609C

1. measured coaxial line $Z_O = 50\ \Omega$
2. tuned ($Z'_O = Z_V$)

VI. Burnout

GENERAL

Schottky barrier diodes are more subject to burnout due to incident RF pulses than are typical junction diodes, even the very small junction diodes used in microwave systems. Basically, there are three reasons for this:

1. The barrier diameters are very small (less than .5 mil diameter), resulting in high dissipated power density.
2. The metal-semiconductor contact is not as stable chemically as a junction between two regions deep within a semiconductor, and can be damaged by temperatures on the order of 400°C.
3. Because of lack of charge storage (conductivity modulation) the resistance of the diode at high currents will not be very low (typically around 10 ohms). Therefore, the diode does not protect itself as well as junction diodes, whose dynamic resistance may drop to a few tenths of an ohm at high forward currents or high incident RF power.

DEPENDENCE OF BURNOUT POWER ON PULSE LENGTH

A diode will begin to degrade when some part of the junction reaches a certain temperature. The exact temperature depends on the metallurgy used, and on the degree of perfection of the junction, especially at the edges. All of the metallurgies used in Alpha Schottky diodes are good for at least 350°C.

For RF pulses less than 5 ns long, the temperature rise is directly proportional to the total pulse energy dissipated in the epitaxial layer just under the barrier metal. This would appear to lead to the conclusion that the energy content of the RF pulse determines whether the diode will burn out, but the situation is not that simple. For example, if the incoming RF pulse has a peak-to-peak voltage (at the diode) less than the diode breakdown, there will be relatively little dissipation in the junction. At higher pulse voltages, the percentage of the incoming energy that is dissipated will increase. The amount of dissipation in the diode will also depend on the circuit, which determines what happens to the energy reflected by the diode. All that can be said without exact knowledge of both the diode and the circuit is that the susceptibility of the diode to burnout is related to both the power (or voltage) in the incoming RF pulse and the pulse duration.

One note of caution: RF pulses are more damaging than video pulses of the same energy content and pulse length. The "erg" burnout ratings quoted on some data sheets are based on the energy content of video pulses from a Torrey line pulser and should be converted to equivalent RF energy before being used for system design.

For longer pulse lengths (5 ns to 100 ns) the temperature of the diode junction is dominated by thermal diffusion, and the temperature rise will be proportional to the square root of time for a given power dissipation. Therefore, the burnout is not expected to depend on the total dissipated energy for pulse lengths over 5 ns, but is more related to the incident power (if the peak-to-peak voltage is high enough).

If the pulse length is longer than about 100 ns, the maximum junction temperature is controlled by the thermal resistance of the chip and package. In this case, the burnout rating will depend to some extent on the quality of the heatsink used for the diode.

BURNOUT vs. FREQUENCY

Because the capacitance of mixer diodes must be smaller at higher frequencies, smaller diameter junctions are used. This, of course, makes higher frequency diodes more susceptible to burnout than low frequency diodes. For short pulses, the burnout power is approximately inverse with frequency, whereas for long pulses, or CW, the effect is more gradual.

Detector diodes typically have lower capacitance and thus smaller junctions than mixer diodes for any given frequency. Therefore, detector diodes are more susceptible to burnout than mixer diodes. This is often not an issue, because detector diodes are not usually exposed to high power RF pulses. However, if the system requires that they be exposed, then the burnout rating should be given serious consideration in selecting the diode.

The burnout power of a mixer or detector diode cannot be directly measured without destroying or deteriorating the diode. Production diodes can be screened to a particular RF power level if necessary, but this is not recommended. If the mixer or detector circuit is likely to be subjected to short RF power pulses of over 1W, or long pulses over 100 mW, the use of a PIN limiter ahead of the mixer or detector should be considered. (It is not feasible to include a limiter diode in the package with a Schottky diode, since proper limiter action requires the limiter junction to be 0.1 wavelengths away from the Schottky diode.)

TRANSIENTS AND ELECTROSTATIC DISCHARGES

For the same reasons outlined above, Schottky diodes are subject to burnout due to circuit transients and electrostatic discharges. (The majority of diode burnout problems we encounter are due to these two causes.)

Electrostatic discharge is becoming even more of a problem than it used to be, since most people wear plastic clothes (and even plastic shoes). A person's hand can easily acquire a charge of over 5000 volts on a dry winter day, and when it touches the hapless diode, can release as much as 10 amperes of short circuit current in less than a nanosecond. The solution is to always ground your hand and tweezers, pliers, or other tool before touching the diode. (Also, both terminals of the circuit it goes into should be grounded — someone may have touched one of the conductors and charged it.)

Another way of damaging diodes is to check the front-to-back ratio with a conventional multimeter to see if it is "still a diode". (It won't be.) The ohmmeter batteries in typical multimeters range from 1.5 to 9 volts, and the leads will be charged to this voltage until they touch the diode. The discharge is usually sufficient to burn out the diode within about 2 nanoseconds (the longer the leads, the worse the effect). This effect can be avoided by using a push-to-test switch across the diode when testing it in this way, or by using a curvetracer instead of a multimeter. Some DVM's are just as bad as multimeters, because they produce digital pulses which hit the diode.

Switching transients in actual circuits can cause the same effect, if there is sufficient inductance between the source and the diode. This can be eliminated by using a small capacitor between the source of the transient and the diode.

VII. Guide to Specifying Schottky Diodes

"TYPICAL" vs. "MAXIMUM"

To specify a parameter, specify a minimum or a maximum (or both if necessary). In some cases this is too expensive or technically infeasible, e.g., measuring noise figure on beam-lead diodes. Specifying "typical" parameters is not the solution, because the word typical is very poorly defined. Testing a sample of a specified size or a specified percentage of the shipment will often provide the required information while at the same time reducing cost.

Another method of reducing testing cost is to do lot qualification in the actual circuit, if this is mechanically feasible. Often, our customers will send us their circuit to save money and time in qualifying lots of diodes, and to avoid paying for a battery of parameter measurements that might be irrelevant. This allows us to optimize the device design to a particular circuit, with a minimum cost.

SCREENING

Another category of test that can get very expensive is Group B screening. If cost is the main objective, this should be made as realistic as possible without sacrificing quality. A good example is screening for burnout. Experience has shown that 100% testing with high RF pulses deteriorates diodes even if they don't fail and therefore repeating the test will produce further failures, and more yield loss. One solution is to screen the diodes for burnout, but not actually use diodes that have been subjected to high power pulses even if they passed.

More information on screening is given in other application notes.

AVOID OVERSPECIFYING

People often put in specifications that represent what they desire rather than what they require. Sometimes this is entered as a "typical" spec, sometimes as an unnecessary min-max spec, or min-max spec values that are tighter than necessary.

If there is a question as to what is necessary, call our Applications Department. We will be glad to recommend the most cost-effective way of specifying your product to get you what you need to make your circuit work, using the least expensive testing method that accomplishes the result. Depending on the diode type and package style, we may recommend testing RF parameters, or diode parameters. We may recommend lot sampling, sampling a percentage of product, or 100% testing depending on your requirement.

Appendix

ELECTRICAL CHARACTERISTICS AND PHYSICS OF SCHOTTKY BARRIERS

Schottky barrier diodes differ from junction diodes in that current flow involves only one type of carrier instead of both types. That is, in n-type Schottkys, forward current results from electrons flowing from the n-type semiconductor into the metal, whereas in p-type Schottkys, the forward current consists of holes flowing from the p-type semiconductor into the metal.

Diode action results from a contact potential set up between the metal and the semiconductor, similar to the voltage between the two metals in a thermocouple. When metal is brought into contact with an n-type semiconductor (during fabrication of the chip), electrons diffuse out of the semiconductor, into the metal, leaving a region under the contact that has no free electrons ("depletion layer"). This region contains donor atoms that are positively charged (because each lost its excess electron), and this charge makes the semiconductor positive with respect to the metal. Diffusion continues until the semiconductor is so positive with respect to the metal that no more electrons can go into the metal. The internal voltage difference between the metal and the semiconductor is called the contact potential, and is usually in the range .3–.8 volts for typical Schottky diodes. A cross section is shown in Figure A-1.

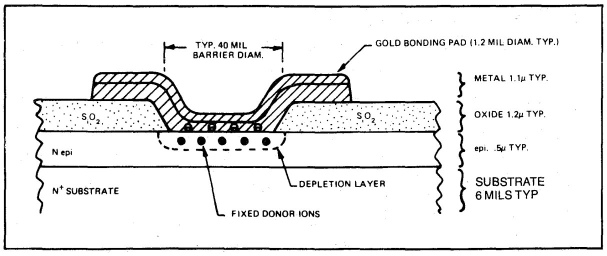


Figure A-1. Schottky Diode Chip Cross Section

When a positive voltage is applied to the metal, the internal voltage is reduced, and electrons can flow into the metal. The process is similar to thermionic emission of electrons from the hot cathode of a vacuum tube, except that the electrons are "escaping" into a metal instead of into a vacuum. Unlike the vacuum tube case, room temperature is "hot" enough for this to happen if enough voltage is applied. However, only those electrons whose thermal energy happens to be many times the average can escape, and these "hot electrons" account for all the forward current from the semiconductor into the metal.

One important thing to note is that there is no flow of minority carriers from the metal into the semiconductor and thus no neutral plasma of holes and electrons is formed. Therefore, if the forward voltage is removed, current stops "instantly", and reverse voltage can be established in a few picoseconds. There is no delay effect due to charge storage as in junction diodes. This accounts for the exclusive use of barrier diodes in microwave mixers, where the diode must switch conductance states at microwave local oscillator rates.

The voltage-current relationship for a barrier diode is described by the Richardson equation (which also applies to thermionic emission from a cathode). The derivation is given in many textbooks (for example, Sze).

$$I = AA^{**}T^2 \exp\left(-\frac{q\phi_B}{kT}\right)\left[\exp\left(\frac{qV_J}{kT}\right) - M\right] \qquad \text{(A-1)}$$

where

A = area (cm^2)
A^{**} = modified Richardson constant (amp/($°K)^2/cm^2$)
k = Boltzman's Constant
T = absolute temperature (°K)
ϕ_B = barrier height in volts
V_J = external voltage across the depletion layer (positive for forward voltage) = $V - IR_S$
R_S = series resistance
M = avalanche multiplication factor
I = diode current in amps (positive forward current)

The barrier height, ϕ_B is typically a few tenths of a volt higher than the contact potential, ϕ_C (about .15 volts higher than ϕ_C for silicon). This equation agrees well with experimental data for diodes without surface leakage, but is difficult to use because A^{**}, ϕ_B, and M are all dependent on applied voltage.

The major cause of the variation of ϕ_B with voltage is the so-called "image effect", in which the barrier height is lowered as the electric field near the metal is increased, especially at the edges.

A better equation for circuit designers to use is one in which all parameters are independent of voltage and current. The simplest one that agrees reasonably well with Richardson's equation is:

$$I = I_S\left[\exp(V_J/.028) - 1 + K/(1 - V_B/V)\right] \qquad \text{(A-2)}$$

where

I_S = "saturation current" (a temperature dependent quantity)
".028" = nkT/q at room temp ($n = 1.08$)
n = "forward slope factor" (derived from the variation of ϕ_B with forward voltage)
K = reverse slope factor (expressing the variation of ϕ_B with reverse voltage)
V_B = breakdown voltage (the voltage at which $M = 1$)

As before, V and I are considered positive for forward bias and negative for reverse bias.

Typical ranges for these parameters for microwave Schottky (and point contact) mixer diodes are:

$I_S = 10^{-12} - 10^{-5}$ amp
$n = 1.04–1.10$
R_S = 2–20 ohms
K = 8–100
V_B = 2–20 volts

The quantities I_S and ".028" are strongly temperature dependent, while both R_S and V_B increase with temperature to a slight degree. R_S increases with current at high current levels (due to carrier velocity saturation) but is essentially independent of current at 10 mA and below for mixer diodes. Thus, for normal mixer and detector operation, R_S can be considered constant.

Agreement between equations (A-1) and (A-2) is not perfect but equation (A-2) is much easier to use and is preferred by most circuit designers. A comparison of the two equations near zero bias gives the following relationship between zero bias barrier height, ϕ_O, and saturation current:

$$I_S = AA^{**}T^2 \exp -\frac{q\phi_O}{kT}$$
$$\cong (10^7 A/cm^2)\ A \exp\left(-\frac{\phi_O}{.026}\right) \text{(for n-silicon at room temperature)} \qquad \text{(A-3)}$$

SMALL SIGNAL PARAMETERS

By combining equations (A-2) and (A-3) the values of the parameters in equation (A-2) can be derived from a few simple measurements. Many specific equations can be derived, but the following are used for production measurements at Alpha:

$$R_S = \frac{V_{F10} - V_{F1} - .065}{.009} \text{ (for n = 1.08)} \qquad \text{(A-4)}$$

$$\phi_O = \frac{V_{F1} - .001R_S + .280 + .12\log_{10}D}{1.08} \qquad \text{(A-5)}$$

$$n = \frac{V_{F1} - V_{F.1} - .0009R_S}{.060} \quad \text{(A-6)}$$

$$K = \left(\frac{I_{R1}}{I_S} - 1\right)V_B \quad \text{(A-7)}$$

$$I_S = \exp.\left(-\frac{V_{F1}}{.028} + \frac{R_S}{28}\right)(\text{in mA}) \quad \text{(A-8)}$$

where $V_{F.1}$, V_{F1}, and V_{F10} are the forward voltages at .1 mA, 1 mA and 10 mA, respectively, and I_{R1} is the reverse current at 1 volt. (The derivation of these equations requires that I_S be small compared to .1 mA.) The quantity "D" is the diameter of the metal-silicon contact in mils. Measuring V_F at 1 mA and 10 mA instead of some other current levels leads to the best accuracy for typical mixer diodes.

The total dynamic resistance for a forward biased diode is given by:

$$R_T = \frac{dV}{dI} = R_S + \frac{nkT}{q(I + I_S)} = R_S + R_B \quad \text{(A-9)}$$

$$R_B = \frac{28}{I + I_S}$$ at room temperature, (with I and I_S in mA, n = 1.08)

and

This equation is also good at zero bias (unless K is very large or there is significant surface leakage). That is,

$$R_O = R_S + \frac{28}{I_S}$$

For reverse voltages of a few volts, the dynamic resistance is dominated by the K-term:

$$R_R = \text{Reverse resistance} = \frac{dV}{dI} \cong \frac{V_B}{KI_S} \quad \text{(A-10)}$$

For typical values of I_S, R_O is larger than 5000 Ω and R_R is larger than 100 kΩ. For some zero bias Schottky applications it is desirable for R_O to be made smaller than this.

The factors that determine R_S are: the thickness of the epitaxial layer, the epi doping level (N_D), the barrier diameter, the substrate resistivity ("spreading resistance"), the contact resistances of the metals used for the barrier and the substrate contact, and the resistance associated with the bonding wire or whisker. The barrier height is about .15 volt higher than the contact potential between the barrier metal and the semiconductor, and is influenced by the method used to apply the metal, conditions at the edge of the junction, and the doping level. Saturation current depends on barrier height, junction area, and temperature; and the slope factors, n and K, depend on doping level, punch through voltage, and edge conditions.

JUNCTION CAPACITANCE

The capacitance of a Schottky barrier chip results mainly from two sources, the depletion layer under the metal-semiconductor contact and the capacitance of the oxide layer under the bonding pad (the so-called overlay capacitance). The bonding pad is required because the typical Schottky barrier diameter is so small that it is impractical to bond directly to the metal on the junction. If the semiconductor epitaxial layer is uniformly doped, the capacitance-voltage characteristic is similar to that of a textbook "abrupt-junction" diode.

$$C_J = \frac{\epsilon_S \epsilon_O A'}{X_D} + C_O \quad \text{(A-11)}$$

$$X_D = \sqrt{\frac{2\epsilon_S \epsilon_O(\phi_C - V)}{qN}} \quad \text{(A-12)}$$

where:

ϕ = contact potential
C_O = overlay (bonding pad) capacitance
ε_S = dielectric constant of the semiconductor ≅ 12 for silicon or GaAs
N = doping level in the epitaxial layer
A′ = effective contact area, including fringing corrections

In practical terms, the capacitance can be related to the zero volt barrier capacitance defined by:

$$C_{BO} = \frac{\epsilon_S \epsilon_O A'}{X_{DO}} \quad \text{(A-13)}$$

where

$$X_{DO} = \sqrt{\left(\frac{1.3 \times 10^{15}}{N_D}\right)\phi_C} \ (\text{in microns}) \quad \text{(A-14)}$$

The resulting C–V relationship can be written

$$C_J = \frac{C_{BO}}{\sqrt{1 - \frac{V}{\phi_C}}} + C_O \quad \text{(A-15)}$$

The contact potential, ϕ_C, is related to the barrier height as follows:

$$\phi_C = \phi_B - .026\left[1 + L_n\left(\frac{N_C}{N}\right)\right] \quad \text{(A-16)}$$

$$\cong \phi_B - \cdot 15 \ (\text{for silicon with } N = 10^{17})$$

The theoretical meaning of these terms can be clarified by looking at Figure A-2.

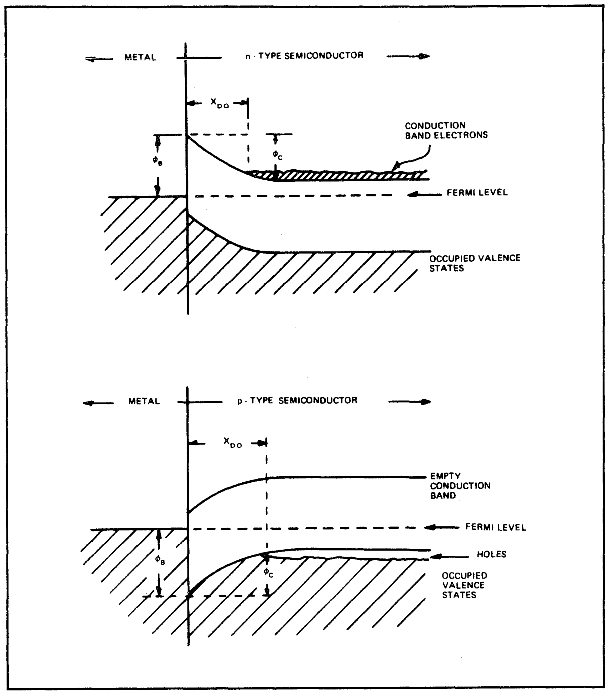


Figure A-2. Schottky Diode Band Diagrams

Application Note 80850: Handling Precautions for Schottky Barrier and Point Contact Mixer and Detector Diodes

Microwave diodes can be damaged by electrical overloads that may occur from several different sources. The first or most sensitive indication of excessive electrical stress or burnout is an increase in the level of low frequency of 1/f noise. A larger overload will cause the breakdown voltage to decrease to a very low value, possibly a few millivolts. Severe burnout causes the forward voltage to decrease. At this point the diode ceases to function in its normal manner and almost total degradation of circuit performance will occur.

One source of diode burnout is static electricity. Static electricity is more prevalent in dry climates such as experienced during the winter months and may be generated on one's person or on the diode packaging. Therefore, extreme care must be taken when handling these diodes. Several methods of preventing static electricity may be employed. Perhaps the easiest and most effective one to use is a grounded wrist strap. This, coupled with a grounded or static-free bench top, provides the best protection available. Ionized air sources also effectively eliminate static electricity. One or more of these methods must be used whenever diodes are handled.

Another source of diode burnout is the use of improper test equipment or the improper use of test equipment. Improper test equipment can be as simple as the wrong selection of the scale on an ohmmeter being used for checking the DC characteristics of a diode. Diodes can be damaged by the application of open circuit voltages as low as 3 volts even when current is limited to a very small value (such as a few microamps). Therefore it is preferable to use only ohmmeters having an open circuit voltage of 1.5 volts maximum. Curve tracers should always be set at zero volts before diodes are inserted for testing. At the completion of the testing sequence (and any time that the polarity is reversed) the voltage control should once again be set to zero.

When diodes are being installed in a circuit, all powers and voltages should be "off" and not turned "on" until the diodes are completely in position. This is particularly important if DC bias is to be applied to the diode. Most bias circuits use a fixed voltage source, such as 12 or 24 Vdc, with a series resistor to provide a constant bias current to the diode. The open circuit voltage in this case is that of the supply voltage and this instantaneous surge when the diode is connected can cause diode burnout. To prevent this, a short can be placed across the diode terminals and removed after the diode is installed. If any soldering is involved, a grounded or isolated iron must be used.

If auxiliary test equipment, such as an oscilloscope or a digital voltmeter, is to be used for monitoring diode operation, it should be connected before the diode is installed if possible. If not, the ground side of the instrument must be connected first or the diode could be damaged by AC current flowing in the ground loop and through the diode.

RF fields are another source of energy that can cause diode burnout. This can be in the form of microwave radiation from the operating system in which the diode is installed or from other systems operating in the vicinity. Protection of the diode in the system is accomplished by the use of limiters or shutters. In addition, it is important to store the diodes in shielded containers and to install them only in areas that are known to be free of RF fields. These fields can also come from non-microwave equipment such as induction heaters.

Oven controllers, motor controllers and the like can also cause diode burnout, particularly if there are long leads connected to the diode. This might occur when using a curve tracer or performing 100% screening tests such as burn-in, temperature cycle, or temperature storage. Generally speaking, ovens with solid state controllers do not create this problem. The best procedure would be to run a controlled experiment prior to any large-scale 100% screening tests.

In general, the same precautions regarding mechanical and thermal stress in handling and installation should be observed as one would for any small electric component. Point contact diodes and pressure contact diodes, however, do require some special care. These devices are manufactured in the 005 outline (ceramic) or 062 and 075 outlines (glass).

Although these latter devices withstand the various stresses called out in MIL-STD specifications, they may be damaged by being dropped several inches onto a hard surface such as a bench top, floor or mechanical inspection flat surface plate. Care must also be taken if the leads of a glass diode are to be formed or cut. The shock of these operations may also move the whisker, causing diode degradation. Diodes should be kept in separate envelopes so that they will not rattle against each other during handling, since this also could cause whisker movement.

For further information or advice on specific problems, contact the Applications Department, Mixer and Detector Diodes.

The following table lists some causes of diode damage and corresponding methods of prevention.

Application Note 80850: Handling Precautions for Schottky Barrier and Point Contact Mixer and Detector Diodes

1. DAMAGE BY BURNOUT FROM STATIC ELECTRICITY

Source of Static Electricity	Handling Precautions
1.1 Operator discharging charge on self through diode	Use metal or conductive plastic bench tops and chair seats. Ground operator with strap or use static eliminators, radioactive or ionized air type. Instruct operator in handling precautions.
1.2 Use of snow (expanded polystyrene) to hold diodes	Don't use.
1.3 Use of plastic bags	Avoid if possible.

Note: Cold dry weather (resulting in low humidity) will increase the likelihood of static burnout.

2. DAMAGE BY BURNOUT ON TEST KITS

Note: It is extremely important in all diode testing that the test equipment, test jig, and test fixtures be all connected and at the same electrical potential before the diode is inserted.

Source of Transient	Handling Precautions
2.1 Bias circuit voltage transient	Have low voltage supply — not high voltage with dropping resistor. Do not use high value capacitance in voltage network. Bring bias voltage to zero before inserting diode.
2.2 Bias voltage wrong polarity	Use polarized plugs and supplies.
2.3 Transients in power supplies	Use regulated power supply shunting diodes.
2.4 Coupled voltage from other circuits	Use shielded leads to diodes. Avoid common wire harness for diode leads and high voltage circuits.
2.5 Charge in cables while connecting to circuit	Design checkout procedure and circuits to avoid this.
2.6 Ground loops	Have all connecting cables touch outside connections first.
2.7 High resistance scale ohmmeter	Maximum open circuit voltage should be 1.5 volts. Use appropriate circuit or ohmmeter.

3. DAMAGE FROM BURNOUT BY MICROWAVE ENERGY

Source of Microwave Power	Precautions
3.1 Pulse energy from same system	Use TR tubes in good condition. Use solid state limiters as well as TR tubes.
3.2 Pulse energy from other systems	Use shutter tubes when system not working.
3.3 High rectified voltage	Restrict dynamic range of signal or limit load resistor size.

4. DAMAGE FROM BURNOUT DURING ELECTRONIC ASSEMBLY AND TEST

Source of Burnout Energy	Precautions
4.1 Leakage current from welding equipment and soldering irons	Ground equipment if possible. Test for leakage current and ground loops.
4.2 Pulse voltages from controllers and relays on ovens, environmental test equipment, etc.	Put capacitors across relays. Shield equipment. Shield diodes.
4.3 Pickup of RF energy from sources such as induction heaters, high power transmitters	Shield and ground transmitters. Keep diodes in shielded containers. Keep diode and plumbing subassemblies shielded.

Application Note 80850: Handling Precautions for Schottky Barrier and Point Contact Mixer and Detector Diodes

5. DAMAGE BY MECHANICAL SHOCK

Source of Shock	Precautions
5.1 Handling	Don't drop diodes or packages on bench or floor. Don't shake in packages.
5.2 Insertion in equipment	Diodes should not seat with a jerk or snap. Adjust mechanical tolerances for smooth insertion.
5.3 Cutting and forming leads	Support diode during operation. Have cutting and forming tools work smoothly.

6. DAMAGE BY EXCESSIVE HEAT

Source of Heat	Precautions
6.1 Soldering	Use heat sink between diode body and point of soldering heat application. Keep exposure to heat to a minimum.

7. DETECTION OF DAMAGE

7.1 DC reverse test – 3 volts reverse	Low resistance indicates burnout of some type.
7.2 DC forward test	High resistance indicates mechanical or thermal damages.

8. GENERAL PRECAUTIONS

8.1 Mark packages containing diodes with cautionary notices. (Upon request, Alpha will supply diode packaging with such notation.)

8.2 Post instructions at locations where diodes are handled (such as incoming inspection, test stations, etc.).

8.3 Instruct inspectors and test operators as to precautions required.

8.4 It is extremely important in all microwave diode testing that the test equipment, test fixtures, diode holders, etc., all be connected together and at the same potential before the diode is inserted in the diode holder.

Section 3
Control Diodes

PIN Switching, Attenuator, and Limiter Diodes

Silicon and GaAs Tuning Diodes

Selection Guide for PIN and Limiter Diodes

This note is intended to offer brief but hopefully not too simplified suggestions for the optimum classes of Alpha PIN and Limiter diodes for various applications.

Guidelines on required Junction parameters:

The incident RF voltage is VRf $=\sqrt{2 P_{in} Z_o}$

The diode V_B must exceed the sum of the peak VRf plus the bias voltage. Be sure to allow a margin for reflections. The bias voltage required to keep a diode in the open circuit state depends upon frequency, power, diode lifetime, and diode I region thickness. The maximum junction capacitance for a mounted chip or diode is dependent on frequency, bandwidth considerations, and your design ingenuity. For high power applications, large values of Cj, with concomitant lower Rs and thermal resistance, are desirable. Matching techniques for both chip and packaged diodes make it possible to use almost any diode for narrow band applications. There are no theoretical limitations to the use of PIN diodes at high frequency. Beam-lead diodes have been used to 100GHz, and chip and packaged diodes can also be used. For example, 075 glass packaged PIN has been successfully employed in 35GHz designs.

I. Series mount:

A. For multithrow, wide band switches, the low capacitance beam-lead diode is optimum.
Average power up to 2-3 watts, with switching times from 5 to 50 nanosec.
Recommended diodes: DSG6474, DSM4380, DSM4355, 4356.

B. For certain applications, multi-junction PIN and NIP chip diodes can be used:
Recommended diodes: CSP9200 series, PIN
CSN9250 series, NIP

II. Shunt mount:

A. Switching under 10 nanosec, voltage breakdown up to 125 volts;
CSB7002-01, 02, 03, 04, CSB7152, 7156; DSM4355, 4356 beam-leads.
For lowest loss, low power: CSB7002-05, 06, 07

B. Switching in 10 to 30 nanosec, voltage breakdown to 200 volts:
CSB7003

C. Switching 30-100 nanosec, voltage breakdown to 300 volts: CSB7151
Selected variations of CSB7003 series.

D. Switching 100 plus nanosec, DC voltage breakdown 500 volts, with RF breakdown exceeding 800 volts.
CSB7205, DSA6925, 6928.

See Application Note 80200 in this section for guidelines on power handling.

III. Attenuators:

A. Low modulation rate, low RF frequency limit approx. 10MHz: CSB7201 series; DSB6419 series, 1N5767

B. High modulation rate, low RF frequency limit approx. 1GHz: CSB7401 series.

Both series and shunt mount circuits, including bridge tees and networks, can be designed around the diodes recommended.

The power limitations for attenuator diodes depend upon RF frequency, modulation rates, dynamic range, and allowable distortion products. See Application Note 80200 for some guidelines.

IV. Limiters:

A. For inputs to 4kw peak:
CLA3133 series

B. For inputs to 800 watts peak:
CLA3132 series

C. For inputs to 200 watts peak and lower leakage power: CLA3131 series

D. For inputs to 100 watts peak, and lowest flat leakage: CLA3134, 3135 series

E. Peak power beyond 20kw — special high voltage limiter diodes have been developed. Contact Alpha.

See Application Note 80300 in this section for guidelines.

V. Diode Package:

For broad band high frequency designs it is almost mandatory to use unpackaged chip and beam-lead diodes. The parasitic capacitance and inductance of most packages produce extra design problems. However, some situations demand packaged diodes, and Alpha has available many package styles which minimize these problems for both shunt and series mounting in stripline and microstrip. These packages include (see pkg. outline drawings):

1. Up to 18GHz: 130, 131, 132, 173, 190, 197, 364.
2. Up to 12GHz: 325

Shunt:

Up to 18GHz: 176, 190, 197, 375.

The above packages offer lowest available parasitics in hermetic sealed and epoxy protected diodes. In regard to epoxy, Alpha has performed extensive reliability tests on diodes "protected" by epoxy, with outstanding results.

3. Modules — see "Switch and Limiter Modules" for 50 ohm stripline modules for switches and limiters.

For applications requiring chips, we offer package styles: 176, 179, 184, which can be used to eliminate "top contact bonding" by the customer.

Conventional metal — ceramic packages:

If you must use such a package, or are in waveguide or coax in narrow band applications, some packages are better than others:

1. To 18GHz: 023, 135, 158
2. To 26GHz: 067, 082, 084, 296, 305
3. To 40GHz: 067, 296, 305
4. Above 40GHz: 290, 296
5. For series mounting, pkg 247, with L shaped leads

Please note that chip size limitations preclude certain combinations of chip and package.

VI. Glass packaged diodes:

The ubiquitous axial leaded glass PIN diode is still quite popular.

1. High speed PIN switch — D5151.
2. Low frequency attenuator (current controlled resistor) DSB6419 series, 1N5767
3. Low inductance, low cost double slug — DSB3608, 3609
4. Most of our other PIN chips are available in glass packages.
5. All our glass packaged diodes are available in chip form, on request.

VII. Junction polarity — PIN or NIP

The question of polarity is not relevant with beam-lead diodes, or stripline packages, but is quite relevant with chips and packages.

For *PIN* diode chip, the large area substrate is the *cathode,* and the small bonding area the *anode.*

For a *NIP* diode, the terminals are reversed — the bond area is the *cathode.*

The substrate is always the heat sink. Most chips are available, or can be readily fabricated, with either PIN or NIP polarity. The high voltage diodes, with V_B greater than 500 volts, are exclusively *PIN*; however, we welcome your inquiries.

VIII. Planar vs. Mesa Construction

In most cases, the electrical characteristics of planar and mesa diodes are similar, and only physical examination could discern a difference.

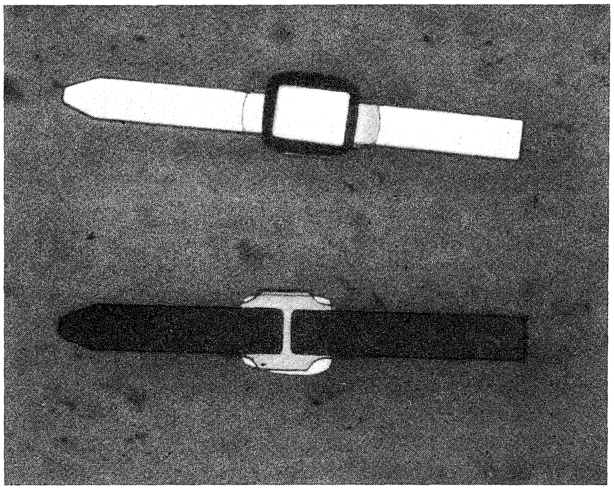
Relative to similar mesa diodes, planar diodes are a little slower in switching time, have higher lifetime and have somewhat higher resistance at low bias currents.

It is more difficult to make very low capacitance planar diodes, and very high voltage planar diodes are almost impossible.

On the other hand, planar chips are most easily bonded, owing to the elimination of the mesa edge, which can be fractured if the bonding tool is improperly positioned or dimensioned.

Because the contact area is flat, it is necessary to insure that the bond wire or ribbon is dressed above the substrate, to reduce fringe capacitance.

Beam-Lead PIN Diodes



Features

- Low Capacitance .... .02 pF
- Low Resistance .... 3.0 ohms
- Fast Switching .... 15 nsec on, 25 nsec off
- High Voltage .... 200 volts
- Oxide Passivated

Types

- DSG6470 Series
- DSG6474 Series

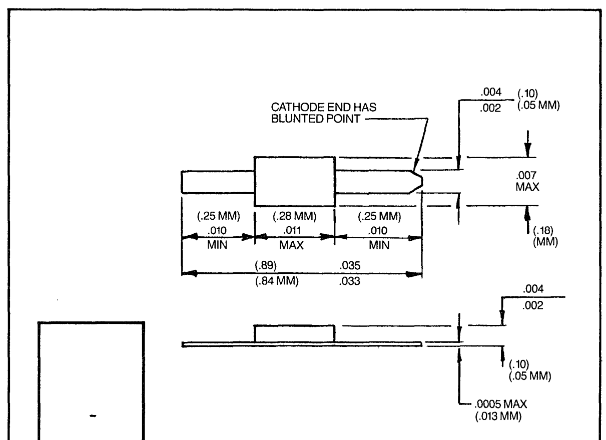
Description

The DSG6470 and DSG6474 Series of silicon oxide passivated beam-lead PIN diodes are designed for stripline and microstrip signal processing applications through 34 GHz. Extremely low junction capacitance combined with low series resistance makes these diodes ideal for circuits requiring high isolation from a series mounted diode, such as broadband multi-throw switches, and certain types of phase shifters, limiters, attenuators and modulators.

The DSG6470 and DSG6474 beam-lead PIN diodes are constructed with a surface oriented junction and with plated gold beam leads for assembly onto stripline or microstrip microwave integrated circuits.

The silicon oxide passivation provides complete sealing of the junction, permitting use in assemblies with some degree of moisture sealing. For military and other high-rel applications, hermetic assemblies are recommended.

Outline Drawing



Note: Millimeters in parentheses.

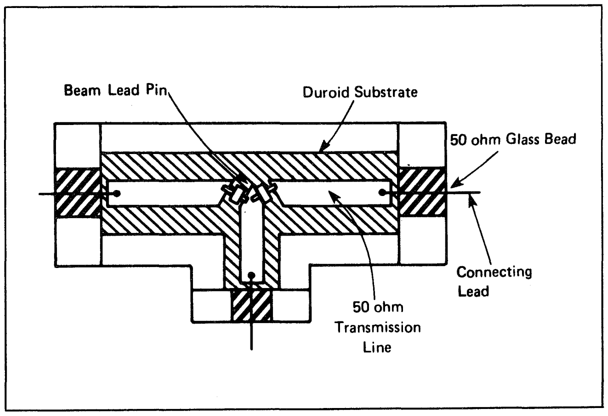


Figure 1a. Typical SPDT Circuit Arrangement

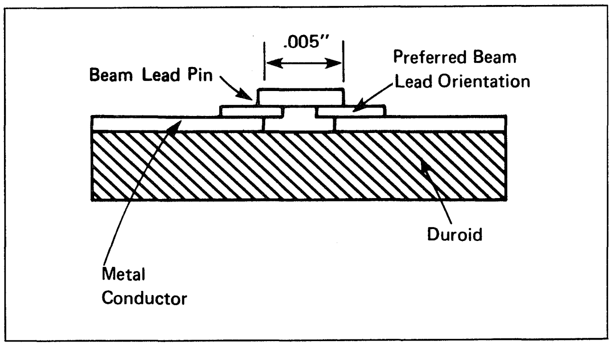


Figure 1b. Typical Beam-Lead Mounting

See Application Note 80000 in Section 7 on suggested handling and bonding procedures for these diodes.

Absolute Maximum Ratings

Total Power Dissipation ....250 mW
Reverse Working Voltage.............200/100 Volts
Storage Temperature ....175°C
Operating Temperature ....150°C

Applications

A typical application of beam-lead PIN diodes is shown in Figure 1, a single pole double throw 1–18 GHz switch. The diodes are mounted on alumina, Duroid, or Teflon-fiberglass 50 ohm microstrip circuits. Typical bonding methods include thermal-compression bonding, parallel gap welding and soldering.

SPDT isolation curves are shown in Figure 2 and insertion loss in Figures 3 and 4. With proper transitions and bias circuits, VSWR is better than 2.0 to 1 through 18 GHz.

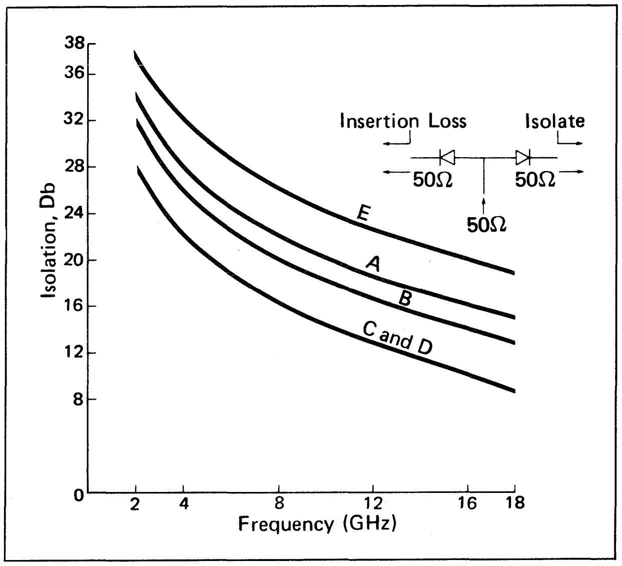


Figure 2. Isolation vs Frequency, SPDT DSG6470, DSG6474 Series

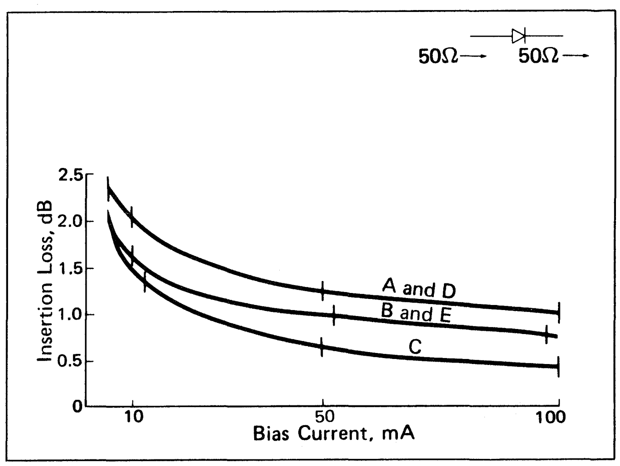


Figure 3. Diode Insertion Loss vs Bias SPST, 18 GHz DSG6470, DSG6474 Series

Switching Considerations

The typical minority carrier lifetime of the DSG6470 and DSG6474 diodes is 100 nanosec. With suitable drivers the individual diodes can be switched from high impedance (off) to low Rs (on) in about 10 nanoseconds. Switching in the opposite direction is slower, due to the need to extract stored charge (carriers) which have diffused away from the junction. Typically, at high reverse bias voltage, say – 20 volts, this requires about 20–50 nanoseconds. With a reverse bias of – 1V, which is the maximum available in simple SPDT without individual biasing circuits, the switching time is on the order of 100 nanoseconds.

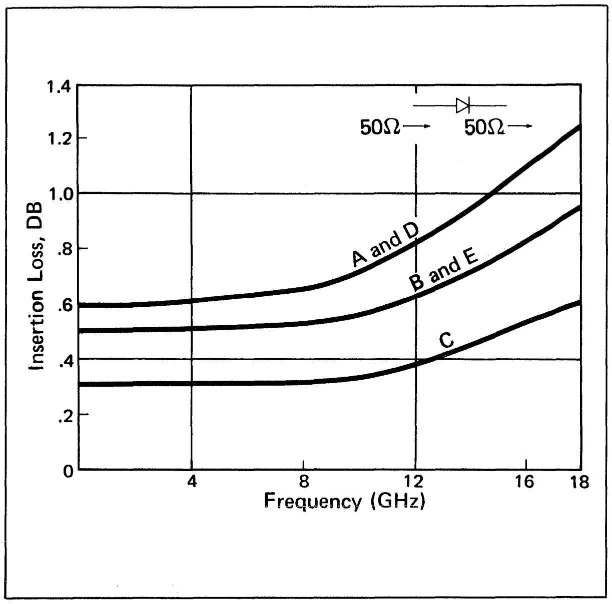


Figure 4. Diode Insertion Loss vs Frequency SPST, 50 mA Bias DSG6470, DSG6474 Series

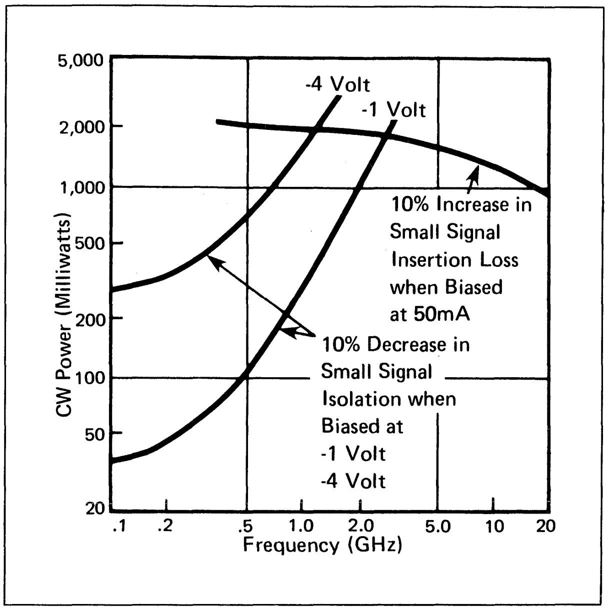


Figure 5. Typical Series Switch Behavior at Room Temperature and Biased at 50 mA/1 volt/ 4 volt DSG6470, DSG6474 Series

Power Handling

Due to a high internal thermal impedance of about 300 degrees C/watt beam-lead diodes are not suitable for high power operation.

With maximum CW power dissipation of 250 mW the DSG6470 and DSG6474 diodes are normally rated at 2 Watt CW with linear derating between 25°C and 150°C. Figure 5 presents data on CW power handling as a function of bias and frequency.

For pulsed operation the total RF plus bias voltage must not exceed the rated breakdown. Alpha has made high power tests at 1 GHz with 1 microsec pulses, .001 duty, with 200 volt diodes. With 50 mA forward bias there is no increase in insertion loss over the 0 dBm level with a peak power input of 50 watts. In the "open" state reverse bias voltage is required to keep the diode from "rectifying," with resultant decrease in isolation and possible failure. Figure 6 shows allowed peak power versus reverse bias at 1 GHz.

At this frequency the required reverse voltage is almost equal to the peak RF voltage; at high frequency the bias can be reduced somewhat. Experimentation is necessary.

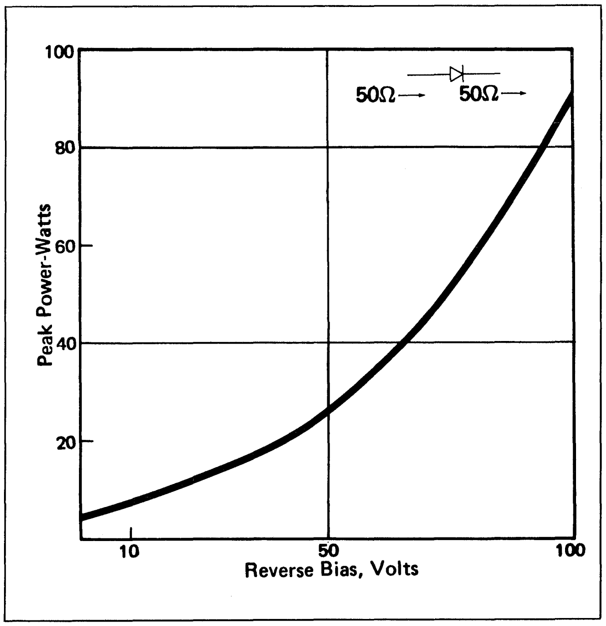


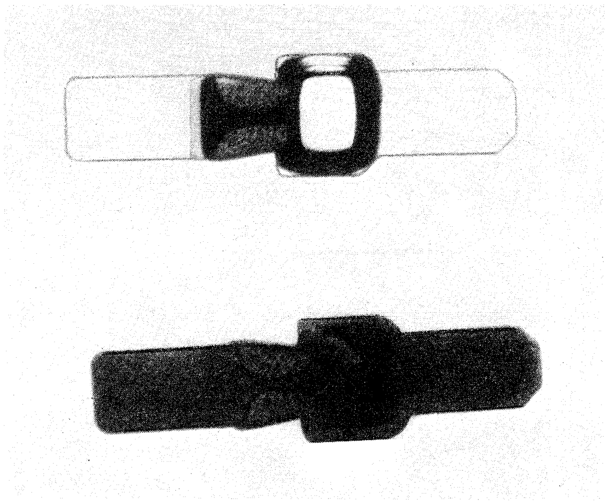
Figure 6. Peak Power Handling, SPST, 1 GHz DSG6470, DSG6474 Series

Specifications

Model Number	Min[1] V_B	Max Series[2, 3] Resistance Rs (ohms)	Max Junction[3] Capacitance C_j (pf)	RF[4] Switching Time T_S (ns)	Minority Carrier Lifetime Typ. (ns)
DSG6470A	200	5.5	.03	25	100
DSG6470B	200	4.0	.04	25	100
DSG6470C	200	3.0	.06	25	100
DSG6470D	200	5.5	.06	25	100
DSG6470E	200	4.0	.02	25	100
DSG6474A	100	5.5	.03	25	100
DSG6474B	100	4.0	.04	25	100
DSG6474C	100	3.0	.06	25	100
DSG6474D	100	5.5	.06	25	100
DSG6474E	100	4.0	.02	25	100

Notes:
1. Breakdown voltage measured at 10μA.
2. Series resistance calculated from insertion loss at 3 GHz, 50 mA.
3. Total capacitance calculated from isolation at 9 GHz, zero bias. Series resistance and capacitance are measured at microwave frequencies on a sample basis from each lot. All diodes are characterized for capacitance at −50 volts, 1 MHz, and series resistance at 1 KHz, 50 mA, measurements which correlate well with microwave measurements.
4. T_S measured from RF transmission, 90% to 10%, in series configuration. Refer to section on RF Switching.

Mesa Beam-Lead PIN Diodes



Features

- Low Capacitance .... .025 pF
- Low Resistance .... 2.5 Ohms
- Fast Switching .... 1 nsec on, 5 nsec off
- High Voltage .... 200 Volts
- Oxide Passivated

Types

- DSM4380 Series
- DSM4381 Series

Description

Alpha's new Mesa Beam-Lead PIN diodes have the handling convenience and excellent microwave performance of Planar Beam-Lead diodes combined with switching performance nearly that of PIN chip diodes. Mesa Beam-Lead PIN's are ideal for use as series diodes in broadband multi-throw switches when extremely fast switching is required. A plot of switching speed for several types of PIN diodes is on the following page.

The plot clearly shows the superiority of Mesa Beam-Lead PIN's over the conventional types; ten dB attenuation is equivalent to 0.5 dB power lost to the off arm. This attenuation is reached in three nanoseconds.

The silicon oxide passivation provides complete sealing of the junction, permitting use in assemblies with some degree of moisture sealing. For military and other high-rel applications, hermetic assemblies are recommended.

Alpha's unique beam construction makes the Mesa Beam-Lead diode mechanically as strong as conventional beam-lead diodes.

See Application Note 80000 in Section 7 on suggested handling and bonding procedures for these diodes.

Absolute Maximum Ratings

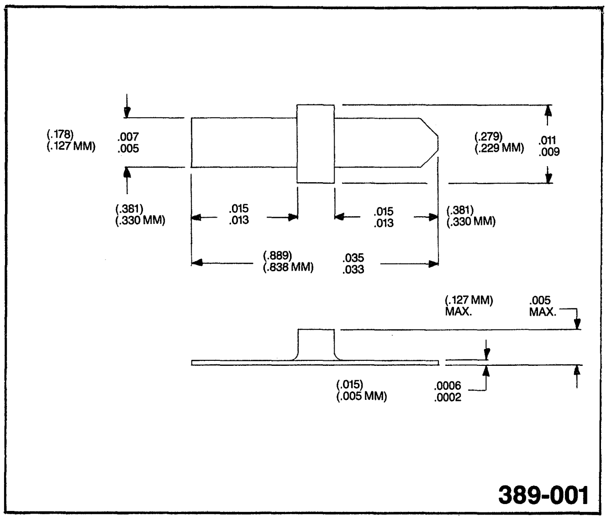
Total power dissipation ....250 mW
Reverse working voltage ....100/200 volts
Storage temperature ....175°C
Operating temperature ....150°C

DSM4380	V_B = 100 VOLTS MIN.	
DSM4380A	R_S = 3.5 Max.,	C_T = 0.03 pF Max.
DSM4380B	R_S = 3.0 Max.,	C_T = 0.04 pF Max.
DSM4380C	R_S = 2.5 Max.,	C_T = 0.06 pF Max.
DSM4380D	R_S = 4.0 Max.,	C_T = 0.06 pF Max.
DSM4380E	R_S = 3.0 Max.,	C_T = 0.025 pF Max.

DSM4381	V_B = 200 VOLTS MIN.	
DSM4381A	R_S = 3.5 Max.,	C_T = 0.03 pF Max.
DSM4381B	R_S = 3.0 Max.,	C_T = 0.04 pF Max.
DSM4381C	R_S = 2.5 Max.,	C_T = 0.06 pF Max.
DSM4381D	R_S = 4.0 Max.,	C_T = 0.06 pF Max.
DSM4381E	R_S = 3.0 Max.,	C_T = 0.025 pF Max.

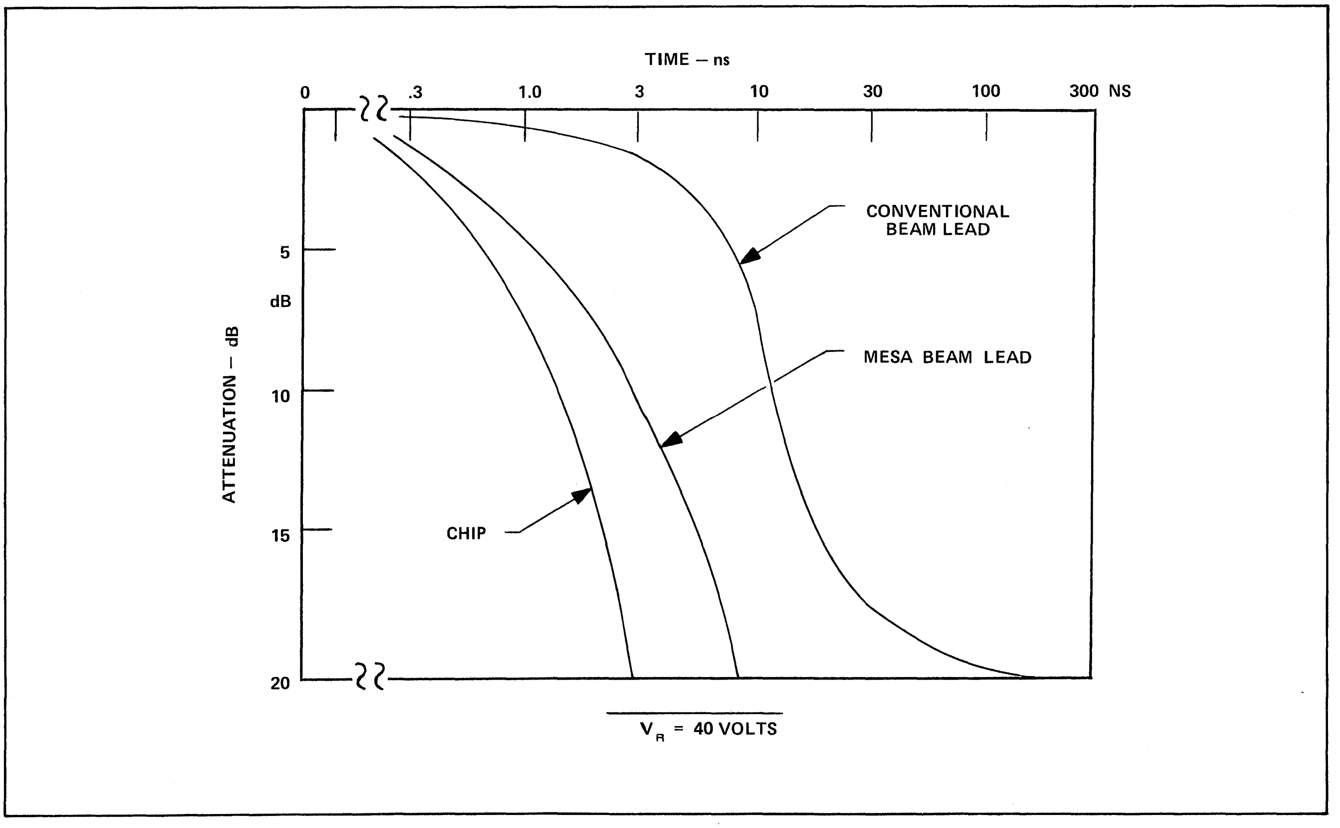
Notes
1. Typical Lifetime 100 ns.
2. Thermal Impedance 300°C/Watt.

Outline Drawing

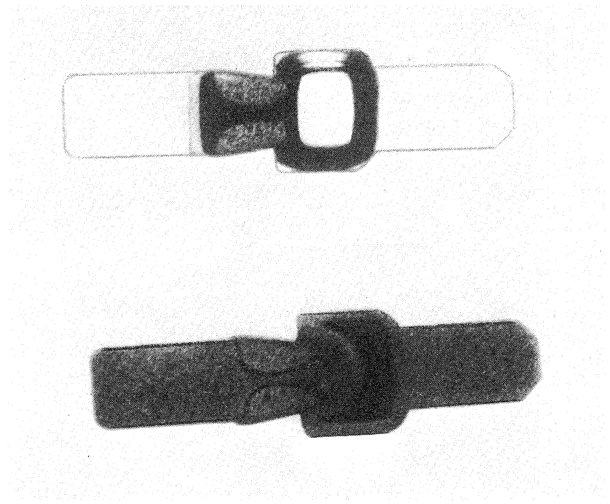


Note: Millimeters in parentheses.

Switching Time Data



Low Resistance High-Speed Beam-Lead PIN Diodes



Features

- Series Resistance Below 1.5 Ohms
- .07 to .12 pF
- Oxide-Nitride Passivated for Reliability
- RF Switching Time Below 10 ns

Types

- DSM4355
- DSM4356

Description

The Alpha DSM4355 and 4356 Series of Mesa Beam-Lead diodes are designed for low series resistance, moderately low capacitance, and fast switching time. Oxide/nitride passivation layers provide reliable operation and stable junction parameters. A layer of deposited glass provides increased mechanical strength.

These beam-lead diodes are designed for microstrip or stripline circuits, for switches, phase shifters, modulators, and attenuators. The inherent low inductance and low series resistance permit use of these diodes as shunt diodes, as well as in the conventional series configuration.

Maximum Ratings at $T_{CASE} = 25°C$

Operating Temperature .... − 65°C to + 175°C
Storage Temperature .... − 65°C to + 200°C
Power Dissipation ....250 mW
(Derate linearly to zero at 175°C)
Minimum Lead Strength .... 4 grams pull on either lead

Electrical Specifications

Model Number	V_B[1] Min.	V_B[1] Typ.	R_S[2] Typ.	R_S[2] Max.	C_P[3] Typ.	C_P[3] Max.	Lifetime[4] (Typ. ns)	Switching[5] Time (Typ. ns)	Video[5] Recovery Time (ns)
DSM4355	50	80	2.0	2.2	.07	.08	50	10	3
DSM4356	30	50	1.2	1.7	.12	.15	40	5	2

Notes:
1. Voltage breakdown is measured at 10 microamps reverse current.
2. Series resistance is measured at 500 MHz, 50 mA.
3. At − 10V, 1 MHz.
4. $I_f = 10$ mA, $I = 6$ mA, recovering to 3 mA.
5. At 2 GHz, from $I_f = 10$ mA to $V_R = 10V$, from 100% to 10% in series configuration. Video reverse recovery time, from $I_f = 10$ mA to $I_R = 2$ mA, with $V_R = 10V$.

Typical Parameters

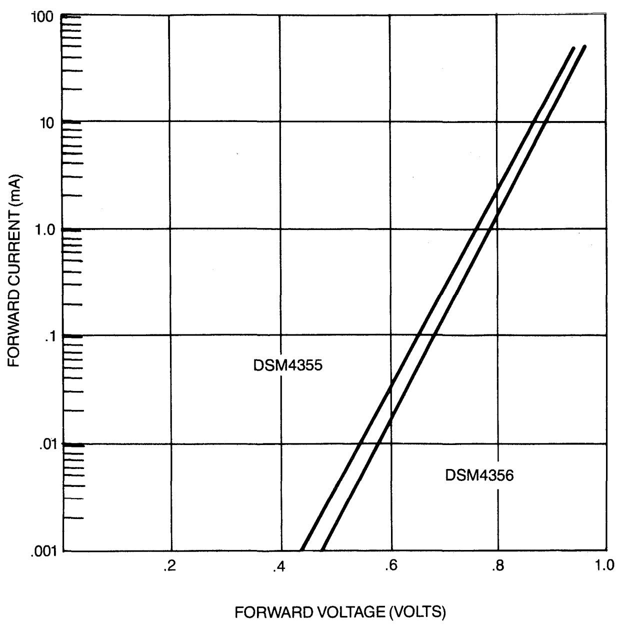


Figure 1. Typical Forward Characteristics

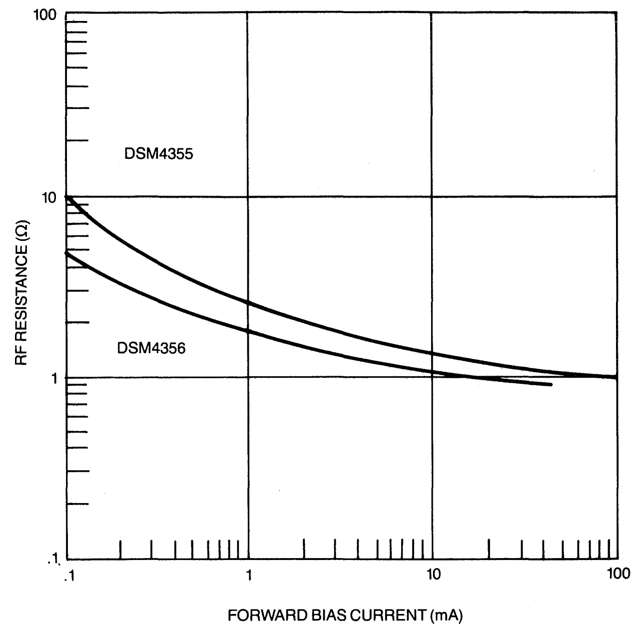


Figure 2. Typical RF Resistance vs. Forward Bias Current

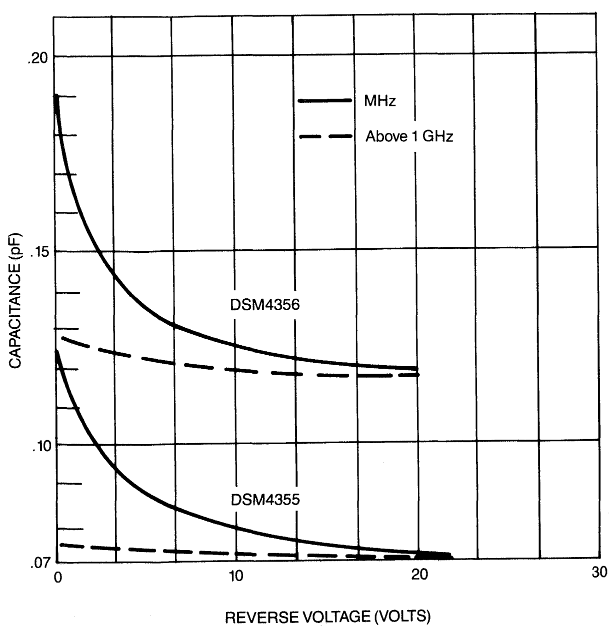
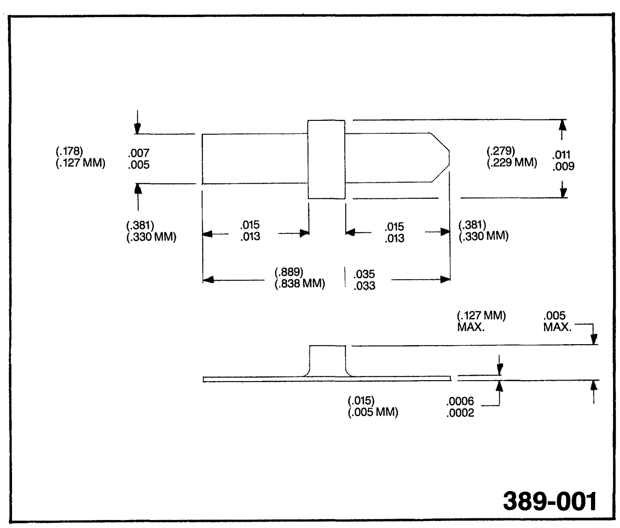


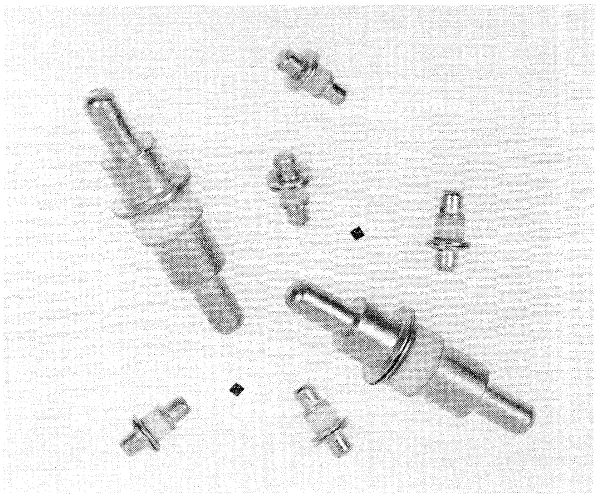
Figure 3. Typical Capacitance vs. Reverse Voltage

Outline Drawing



Note: Millimeters in parentheses.

High Voltage PIN Switching Diodes



Features

- Oxide Passivated
- 500 Volt Breakdown
- 0.1 to 1.0 pF Capacitance
- Low Series Resistance to .25 Ohms
- High Peak and Average Power Handling
- Low Reverse Loss
- Available as Chip or Packaged

Types

- DSA6925 Series
- DSA6928 Series
- CSA7205 Series

Description

The Alpha DSA6925 and DSA6928 Series of high voltage PIN diodes are oxide passivated, double diffused silicon diodes for high power RF switching applications. Low RF resistance and low thermal impedance are optimized for these diodes.

Applications

These diodes, in chip or packaged form, are designed for use in medium to high power pulsed or cw switches, duplexers and phase shifters. Low capacitance and low series resistance provide maximum "open-short" ratios with RF voltages in excess of 500 volts. In chip form, the diodes may be used in hybrid integrated circuits. JAN TX screened units are available in DSA6925 and DSA6928.

Low loss in either forward or reverse bias states combined with low pulsed and average thermal impedance permit use in multi-kilowatt long pulse length systems.

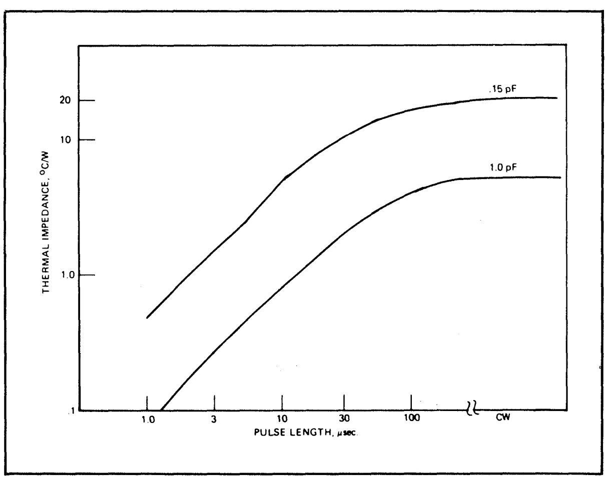


Figure 1. Pulsed Thermal Impedance DSA6925, DSA6928 Series

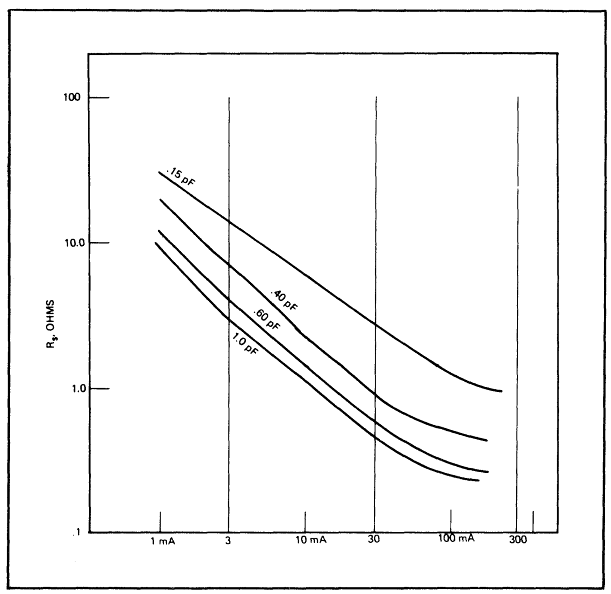


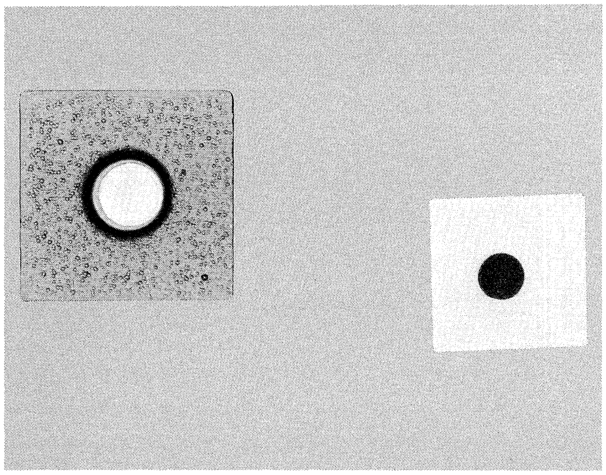
Figure 2. Series Resistance vs. Bias Current DSA6925, DSA6928 Series

Electrical Specifications V_B = 500 Volts Minimum

Model No.	Outline[2] Package	Junction Capacitance[3]	Carrier[4] Lifetime, Typ. µsec.	Series Resistance Typ.[5] ohms	Parallel Rp Typ.[6] ohms	Thermal Impedance °C/W
DSA6925	023-001	.15 pF Max.	.5	1.2	5K	15
DSA6925A	023-001	.40	2.0	.50	4K	10
DSA6925B	023-001	.60	3.0	.40	3K	8
DSA6925C	023-001	4.0	4.0	.25	2K	5
DSA6928	017-001	.15	.5	1.2	5K	15
DSA6928A	017-001	.40	2.0	.50	4K	10
DSA6928B	017-001	.60	3.0	.40	3K	8
DSA6928C	017-001	1.0	4.0	.25	2K	5
CSA7205	150-802	.15	.5	1.2	5K	15
CSA7205A	150-803	.40	2.0	.50	4K	10
CSA7205B	150-803	.60	3.0	.40	3K	8
CSA7205C	150-805	1.0	4.0	.25	2K	5

Notes:
1. 10µA; other V_B available on request.
2. Other packages, glass or metal-ceramic, available on request.
3. – 100 Volts, 1 MHz.
4. 10 mA forward, – 6 reverse, recovering to 3 mA.
5. 100 mA bias, 500 MHz.
6. – 50 V bias, 3 GHz.

Industry Standard PIN Diode Chips



Features

- General Purpose PIN Switching Diodes
- Oxide/Nitride Passivated
- Series Resistance to 0.4 Ohms
- Switching Time to 5 ns

Types

- CSB7151 Series
- CSB7152 Series
- CSB7156 Series

Description

This series of PIN diode chips offers three specific and tightly controlled sets of parameters to duplicate certain industry standard diodes. The 7152 diode is mesa design, oxide passivated. The 7151 and 7156 diodes are planar, with oxide/nitride passivation.

Applications

This series of chips may be used in switches, phase shifters, modulators, and attenuators. In chip form, they are ideal for shunt mounting in stripline and microstrip circuits. They are also conveniently used in LID package styles 173-001 and 173-002, ministrip 176-001 with one or two leads, or post, 184-001 with or without leads.

These chips are also available in standard glass and metal-ceramic packages.

Ordering Information

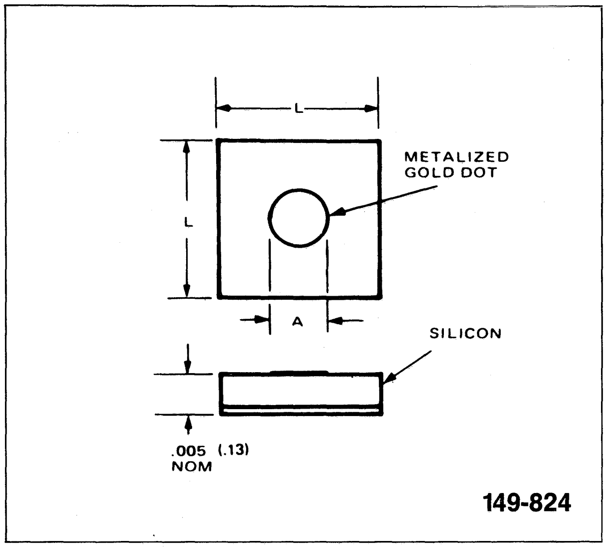
To order, add the six-digit package number or chip designation to model number.

Electrical Specifications

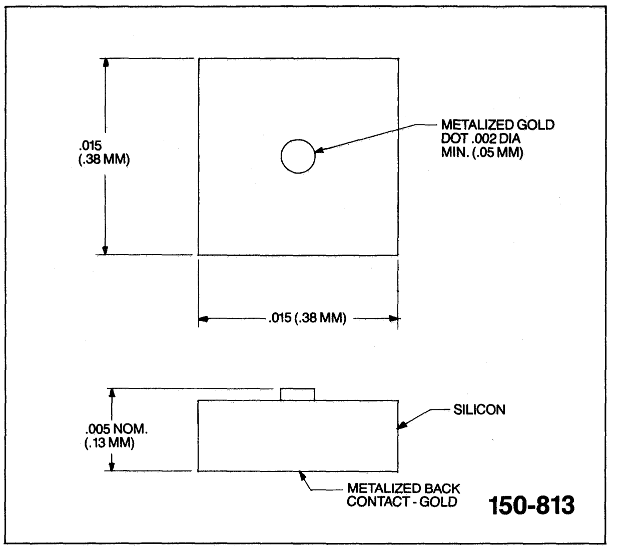
Model Number	V_B[1] (Min.)	C_J[2] (pF Max.)	R_S[3] 1 mA (Typ.)	R_S[3] 10 mA (Typ.)	R_S[3] 100 mA (Max.)	Lifetime[4] (Typ.)	Switching[5] Time (Typ.)
CSB7151-01	150	.12	6.0	2.2	1.0	400	100
CSB7152-01	70	.16	2.5	1.0	0.8	40	5
CSB7156-01	35	.50	1.5	0.5 Max.	0.4	50	12

Notes:
1. Voltage breakdown is measured at 10 microamps reverse current.
2. Capacitance is measured at 1 MHz, 50V for 7151 & 7152, 20V for 7156.
3. Series resistance is measured at 500 MHz.
4. $I_f = 10$ mA, $I = 6$ mA, recovering to 3 mA.
5. $I_f = 20$ mA, $V_R = 10V$.

Outline Drawings

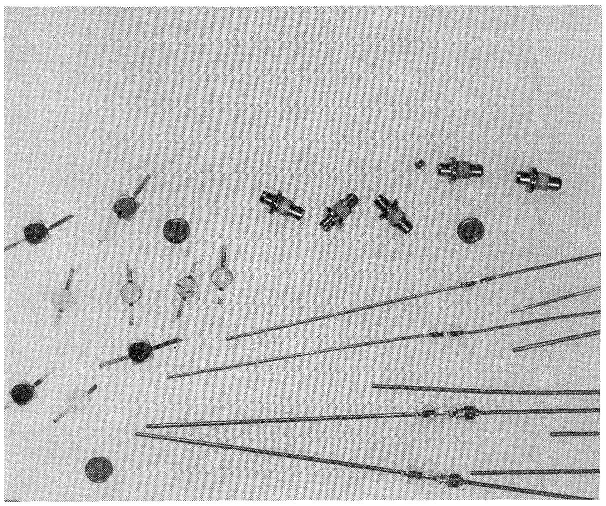


CSB 7151, 7156



CSB 7152

Low Power PIN/NIP Switching and Attenuator Diodes



Features

Optimized for Each Type of Application

- Low Lifetime, Low Resistance for Small Current Drain Switches
- Longer Lifetime, Low Resistance for Medium Power
- Low Lifetime, High Resistance for Attenuators and Modulators
- Long Lifetime for Very Low Frequency Attenuators and Switches

Description

Alpha PIN and NIP diodes are supplied in chip or packaged form for all types of low-loss applications in stripline, microstrip, coaxial and waveguide circuits. They are silicon oxide passivated for highest reliability and are also available in hermetically sealed metal-ceramic and glass packages for use in extreme environmental conditions.

Diode Types

There are four basic types of RF switching applications, and Alpha offers diodes optimized for each type. In all of the products, control of doping profile assures low loss even at zero bias. Diodes with either PIN or NIP polarity are generally available in all types upon request.

1. **Fast Switching:** Diodes for these applications have thin I-regions and low lifetime. Switching speed is under 5 ns, and the diodes have low series resistance at low bias current, offering a steep isolation versus bias characteristic. Suitable for 0.1 to 26 GHz at low power.
2. **Slower Switching:** These diodes have moderately thick I-regions and longer lifetime. They also have a steep isolation curve, but switch in 20 to 100 ns, and can be used with low distortion at power levels to +30 dBm.
3. **High Speed Modulators and Attenuators:** These are low lifetime, thick I-region diodes with gradual isolation curves, making them more suitable for continuously variable attenuators. Low lifetime makes them ideal for switches or attenuators with high modulation rates.
4. **Low Frequency Attenuators and Switches:** For these applications Alpha has developed thick I-region, long lifetime diodes. Minority carrier lifetime to 10 microseconds makes them suitable down to 100 MHz. They are also suitable for higher power applications.

Applications

The table of specifications lists the microwave characteristics of the basic semiconductor chips. The circuit designer may use these data, together with the package parasitic characteristics, in modeling the diode in the particular circuit environment. "PIN Diode Basics" are presented in Application Note 80200 at the end of this section.

Diode Design Trade-Offs

Diode Design Parameters	Fast Switching or High Modulation Rates	Low Capacitance	Low Forward Resistance	Low Reverse Loss	Low Thermal Impedance	High Power
Lifetime	Low	—	High	—	—	High
1 Layer Width	Thin	Thick	Thin	—	Thick	Thick
1 Layer Area	Small	Small	Large	Large	Large	Large
Resistivity	High	High	—	High	—	—

The measurement of diode loss (R_P) and series resistance (R_S) can be made on both packaged diodes (the diode is used as the terminating impedance on a 50 ohm slotted line) and on chips (in microstrip circuitry). If you buy packaged diodes, the parameters will be 100 percent tested; if you buy chips, the voltage breakdown and junction capacitance will be 100 percent tested. The microwave parameters will be determined from a sample evaluation from each wafer, packaged. Wafer identity and evaluation sample data can be provided.

It is easy to describe and explain PIN chip performance in microstrip MIC, and the following deals with such circuits.

By incorporating the chip and the required bonding wire into the transmission line, rather than as shunt elements onto the line, parasitic inductance is almost totally eliminated, and multi-octave performance is achieved.

Consider Figure 1, which shows 3 chips mounted in a 50 ohm microstrip line. The bonding wires are selected, length and size, in conjunction with the capacitance of the chip, to form a low-pass L-C filter section. The characteristic impedance of this section approximates 50 ohms and the electrical length (phase shift) is low enough to provide better than 1.5 VSWR through 18 GHz. Figure 2 shows typical VSWR curves for single diode sections, with different chip capacitance values. Chip spacing ℓ_1 and ℓ_2 are varied to provide broadband matching and isolation characteristics and are typically 0.1 wavelength at X-band. Figure 3 shows isolation as a function of diode spacing for a pair of PIN chips.

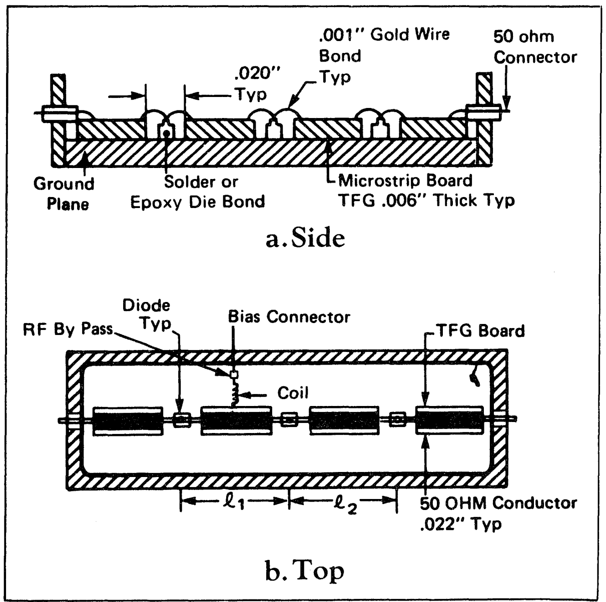


Figure 1. Typical Microstrip Design

Series resistance and isolation for single chips, in a SPST configuration, are shown in Figure 4. Diode insertion loss is caused by a complex dielectric constant and is minimized by optimum control of I-region resistivity and profile. It is characterized as a shunt (parallel) resistance, R_P, which is tabulated for each diode type; this loss is maximum at zero bias. For thicker I-regions loss can be reduced significantly by application of reverse bias of a few volts. Figure 5 presents R_P data on a few of the diodes. The tabulated data on each type, at 3 GHz and zero bias, can be used together with Figure 5 to estimate small signal loss for any diode under various conditions.

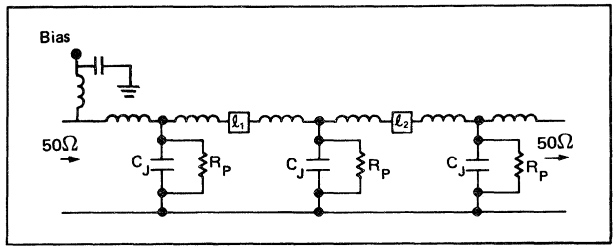


Figure 1c. Zero or Reverse Bias Equivalent Circuit

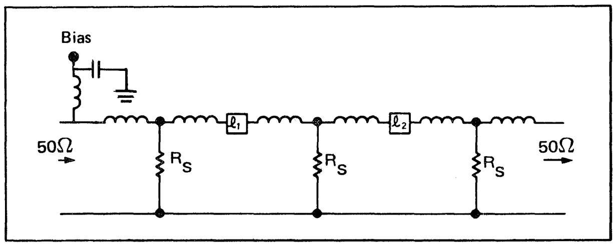


Figure 1d. Forward Bias Equivalent Circuit

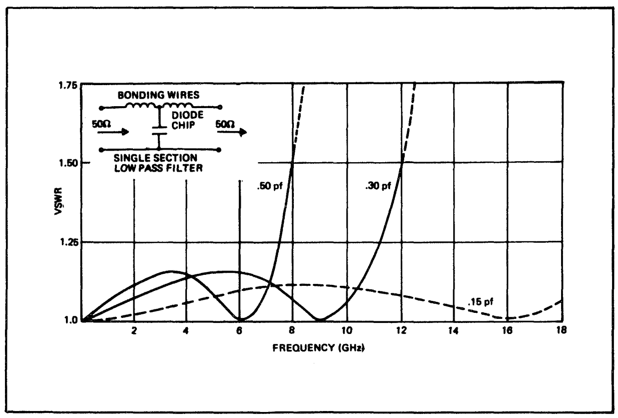


Figure 2. Typical VSWR for Low Pass Filters

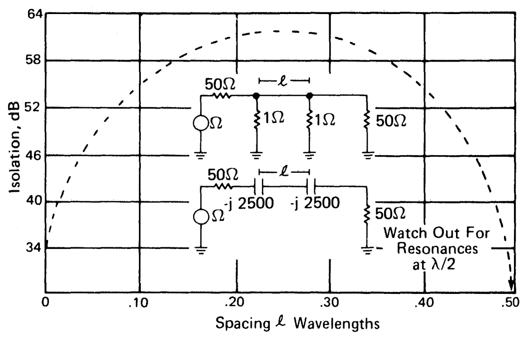


Figure 3. Isolation as a Function of PIN Diode Spacing

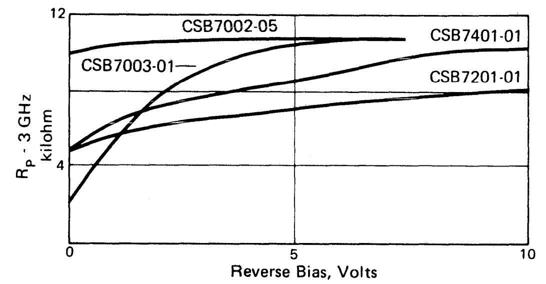


Figure 5. Parallel Resistance vs. Bias

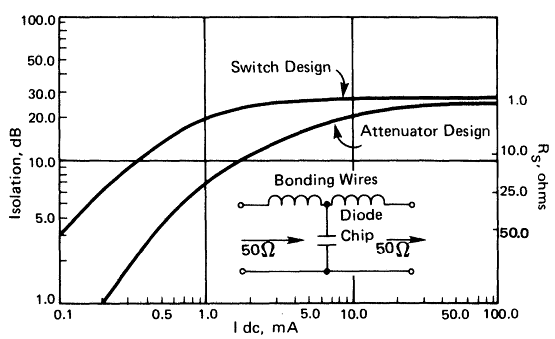


Figure 4. General Curves of Isolation and R_S vs. Bias for Attenuator and Switch Designs

Low Power PIN/NIP Switching and Attenuator Diodes

Specifications[8]

RF Applications	Model Number	Min[1] V_B (V)	C_{J50}[2]	Max[3] R_{100mA} (ohms)	Typ[3] R_{1mA} (ohms)	T_S[4] Typ (ns)	T_L[5] Typ (ns)	R_P[6] Typ (K-ohms)	θcw[7] (typ)
Fast Switching	CSB7002-01	80	.03-.08	1.8	8.0	5	50	3.0	80
	CSB7002-02	80	.08-.13	1.5	2.5	5	80	1.5	60
	CSB7002-03	80	.13-.23	1.2	2.5	5	80	1.5	40
	CSB7002-04	80	.23-.33	1.0	2.0	5	100	1.0	40
Lowest Loss	CSB7002-05	25	.03-.08*	1.5	3.0	5	20	10	100
	CSB7002-06	25	.08-.13*	1.2	2.5	5	20	10	80
	CSB7002-07	25	.13-.23*	1.2	2.5	5	20	10	60
Slower Switching	CSB7003-01	80	.03-.08	1.5	2.5	20	150	2	80
	CSB7003-02	80	.08-.13	1.2	2.5	20	200	2	60
	CSB7003-03	80	.13-.23	0.9	2.5	20	250	2	40
	CSB7003-04	80	.23-.33	0.8	2.5	20	300	1	40
High Speed Attenuator	CSB7401-01	100	.10 max	1.4	15	5	50	5	80
	CSB7401-02	100	.10-.15	1.2	10	5	80	5	60
	CSB7401-03	100	.15-.25	1.0	10	5	100	5	50
Low Frequency Attenuator	CSB7201-01	200	.10 max	1.4	50	20	1μs	3	50
	CSB7201-02	200	.20 max	1.2	30	20	1.5μs	3	40
	CSB7201-03	200	.50 max	0.7	20	—	10μs	2	30
Flat Chip (lower cost general purpose)	CSM7301-01	100	.03-.08	1.2	8	20	100	5	70
	CSM7301-02	100	.03-.13	1.0	8	20	150	5	50
	CSM7301-03	100	.13-.23	0.8	5	20	200	3	40
	CSM7301-04	100	.03-.08	2.0	15	5	50	5	70
	CSM7301-05	100	.08-.13	2.0	15	5	70	5	50
	CSM7301-06	100	.13-.23	1.5	15	5	100	3	40
High Speed 075-001 (glass pkg only)	D5151	50	.20 total	3.0	10	2.5	50	2	300
	D5151A	80	.10 total	2.5	10	2.5	50	2	300

ORDERING INFORMATION
Add six digit package or chip style designation to model number.
EXAMPLE: CSB7002-01 -023 -001

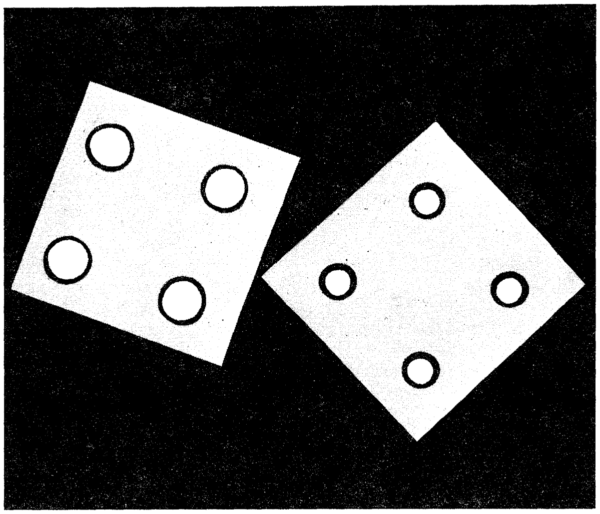
NOTE: Not all chip styles are available in all series. Typically,
CSB7002, 7003 and 7401 series are 150-801 and 802
CSB7201 series are 150-802 and 803
CSM7301 series are 149-801 and 802

EXAMPLE: CSB7002-01 — 150-801 OR CSB7002-03 — 023-001

CSB7002-01	—	150-801	OR	CSB7002-03	—	023-001
Basic model number		Chip		Basic model number		Package style

Notes:
1. V_B is measured at 10μA.
2. C_j is measured at 1 MHz at −50V bias. (*at 6V.)
3. R_s is measured at 500 MHz.
4. T_s is the rf switching time, from 90% to 10% and 10% to 90% transmission. The bias conditions are +10 mA/−10 Volts.
5. T_L is the minority carrier lifetime measured with I_f = 10 mA, I_R = 6mA, recovering to −3 mA.
6. Diode dissipative loss can be represented as a shunt resistance across the junction capacitance. Data presented for 3.0 GHz, zero bias.
7. Typical cw thermal impedance in package 023-001.
8. The diodes listed are representative of a standard product line. Diodes with different or more stringent specifications are available on request. In particular, the variation of series resistance with current can be tailored to meet almost any need. To assist the circuit designer, Table 1 summarizes some of the trade-offs involved in switching diode design.

PIN, NIP Switching Diode Multi-Junction Chips



Features

- Low Capacitance .... .02pF
- Low Forward Resistance .... 1.5 Ohms
- Fast Switching ....10–20 ns
- Low Thermal Resistance
- Full Area Bonding Metal
- Silicon Dioxide Passivation

Description

Designed especially for hybrid microwave circuit applications, these PIN, NIP Diodes are single chip devices which contain several junctions.

More important than the advantage of saving space from the high packing density is the improved performance gained by utilizing devices with closely matched characteristics which result from the close proximity of the junctions of the wafer.

These devices are passivated using thermally grown silicon dioxide with gold metallization covering the mesa surface providing maximum bonding area. Alpha's PIN, NIP Chips are available in 2, 4, 6, and 8 junction configurations.

Applications

The multi-junction PIN (NIP) when mounted on the common arm of a multi-throw switching section, serves as the series diode for each of the ports. In the "off" state, the low capacitance of the diode provides high isolation between ports. In the "on" state, the forward-biased resistance of the diode is low enough to provide low insertion loss. Switching between the two states can be accomplished in 10–20 ns depending upon the type selected.

The physical proximity of the junctions compared to a wavelength at the intended frequency of use makes the device look like a true point junction. This reduces undesirable parasitic effects which can result from the interconnection of several discrete devices. The low thermal resistance achieved through this approach produces a device usable for applications where the power dissipation of beam-lead equivalents might be exceeded.

Absolute Maximum Ratings

Reverse Working Voltage .... 100 Volts
Storage Temperature .... – 65° C to + 175°C.
Operating Temperature .... – 65°C to + 125°C.

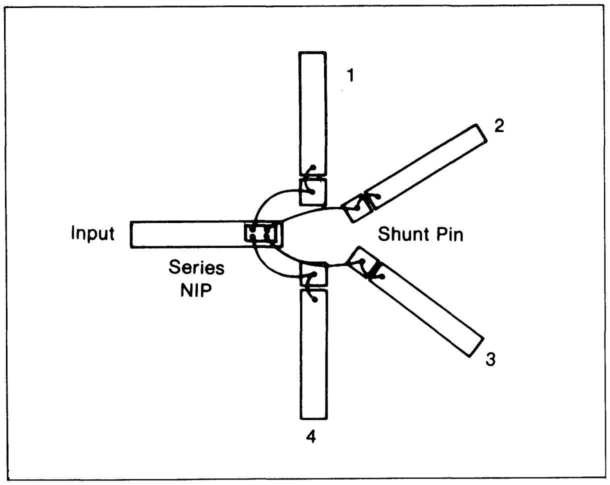
PIN, NIP Switching Diode Multi-Junction Chips

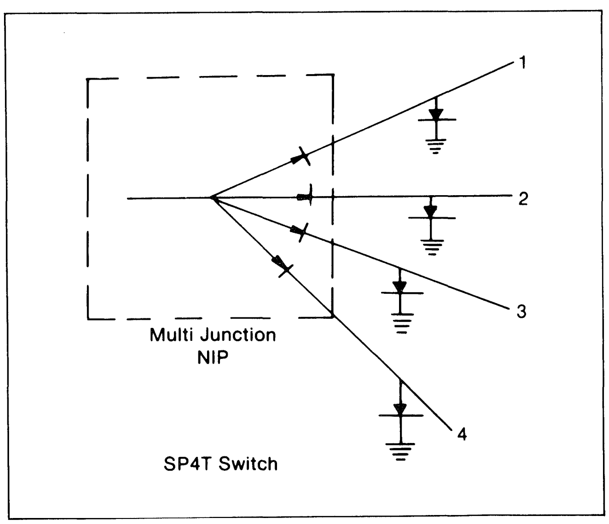
Electrical Specifications ($T_A = 25°$ C)

Model Number	Polarity Designation	V_B Min.[1] @ 10μA (Volts)	C_J[2] @ 50 V (pF)	R_S Max. @ 20 mA (Ohms)	T_L Typ.[3] (ns)	T_S Typ.[4] (ns)
CSP-9200	PIN	100	.015–.03	3.5	100	20
CSP-9210		100	.03–.05	2.5	125	20
CSP-9220		100	.05–.07	1.8	150	20
CSN-9250	NIP	100	.015–.03	3.5	100	20
CSN-9260		100	.03–.05	2.5	125	20
CSN-9270		100	.05–.07	1.8	150	20

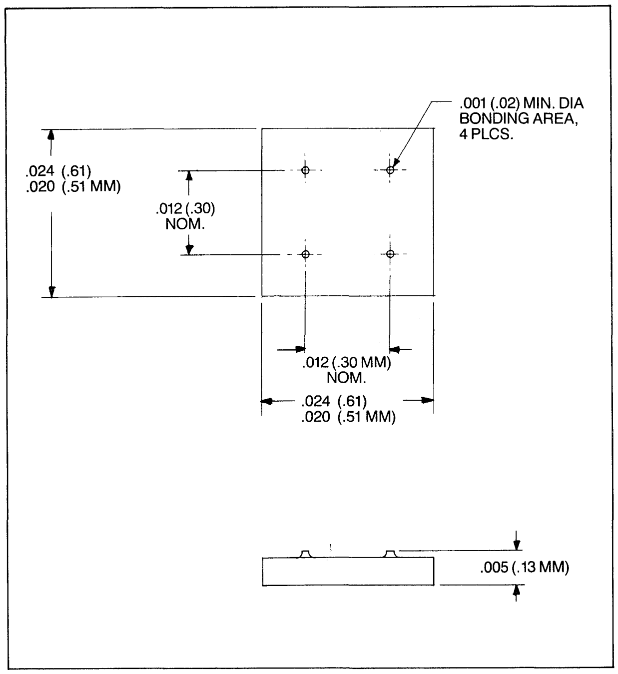
Notes:
1. V_B is measured at 10μA.
2. C_j is measured at 1 MHz at − 50V bias.
3. T_L is the minority carrier lifetime measured with I_f = 10 mA.
   I_r = 6 mA recovering to − 3 mA.
4. T_s is the rf switching time from 90% to 10% and 10% to 90% transmission. The bias conditions are + 10 mA 10 volts.
5. The diodes listed here are representative of a standard product line. Diodes with different or more stringent specifications are available on request.

Typical Application SP4T Switching Section

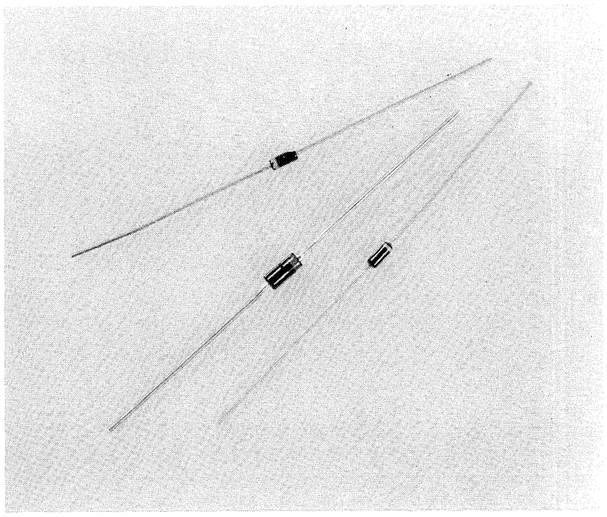




Outline Drawing



Low Cost — Low Inductance Double Slug PIN Diodes



Features

- Hermetically Sealed
- 0.6 nH Inductance
- 300 Volt Breakdown
- 0.5 to 1.2 pF Capacitance
- Series Resistance to .25 Ohms
- Improved Thermal Resistance

Types

- DSB3608 Series
- DSB3609 Series

Description

The Alpha DSB 3608 and 3609 series of low cost PIN diodes are passivated PIN chips bonded between two dumet slugs, and sealed within a sleeve of high temperature glass for hermeticity and mechanical strength. This full area bonding technique eliminates the parasitic inductance of a bonding strap, and also provides maximum heat transfer from the chip.

Notes

1. Parasitic inductance depends on the circuit mounting environment, such as the length of exposed leads, proximity to ground, and so on. For reference, the values quoted by Alpha are measured in a 50 ohm coaxial line, with a center conductor diameter of .050 inches.
2. Thermal impedance depends upon mounting:

Type	°C/Watt suspended in air	°C/Watt, one end soldered to heat sink
3608-02	240	200
3609-01	200	160

Applications

These diodes may be used in applications presently satisfied by conventional glass packaged diodes.

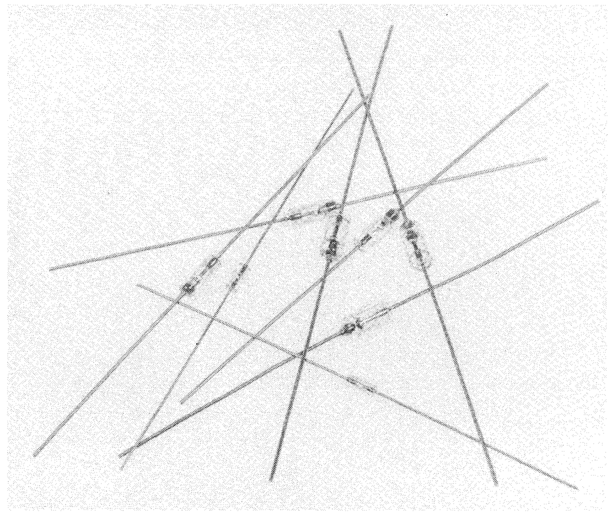
Parasitic capacitance is higher than in a conventional glass package, but is no higher than many commonly used ceramic packages. Typical applications for these diodes include low to medium power pulsed or CW switches, phase shifters, and attenuators.

Electrical Specifications

Model Number	V_B[1]	C_{T50}[2] (Max.)	Rs[3] (5 mA)	Rs[3] (100 mA)	T_L[4] (Min. ns)	Package Outline
DSB3608-01	100	0.6	5.0 typ	1.0 max	600	420-001
DSB3608-02	100	1.0	0.7 max	0.4 typ	100	420-001
DSB3608-03	150	1.5	1.5 typ	1.0 max	800	420-001
DSB3608-04	150	2.0	0.7 max	0.4 typ	400	420-001
DSB3608-05	300	1.0	—	1.4 max	1,000	420-001
DSB3609-01	300	1.0	—	1.4 max	1,000	421-001

Notes:
1. Voltage breakdown is measured at 10 microamps reverse current.
2. Capacitance is measured at 1 MHz, and includes package capacitance.
3. Series resistance is measured at 500 MHz.
4. Minority carrier lifetime is measured with 10 mA forward, 6 mA reverse, recovering to 3 mA.

Current Controlled Attenuator Diodes



Features

- Large Resistance Range
- Low Series Resistance
- Low Harmonic Distortion
- Low Capacitance

Types

- DSB6419 Series

Description

The forward biased resistance of a PIN diode is determined by the magnitude of the bias current. These devices are specifically designed so that the resistance can be varied over a wide range of current (1 µA to 100 mA). The resistance is nearly log-linear with current over this range providing a wide variation in resistance from 10,000 ohms or more at the low current end to 2-4 ohms or less, depending on the device type.

Applications

These devices are designed for use in current controlled attenuator and modulator applications. They can also be used for electronically tuned filters, phase shifter, and switch applications.

The low capacitance allows their use well into the microwave region. These devices also have a long lifetime and thick intrinsic region allowing their use at frequencies as low as 1 MHz with low distortion. Several levels of resistance (10-100 ohms at 1 mA) are available in the series allowing flexibility of design.

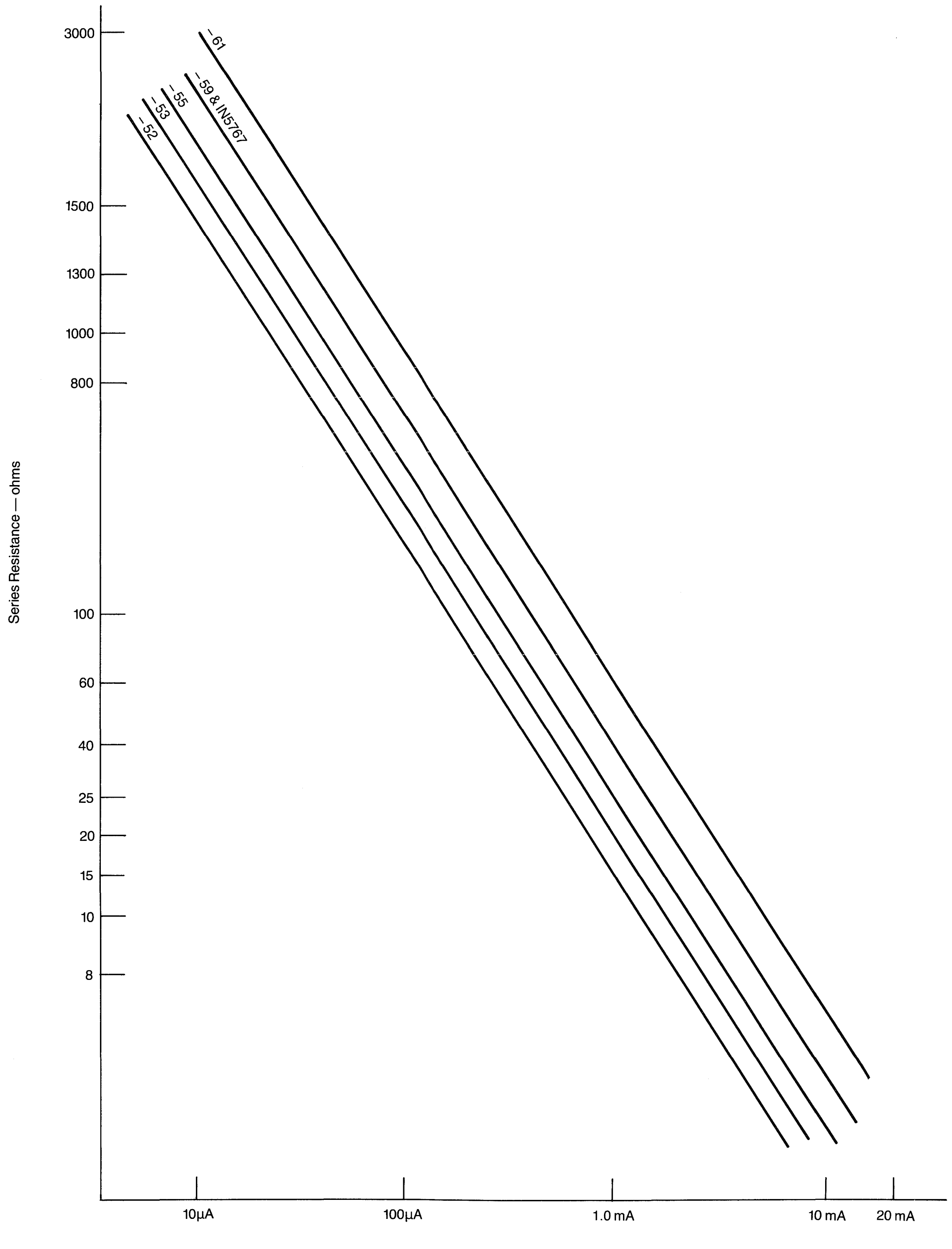
Electrical Specifications[1]

Part Numbers	Typical Resistance 1.0 mA 100 MHz ohms	High Resistance 10.0µA 100 MHz ohms (Min.)	Low Resistance 20.0 mA 100 MHz ohms (Max.)	T_L[(2)] $I_f = 10$ mA $I_R = 6$ mA ns (Min.)	C_T – 50V 1.0 MHz pF (Max.)	V_B $I_R = 10$µA — volts (Min.)	Series Resistance 100 mA 100 MHz ohms (Max.)
DSB6419-52	15	800	—	800	0.3	100	1.5
DSB6419-53	20	1100	—	800	0.3	100	1.5
DSB6419-55	25	1200	—	800	0.3	100	1.5
DSB6419-59	40	1500	8.0	1000	0.4	100	2.5
DSB6419-61	60	1500	—	1300	0.4	100	3.5
1N5767[(3)]	40	1000	8.0	1000	0.4	100	2.5

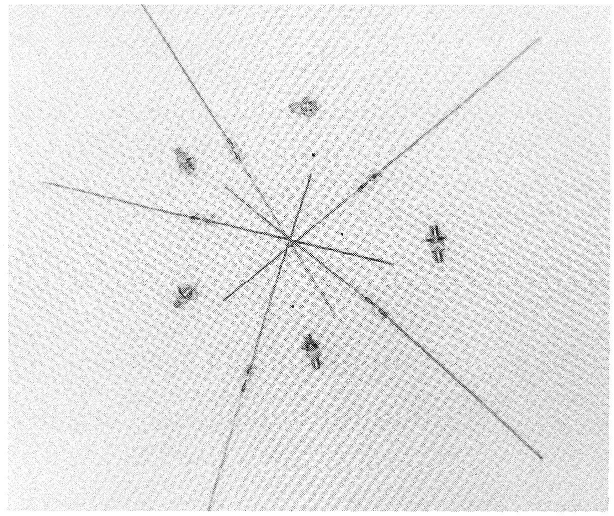
Notes:
1. The diodes listed are representative of a standard product line. These devices are also available in many of the ceramic microwave packages for applications where package parasitics are of concern. Chips are also available.
2. T_L is the minority carrier lifetime.
3. 1N5767, additional specifications: I_R @ – 50 V = 1.0 µA Max.; V_F @ 100 mA = 1.0 V Max.

Current Controlled Attenuator Diodes

Series Resistance vs. Forward Current



Limiter Diodes



Features

- Lowest Loss
- 4 kW Coarse Limiters
- 200 Watt Midrange Limiters
- 10 mW Clean-Up Limiters

Types

- CLA3131 Series
- CLA3132 Series
- CLA3133 Series
- CLA3134 Series
- CLA3135 Series

Description

Alpha Industries has pioneered the microwave limiter diode. Because all phases of manufacture, from design, through epitaxy, to the finished device are specifically tailored to this application, Alpha limiters have lower loss, greater bandwidth and faster turn-on time than equivalent competitive diodes.

The Alpha CLA3131, 3132, 3133, 3134, and 3135 series of thin base limiter diodes will provide passive receiver protection over the entire range of frequencies from 100 MHz to beyond 20 GHz.

These diodes are PIN silicon devices with a thin intrinsic region, typically 2 microns for the CLA3131 and 3134, 4 microns for the CLA3132 and 3135, and 15 microns for the CLA3133 series. They operate as a power dependent variable resistance, through mechanisms of charge injection and storage, similar to rectification, when used in microwave circuitry as shown in Figure 1a. The different "I" region thicknesses and capacitances provide variable threshold and leakage power levels and power handling capability. The CLA3133 series, which can handle incident pulses of up to 4 kW for 1 µs, are used as "coarse" prelimiters, with the thinner diodes used as clean-up or "fine" limiters to reduce the leakage power to as low as 10 mW for protecting the most sensitive receivers.

At receive signal levels these diodes behave at low capacitances, even at zero bias. Loss of 0.3 dB at 18 GHz is typical.

In addition to the passive operation as shown in Figure 1a, the diodes can be used as quasi-active limiters (Figure 1b), with a Schottky barrier detector diode providing DC current to the PIN, and as active PIN switches for STC modes (see Figure 1c), while simultaneously providing the passive limiting mode.

The CLA3131 and 3132 limiter diodes are constructed in a passivated flat-chip configuration and are available in a basic chip form or encapsulated in a variety of Alpha glass or ceramic packages, a few of which are shown.

Limiter diodes with lower capacitance values, to 0.08 pF, constructed with a passivated mesa configuration, are available in the CLA3134 and 3135 series. The mesa devices offer low C_J, and therefore broader bandwidth, lower loss, and faster response, at slightly reduced power. These diodes are also available in chip or package form, and represent the ultimate in limiter performance, not approached by other manufacturers.

The CLA3133 diodes (highest power) are available in both planar and mesa construction.

Model Number	DOT Diameter (Typ.) inches	mm	Typical Chip Style
CLA3131-01	0.0015	0.04	149-801,802,806
CLA3131-02	0.0025	0.06	149-801,802
CLA3131-03	0.0035	0.09	149-801,802
CLA3132-01	0.002	0.05	149-801,802
CLA3132-02	0.003	0.75	149-801,802
CLA3132-03	0.0045	0.11	149-801,802
CLA3133-01	0.003	0.75	149-802,150-802
CLA3133-02	0.004	0.10	149-802,150-802
CLA3133-03	0.005	0.12	149-802,150-802
CLA3134-01	0.001	0.02	150-806
CLA3134-02	0.0015	0.04	150-806
CLA3135-01	0.0015	0.04	150-806
CLA3135-02	0.0025	0.06	150-801

Limiter Diodes

The diagrams in Figures 2a and 2b illustrate the fundamental structures of diodes mounted in a 50 ohm microstrip circuit. The diode characteristics listed in the table refer to chips mounted in such a circuit. The designer can use these parameters in modeling the chip in any package, provided overall package parasitics are considered. Additional information detailing limiter package parasitics are considered. Additional information detailing limiter package parasitics and bonding and handling methods are contained in Alpha application notes.

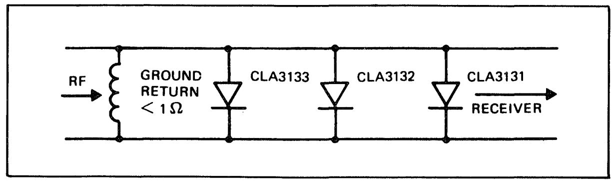


Figure 1a. Cascaded Limiter Design

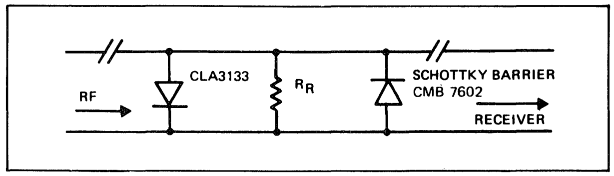


Figure 1b. Quasi-active Limiter

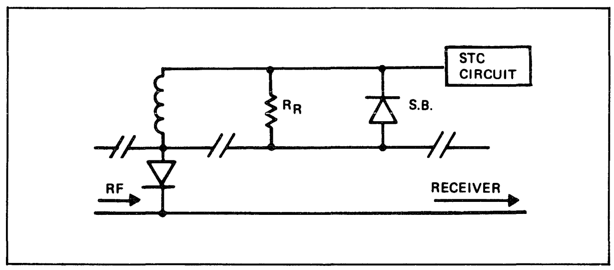


Figure 1c. Limiter/STC Dual Function

Basic Application

When designing microstrip limiters the bonding wire length and diameter, in conjunction with the chip capacitance, form a low pass filter. (See Figure 3). Line lengths of (ℓ_1 and ℓ_2) are varied to provide broadband matching and flat leakage characteristics. Typically, ℓ_1 and ℓ_2 are on the order of 0.1 λ. In Figure 1a, the CLA3133 chip provides about 20 dB attenuation, reducing a 1 kW input to 10 watts. The CLA3132 reduces this to 100 mW and the 3131 to about 20 mW.

During the rise time of the incident pulse, the diodes behave in the following manner. The CLA3131, due to its thin "I" region, is the first to change to a low impedance. Experiments indicate that the 3131 reaches the 10 dB isolation point in about 1 ns and 20 dB in 1.5 ns with an incident power of 10 watts. The CLA3132 takes about 4 ns and the 3133 about 50 ns. Consequently, the CLA3131 provides protection during the initial stages of pulse rise time, with the thicker diodes progressively "turning on" as the power increases. With proper spacing (ℓ_1 and ℓ_2), the "on" diodes reflect high impedances to the upstream diodes, reducing the turn-on time for those diodes and insuring that essentially all of the incident power is reflected by the input diode, preventing burnout of the thinner diodes. At the end of the pulse the process reverses, and the diodes "recover" to the high impedance state; the free charge which was injected into the "I" region by the incident power leaks off through the ground return and additionally is reduced by internal recombination. With a ground return, recovery time is on the order of 50 ns. With a high impedance return, for example the circuit of Figure 1b, the Schottky diode recovers or "opens" in practically zero time, and internal recombination, on the order of several diode lifetimes, is the only available mechanism for recovery. This recovery time can be long — on the order of 1 µs for the CLA3133 series. The shunt resistor R_R minimizes this problem. One hundred ohms will approximately double the recovery time, compared to a short circuit.

When the Schottky diode is directly coupled to the transmission line, in cascade after the coarse limiter, the leakage power will be less than if a zero ohm ground return were used. If the Schottky is decoupled too much, the leakage power increases, owing to the high DC impedance of a Schottky. Similarly, a 3.0 ohm ground return causes an increase of about 3 dB in leakage power compared to a zero ohm return.

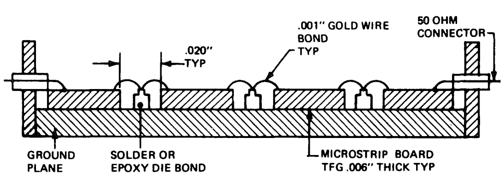


Figure 2a. Side View

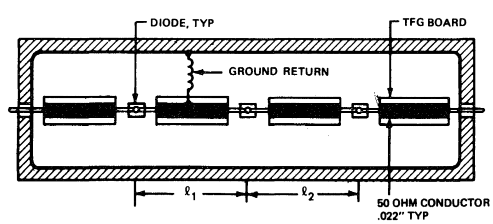


Figure 2b. Top View

Figure 2a and b. Typical Microstrip Design

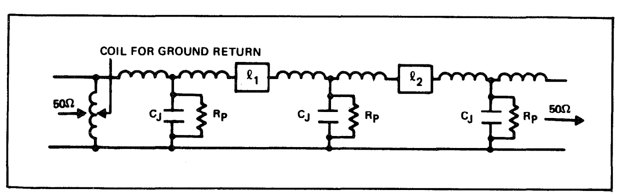


Figure 2c. Low Level Equivalent Circuit

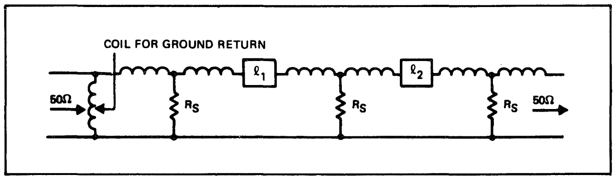


Figure 2d. High Power Equivalent Circuit

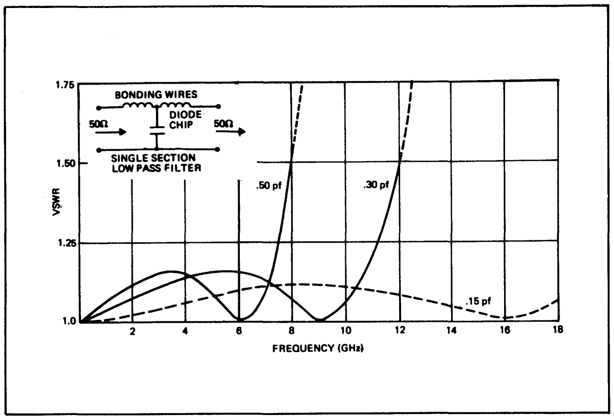


Figure 3. Typical VSWR for Low Pass Filters

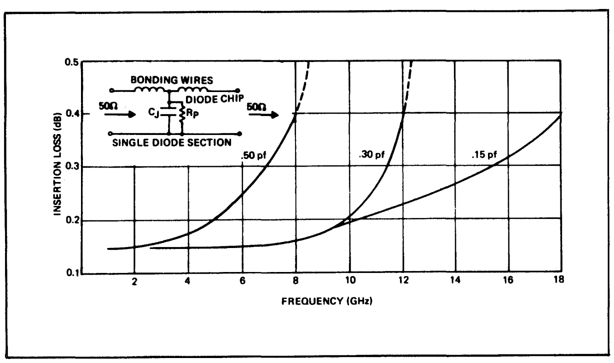


Figure 4. Typical Diode Insertion Loss vs. Frequency

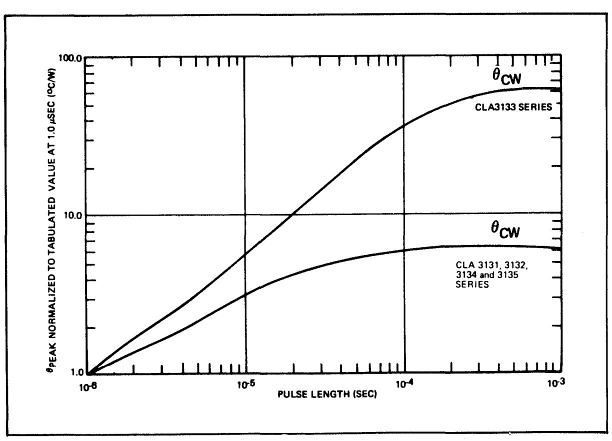


Figure 5. Pulsed Thermal Impedance

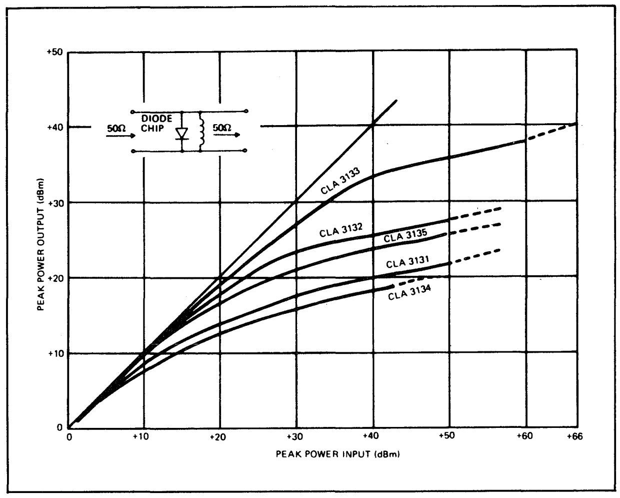


Figure 6. Typical Peak Leakage Power at 1 GHz

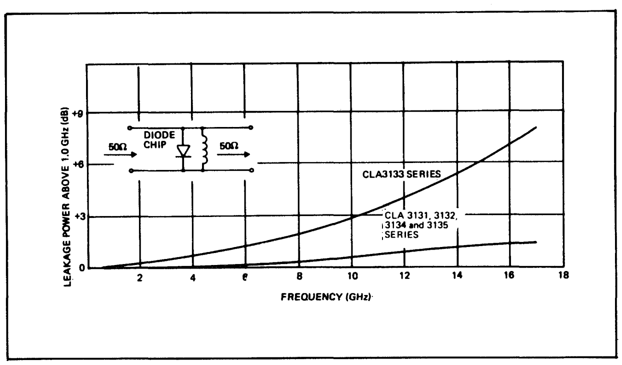


Figure 7. Leakage Power vs. Frequency

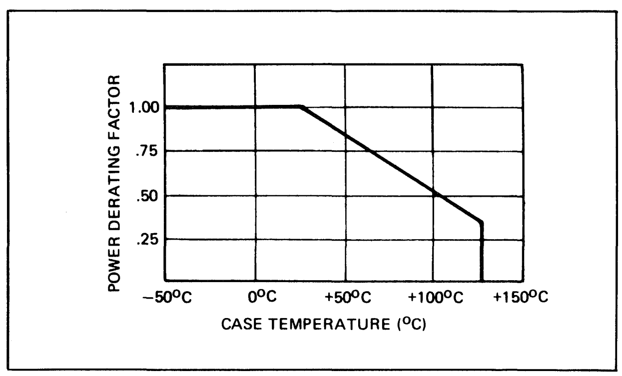


Figure 8. Power Handling Capability vs. Temperature

Limiter Diodes

Chip Electrical Parameters

Model Number	V_B Typ (V)	C_{j0} Typ (pf)	C_{j6} Max. (pf)	R_S Typ @10 mA (Ω)	@1.0 mA (Ω)	R_P[2] Typ (Ω)	θ_P[3] Typ (°C/W)	θ_{cw} (°C/W)	τ_L Typ (ns)
CLA3131-01	20–45	0.20	0.15	1.5	5.0	2000	20	100	5
CLA3131-02		0.50	0.30	1.2	4.5	1000	12	80	10
CLA3131-03		0.70	0.50	1.0	4.0	1000	10	55	10
CLA3132-01	45–75	0.20	0.15	1.5	4.0	2000	15	80	10
CLA3132-02		0.50	0.30	1.2	3.5	1000	10	60	15
CLA3132-03		0.70	0.50	1.0	3.0	1000	6	40	20
CLA3133-01	120–180	0.20	0.15	1.5	3.5	2000	1.2	40	50
CLA3133-02		0.60	0.30	1.0	3.0	1000	0.5	20	50
CLA3133-03		0.80	0.50	0.5	3.0	1000	0.3	15	100
CLA3134-01	15–30	0.12	0.10	2.0	4.0	3000	30	120	5
CLA3134-02		0.20	0.15	1.5	3.0	2000	20	80	5
CLA3135-01	30–60	0.12	0.10	2.0	4.0	3000	20	100	7
CLA3135-02		0.20	0.15	1.5	4.0	2000	15	70	7

Limiter Performance Ratings

Model Number	Peak P_{in} Max. @1.0 μs (dBm)	Threshold[4] Typ (dB)	Leakage[4] P_{out} Typ (dBm)	Insertion Loss[2] Typ (dBm)	CW[5] Power In Max. (W)	Recovery[6] Time, Typ (ns)
CLA3131-01	+50	+10	+22	0.1	2	10
CLA3131-02	+53	+10	+24	0.2	3	10
CLA3131-03	+56	+10	+25	0.2	4	10
CLA3132-01	+53	+15	+27	0.1	3	20
CLA3132-02	+56	+15	+29	0.2	4	20
CLA3132-03	+59	+15	+31	0.2	5	20
CLA3133-01	+60	+20	+39	0.1	5	50
CLA3133-02	+63	+20	+41	0.2	10	50
CLA3133-03	+66	+20	+44	0.2	15	50
CLA3134-01	+47	+7	+19	0.1	2	5
CLA3134-02	+50	+7	+22	0.1	3	5
CLA3135-01	+47	+12	+24	0.1	3	10
CLA3135-02	+50	+12	+27	0.1	4	10

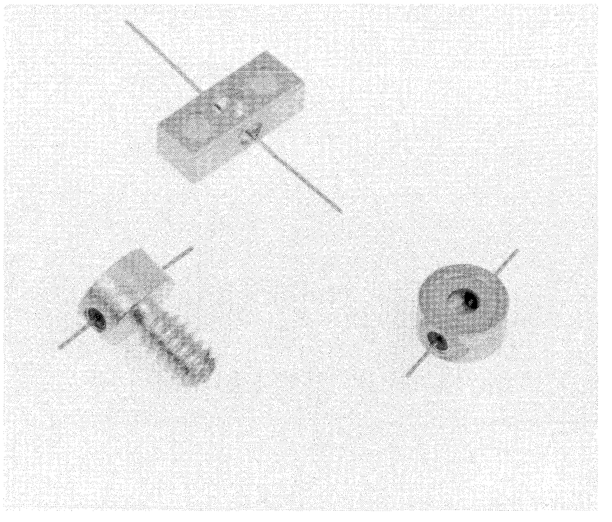
Add six digit package or chip style designation to model number.

NOTE:
Not all chip styles are available in all series. Typically,
CLA3131, 3132 are 149-801, 802, or 806
CLA3134, 3135 are 150-801, 802, or 806
CLA 3133 are 150-801, 802, and 149-801, 802.

EXAMPLE: CLA3131-01 – 149-802 OR CLA3132-03 – 023-001

Basic model number		Chip		Basic model number		Package style
CLA3131-01	–	149-802	OR	CLA3132-03	–	023-001

Notes:
1. Series resistance measured at 500 MHz.
2. Chip loss can be represented as a resistance in shunt with the junction capacitance. Figure 4 indicates typical variation with frequency. Data shown are for 10 GHz for 0.15 and 0.30 pF chips, 5 GHz for 0.50 pF chips. Reflective loss is shown in Figure 3, and is included. Loss is measured at −10 dBm input.
3. Pulsed thermal impedance is given for a 1 μs pulse. Figure 5 shows typical variation for longer pulse lengths. CW thermal impedance presumes infinite heat sink.
4. Threshold input power produces 1 dB increase in insertion loss. Figure 6 shows typical leakage power curves. Data taken for 1.0 GHz. Figure 7 shows typical variation with frequency.
5. Note that CW power and average power are not synonymous. Power ratings are computed in terms of a peak junction temperature of 200°C, for short pulses, an average junction temperature of 125°C, and an ambient of 25°C. Duty factor 0.001 assumed for maximum pulse power input. Figure 8 shows power derating with temperature.
6. Recovery time is measured with ground return (less than 1.0 ohm) to 1 dB excess loss.
7. Limiter diodes with higher capacitance and/or higher breakdown voltage for very high power applications are available on request.



Features

- Stripline Mount
- Switch and Limiter Functions Through 12 GHz

Description

This series of modules consists of a single PIN diode shunt mounted in a 50Ω hermetically sealed package. These modules cover the 0.5 to 12 GHz frequency range and are available using the chips shown in the Low Power PIN/NIP Switching and Attenuator Diodes, and Limiter Diodes catalog pages.

Typical switch characteristics are shown in Figures 1 and 2, using chip CSB 7003-02. Figures 3 and 4 show typical performance using limiter chips (chip style CLA 3134-01).

Please call or write for additional information on your particular requirement. Designs up to 18 GHz are presently under development. Designs with beryllia insulators for high power series configured modules are now available.

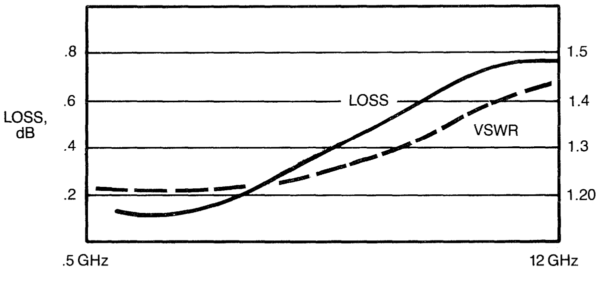


Figure 1. Switch Loss and VSWR – 10 V Bias

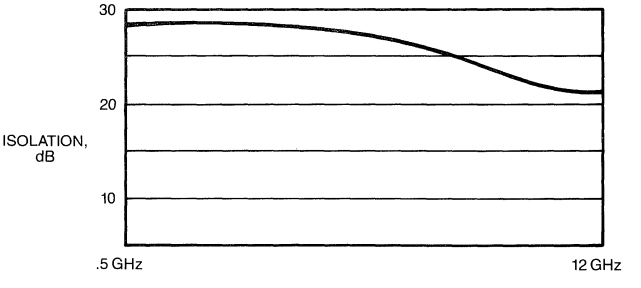


Figure 2. Switch Isolation 100 mA Bias

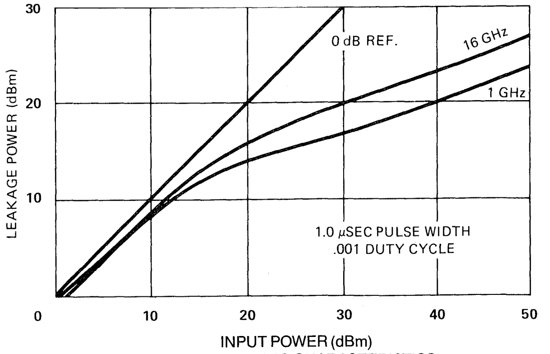


Figure 3. TYPICAL LIMITING CHARACTERISTICS WITH ZERO OHM GROUND RETURN

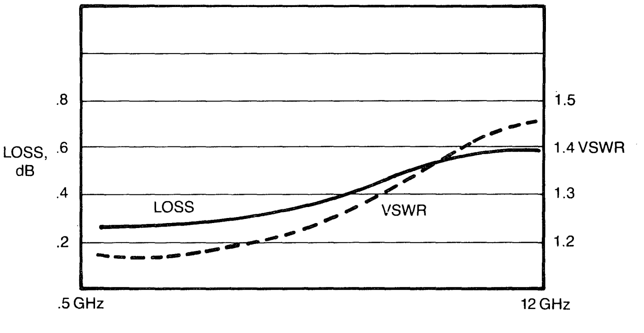
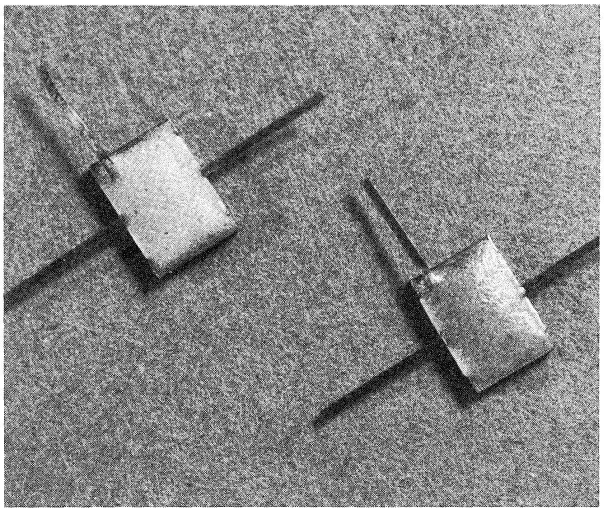


Figure 4. Limiter Loss and VSWR Zero Bias

"T" Attenuator Module



Features

- Ideal for Microstrip/Stripline Use
- Multifunction
- Monolithic Array

Description

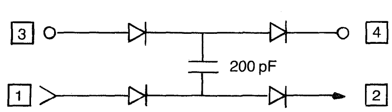
Alpha's "T" attenuator module is of monolithic array construction, utilizing multiple beam-lead diode junctions. Its use of nitride and oxide passivations results in a highly reliable device. The module is supplied in a variety of resin-encapsulated packages for use in microstrip or stripline applications, or it can be supplied in chip form. It is suitable for switching applications as well as for attenuating.

Ratings

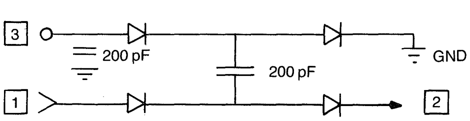
Operating Temperature .... – 55°C to + 150°C
Power Handling ....250 mW

Attenuator Configurations

Type Number	Package Style
DAA5125	276-032
DAA5126	400-001



276-032



400-001

Electrical Characteristics (Module 400-001 — Typical)(6)

Switching

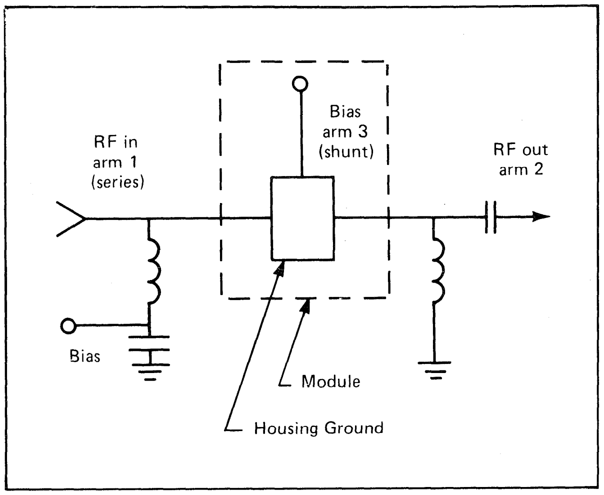
Frequency (GHz)	Insertion(1) Loss dB (Max.)	Isolation(2) – dB (Min.)
.1–3.0	1.5	50
3.0–4.0	2.0	50

Attenuation

Frequency (GHz)	Attenuation(3) dB	Flatness dB Max.	VSWR Max.
.1–3.0	20	= .75	1.5(4)
.5–2.5	40	= 1.0	1.5(4)

Notes:
1. + 50 mA arm 1 (series), 0 bias arm 2 (shunt).
2. + 50 mA arm 3 (shunt), 0 bias arm 1 (series).
3. See Figure 1 for typical biasing conditions.
4. Up to 1.5 GHz, 2.0 Max. up to 3.0 GHz.
5. Typical carrier lifetime — 150 nanoseconds.
6. Additional performance data available from factory.

Bias Circuit (Module) — DAA5126



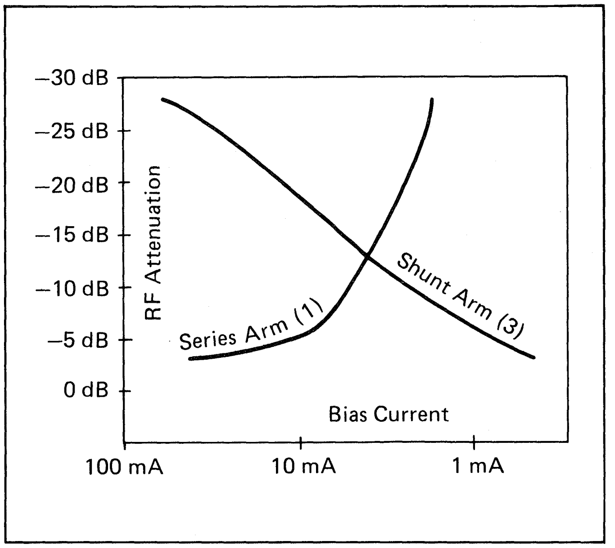


Figure 1. RF Attenuation vs. Bias Current

Application Note 80200: PIN Diode Basics

I. Introduction

The PIN diode, in comparison with other microwave semiconductor devices, is fairly easy to understand. This makes it possible to reduce complex behavior to simple terms and enables the microwave engineer to grasp the operating principles and design details of this family of devices.

We do not attempt to describe the many possible microwave circuits in which PIN diodes are used. Rather, we attempt to explain the behavior of the diode in all aspects, giving the facts and some of the theory behind the facts. We offer the circuit designer the opportunity to understand the PIN, so that he can understand its behavior in his circuits. We assume the reader knows the circuit equations; to that knowledge we hope to add diode equations.

Most of the material presented consists of generalized data on and explanations of the behavior of PIN diodes; we conclude with a brief description of circuit performance, test methods, and some hints on proper PIN specification writing.

The user can then evaluate the trade-offs involved in diode design and performance and be able to select the most nearly optimum diode from the wide range of diodes offered.

II. Basic Theory — Variable Resistance

Intrinsic or "pure" silicon as it can be grown in a laboratory is an almost lossless dielectric. Some of its physical properties are listed below:

Dielectric Constant (Relative)	12
Dielectric Strength	400 V/Mil approx.
Specific Density	2.3
Specific Heat	.72 joules/gm/°C
Thermal Conductivity	1.5 watts/cm°C
Resistivity	300,000 ohm/cm

Since a PIN diode is valuable essentially because it is a variable resistor, let us concentrate initially on the resistivity. Consider a volume comparable to a typical PIN diode chip, say 20 Mil diameter and 2 Mils thick. This chip has a DC resistance of about .75 megohm. High resistivity in any material indicates that most of the likely carriers of electric charge, electrons and holes, are tightly held in the crystal lattice and cannot "conduct."

In real life there are impurities, typically boron, which cannot be segregated out of the crystal. Such impurities contribute carriers, holes or electrons, which are not very tightly bound to the lattice and therefore lower the resistivity of the silicon.

Through various techniques we can adjust the level of impurities, called "dopants," to produce resistivities ranging from 10 K ohm/cm (for good PIN diodes) to .001 ohm/cm (for substrates).

If the impurity adds "electrons" to the crystal, it is called a "donor"; if it adds a "hole," it is called an "acceptor." Boron adds holes, hence it is an acceptor, and the silicon plus boron combination is called "P-type," or "positive," because it has an excess of positive carriers. Phosphorus, on the other hand, is a "donor," adding electrons, and the corresponding mix is "N-type," or negative.

There are many concepts, important to the physicist but not to the diode user, that elaborate upon the impact of the impurities on the behavior of the silicon. These can be studied, e.g., in reference 1.[1] The more carriers added, the lower the resistivity.

If one wished to vary the resistance of a given diode, in principle he could bring it to a semiconductor laboratory, add or subtract carriers as desired, and perhaps even make the process reversible. However, this is a slow, expensive, and impractical way to make a variable resistor; one would be better advised to take a wrench and a soldering iron and replace a component.

The PIN diode derives its value from the fact that the free charge carrier concentration in the silicon, and hence the resistance, can be varied electronically by means of current from a simple bias supply. This can be done rapidly, nanoseconds in some cases, reversibly, repeatibly, and accurately. The thing that makes this possible is called a "junction," the interface between the relatively pure silicon in the middle of a PIN diode ("I" means intrinsic) and the heavily doped layers on either end, P^+, and N^+. The P^+ region is rich in holes; the N^+ is rich in electrons. Both of these regions have low resistance. The I region is the variable resistive element in the diode (see Figure 1). In the absence of any external bias, internal effects within the crystal keep the charges fixed; the resistance of the I region is high.

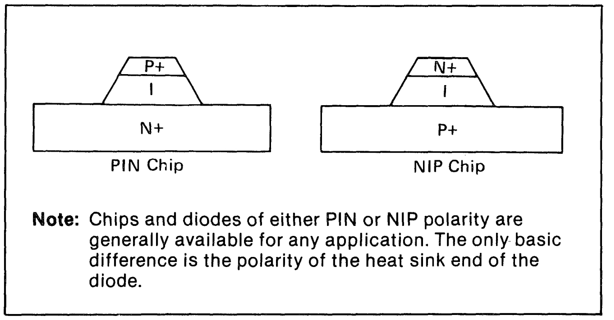


Figure 1. General Outline of PIN Diode Construction

When the P^+ region (anode) is biased positively with respect to the N^+ region (cathode), the interface potential "barrier" is overcome, and DC current flows in the form of holes streaming from P^+ toward N^+, with electrons moving in the opposite direction; we say that free carriers have been injected into the I region. The resistance of the I region becomes low.

The number of free carriers within the I region determines the resistivity of the region and thus the resistance of the diode.

Consider "one hole" and "one electron" drifting in opposite directions in the I region under the impetus of the applied field. Under certain conditions imperfections in the silicon may cause these carriers to recombine. They are no longer available to constitute current or to lower the resistivity of the I region.

It can be shown that the amount of "recombination" between holes and electrons that continuously takes place in a semiconductor is governed by a property of the lattice called "lifetime." In fact lifetime is defined as the reciprocal of recombination rate.

Thus $Q_S = Q_O \exp(-t/T_L)$ where Q_S is the total amount of free charge "stored" in the I region, and T_L is the lifetime, or the mean time between recombination events. In steady state condition the bias supply must deliver current to maintain constant Q_S. The required current is:

$$Idc = \frac{Q_s d}{dt} = \frac{-Q_s}{T_L}$$

or $Q_s = IdcT_L$, dropping the minus sign.

Ignoring some details which are not crucial to this note, we can now calculate the resistance of a given diode, of area "A" and thickness "W". ("W" stands for "base width," the width or thickness of the intrinsic layer). The P^+ and N^+ regions have essentially zero resistance, as they are very heavily doped.

The resistivity of a given material is inversely proportional to the number of free carriers, N, and the mobility (not quite the same as velocity) of the carriers. Thus

$$\varrho = \frac{1}{q(\mu_n N + \mu_p P)}$$

, where q is the electronic charge of both holes and electrons, μ_n, μ_p are mobilities of electrons and holes, and N, P, numbers of electrons and holes. Simplifying, $\varrho = C/Q_s d$, where C is a collection of constants, and $Q_s d$ the stored charge density (numbers per unit volume). For our piece of silicon, volume is WA, and $Q_s d = \frac{Q_s}{WA}$. The resistivity: $\varrho = \frac{CWA}{Q_s}$, and the resistance is: $R_s = \varrho \frac{W}{A} = \frac{CW^2}{I_{dc} T_L}$

This is the first fundamental equation in PIN diode theory.[2]

Rigorous analysis shows:

$$R = \frac{2Kt/q}{I_f} \text{Sinh} \left(\frac{W}{2\sqrt{DT_L}} \text{Tan}^{-1} [\text{Sinh} \frac{W}{2\sqrt{DT_L}}] \right)$$

K = Boltzmann's constant,
T = Temperature, Kelvin,
D = Diffusion coefficient
$= \frac{\mu KT}{q}$

For most PIN diodes W/DT_L is less than unity, and the equation simplifies to the simple expression above.

Typical data on R_s as a function of bias current are shown in Figure 2. A wide range of design choices is available, as the data indicate. Many combinations of W and T_L have been developed to satisfy the full range of applications.

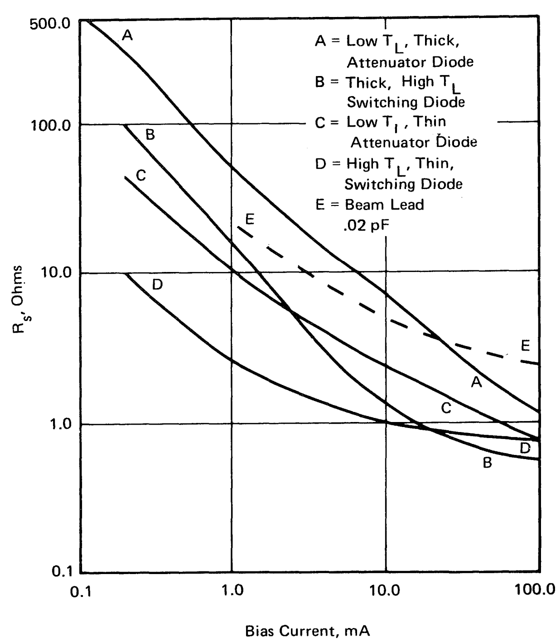


Figure 2. Typical Series Resistance as a Function of Bias, (1 GHz)

III. Breakdown Voltage, Capacitance, Q Factor

The previous section on R_s explained how a PIN can become a low resistance, or a "short." This paragraph will describe the other state — a high impedance, or an "open." Clearly the better PIN diode is the one that has the better on-off ratio at the frequency and power level of interest.

Application Note 80200: PIN Diode Basics

If we return to the undoped or intrinsic I region, we note that it is an almost lossless dielectric. As such it has a dielectric strength of about 400 volts per Mil, and all PIN diodes have a parameter called Vb, breakdown voltage, which is a direct measure of the width of the I region. Voltage in excess of this parameter results in a rapid increase in current flow (called avalanche current). Figure 20 illustrates the I — V characteristics of PINs. When the negative bias voltage is below the bulk breakdown of the I region, a few nanoamps will be drawn. As Vb is approached, the leakage current increases, often gradually, as is exaggerated in the curve. This current is primarily caused by less than perfect diode fabrication, although there is some contribution from temperature. Typically the leakage current occurs at the periphery of the I region. For this reason various "passivation" materials (silicon dioxide, silicon nitride, hard glass) are grown or deposited to protect and stabilize this surface and minimize leakage. These techniques have been well advanced over the years, and PIN diode reliability improved as a result.

Most diodes are specified in terms of minimum Vb for a nominal leakage, usually 10 microamps.

It will be noted later that RF voltage swings in excess of the rated Vb are permitted, for the mechanisms causing leakage current do not always respond at RF frequencies. However, bulk breakdown is effectively instantaneous, and that voltage should never be exceeded.

The next characteristic of our "open" circuit is the capacitance. In simplest form the capacitance of a PIN is determined by the area and width of the I region and the dielectric constant of silicon; however, we have discussed the fact that intrinsic does contain some carriers and therefore has some conductivity. An E field could not exist unless all these carrieres were swept out, or depleted.

Application of a reverse bias accomplishes this. At zero bias the excess carriers on either side of the junction are separed, held apart, by "built in" fields. This is the contact potential, about 0.5 volts for silicon. If there are only a few excess carriers in the I region, this "potential" can separate the charges more easily. The junction "widens" in the sense that, starting at the P^+ and I interface, there is a region of no free carriers, called the "depletion zone." Beyond this depletion zone the I region still contains the free charges it started with. With the application of reverse bias the depletion zone widens. Eventually, at a bias equal to a so-called "punch-through" voltage (V_{PT}), the depletion zone fills the entire I region. At this voltage the 1 MHz capacitance bottoms out and the diode Q reaches its maximum. Figure 3 illustrates the equivalent circuit of the I region before punch-through.

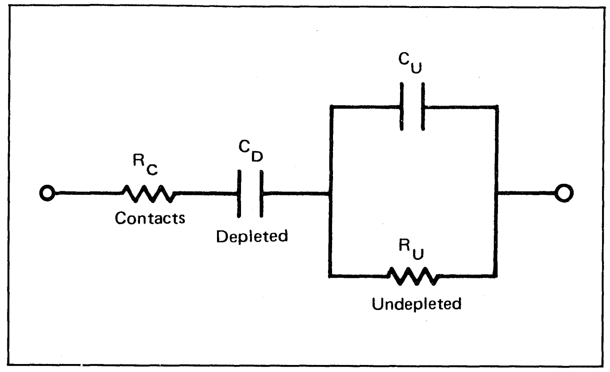


Figure 3. Equivalent Circuit of I Region Before Punch-Through

Some very interesting facts can be derived from this model. Consider the undepleted region; this is a lossy dielectric consisting of a volume (Area A, length ℓ), of silicon of permittivity 12 and resistivity ϱ. The capacitance is

$12\frac{\epsilon_0 A}{\ell}$, and the admittance is $2\pi\frac{(12\epsilon_0 A)}{\ell}$. The resistance is $\varrho\ell/A$ and the conductance $A/\varrho\ell$.

At very low frequencies the undepleted zone looks like a pure resistor. At very high frequencies it looks like lossy capacitor. The "crossover" frequency depends on the resistivity of the I region material. For ϱ of 160 ohm/cm the frequency is 1 GHz. Higher resistivity is generally used for PINs, say 1000 ohm/cm, and the crossover frequency is 160 MHz.

Diode manufacturers measure junction capacitance at 1 MHz; clearly, what is measured is the depletion zone capacitance.

If the I region thickness is W and the depletion width X_d, the undpleted region is $(W - X_d)$.

The capacitance of the depleted zone is, proportionally,

$\frac{1}{X_d}$; of the undepleted, $\frac{1}{W - X_d}$.

The 1 MHz capacitance as a function of reverse bias is seen in Figure 4.

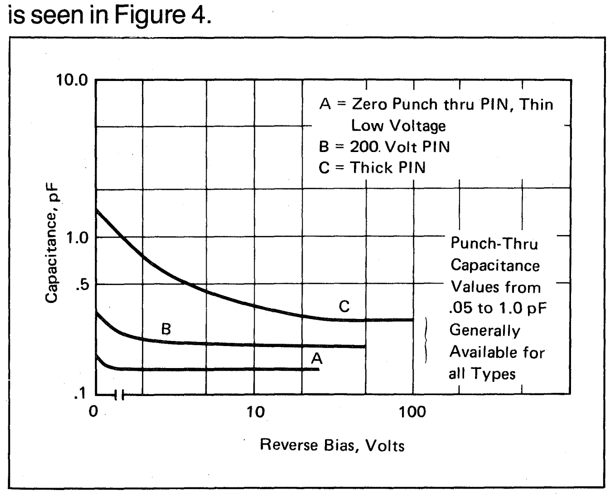


Figure 4. Typical 1 MHz Capacitance

The 1 MHz capacitance decreases with bias until "punch-through" where X_d = W. However, at microwave frequencies well above the crossover the junction looks like two capacitors in series.

$$C_T = \frac{Cd\ Cu}{Cd + Cu} \alpha \frac{1}{W}$$

i.e., the microwave capacitance tends to be constant, independent of X_d and bias voltage.

However, since the undepleted zone is lossy, an increase in reverse bias up to the punch-through voltage reduces the loss.

At any given frequency the equivalent network can now be drawn as Figure 5.

R_v is now the equivalent series resistance of the undepleted region. Typical R_v data is shown in Figure 6.

An alternate equivalent network is shown in Figure 7, and typical R shunt data are shown in Figure 8.

A good way to understand the effects of series resistance is to observe the insertion loss of a PIN chip shunt mounted in a 50-ohm line, as shown in Figure 9.

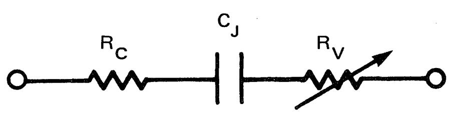


Figure 5. Simplified Equivalent Circuit, Series

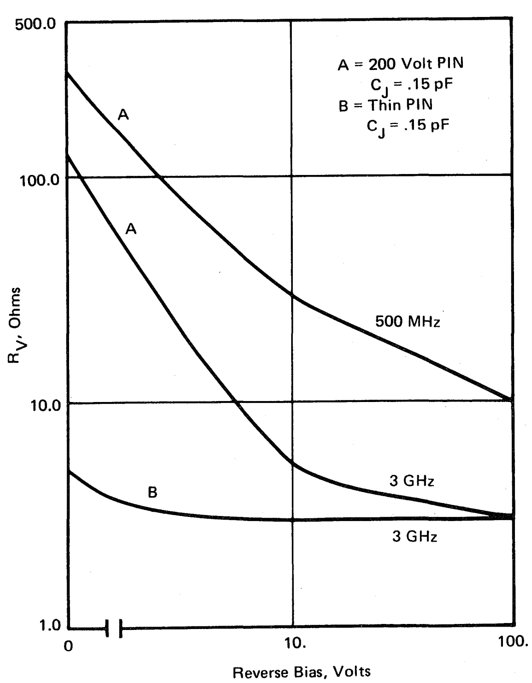


Figure 6. Reverse Series Resistance, R_v

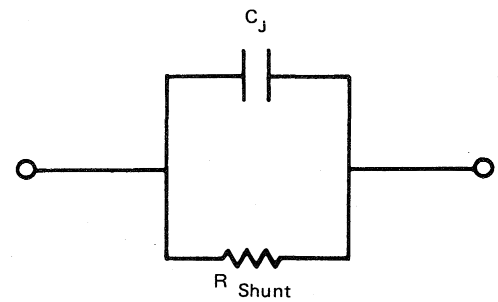


Figure 7. Simplified Equivalent Circuit, Shunt

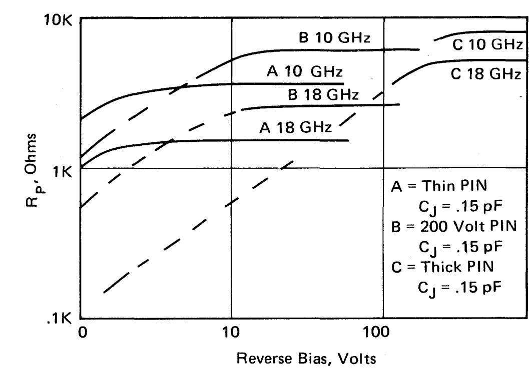


Figure 8. Reverse Shunt Resistance, R_p

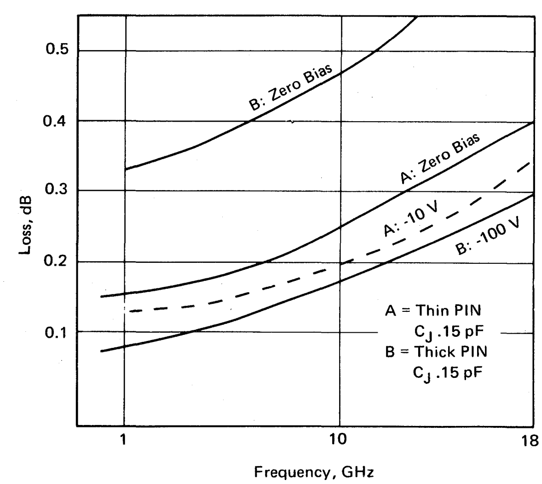


Figure 9. Insertion Loss vs. Frequency

An accepted way to include reverse loss in the figure of merit of a PIN is to write

$$Q = \frac{1}{2\pi + \sqrt{Rs\,Rv\,C}}$$

where R_s and R_v are measured under the expected forward and reverse bias conditions at the frequency of interest.

The punch-through voltage is a function of the resistivity and thickness of the I region. It is advisable to measure loss as a function of bias voltage and RF voltage to determine if the correct diode has been selected for your application.*

Incidentally, if you are working with PIN or NIP chips which do not have an opaque covering, please be advised that PIN diodes are photosensitive. Incident light causes photo-generation of carriers in the I region, and insertion loss will rise.

IV. Thermal Impedance, Peak and CW

As is well known, semiconductor devices cannot be operated reliably at elevated temperatures. Silicon PIN diodes are no exception. In the forward bias mode the junction should not exceed 250°C. In reverse bias the limitation is about 175°C. At higher temperatures not only do the physical properties change sufficiently to influence performance, but the metals used in contacting the silicon to the package can diffuse, or even melt, destroying the diode. Since we know that the diode has resistive losses in any state, and assuming we can calculate or estimate the amount of power that will be dissipated in the silicon, we now need to understand the thermal properties of the diode in order to be able to calculate the junction temperature.

It is reasonable to assume that all energy dissipation occurs in the I region. Let us consider the various thermal paths between this region and the ultimate heat sink.

As soon as power is dissipated, the temperature rises according to the volume, density and specific heat of the material. As temperature rises energy flows from the I region into the chip substrate. The time required for heat to flow is called the thermal time constant, and for silicon this is about 16 microsec per mil squared. For example, if the I region and substrate are 1 and 3 mils thick respectively, it will take about 16 microsec for the energy to begin to flow into the substrate and about 250 microsec to flow to the heat sink, or whatever the chip is bonded to. If it is bonded, say, to a copper pedestal, the next time constant is about 6 microsec per mil squared.

If all this sounds confusing, consider this: For short pulses of energy, under 16 microsec for a one mil I region, the only thing that counts is the thermal capacity of the silicon. For longer and longer pulses the various thermal resistances, from I region to substrate, substrate to pedestal, pedestal to heat sink, all get involved, and the junction temperature rises.

For various PIN diodes, curves of thermal impedance vs. pulse length are shown in Figure 10.

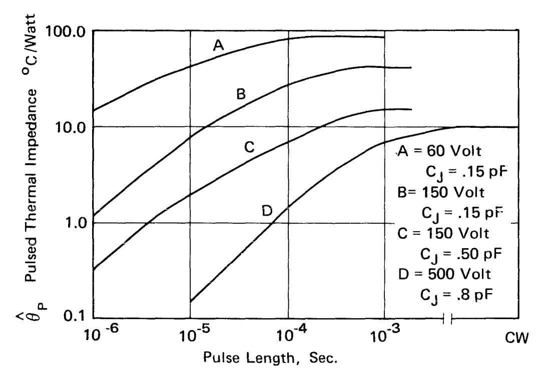


Figure 10. Thermal Impedance as a Function of Pulse Length

In computing junction temperature, T_J, a conservative approach is to compute pulse rise, add to it the average rise, and then add the heat sink temperature.

If this indicates anything approaching 150°C or so, it is advisable to measure T_J, to avoid reliability problems. The primary problem is that you are unsure how much power the diode is dissipating.

Temperature is measured by using the forward voltage drop at low current, since just about all PINs have a temperature coefficient of about −1.80 millivolt/degrees C at 1 mA forward. (For maximum accuracy each diode type should be calibrated in an oven.)

In a typical pulsed application you operate the diode under normal bias conditions; at the end of the RF pulse quickly switch to a 1 mA reference current and monitor Vf on an oscilloscope. You must switch within a few microseconds, so that the junction does not cool appreciably during this period. Also, you must carefully synchronize RF and switching pulses, etc.

When done correctly, the scope data look like Figure 11.

Note: At frequencies below crossover, and for thin I-region diodes, the effective junction capacitance can increase substantially at low forward bias, on the order of 1 to 200 microamp.

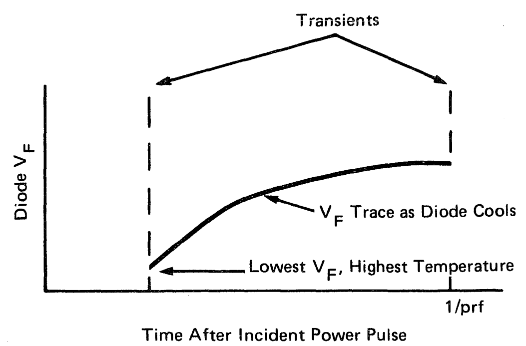


Figure 11. Diode Junction Interpulse Cooling

If everything is done correctly, the switching interval can be made much shorter than the I region time constant, so that extrapolation is hardly necessary.

V. RF Voltage and Current Limitations

The discourse on thermal impedance implies an obvious fact: "Don't try to handle so much RF power that the diode melts." There are other not-so-obvious limitations which you may encounter. Essentially, these can be understood as follows: The ideal PIN diode has an RF impedance determined entirely by the bias, and this impedance must be linear, independent of RF voltage, or current amplitude. In principle this condition is met because of the relatively long "time constant" — lifetime of electronic charges in the I region.

If the diode is in the "open" mode, it generally takes much longer than an RF cycle to inject carriers and lower the impedance. The normal limitation on RF voltage, then, is breakdown. The maximum negative RF voltage, added to the negative bias, must be less than the true bulk breakdown of the I region. In the case of high voltage PINs (500–1200 volts or more), the rated V_B is somewhat less than bulk breakdown, and you can exceed the rating somewhat. Care must be taken, because excess voltage will cause noise, harmonics and possible failure.

When the RF voltage goes positive, large excursions into the forward bias direction are permitted. For example, using a 1000-volt diode with 100 volts of reverse bias, an RF swing of 600 volts (for a net 500 volts positive) can be tolerated at S band with no perceptible change in impedance. However, a mechanism for change is present. The high forward voltage does inject charge into the I region, but not through it, owing to the diffusion and drift times involved. As one raises power or lowers frequency or uses a thinner I region, the quantity and diffusion of injected charges is sufficient to cause some recombination in the I region, somewhat akin to "rectification"; a net DC forward current flows. This is manifested in a lower impedance and increased loss, harmonics, temperature rise and failure.

Since a high power application requires a thick I region, the switching time is increased. The basic rule is: you cannot switch high power fast. The definitions of "high" and "fast" are left to the systems engineers and the diode designers. However, even 10 watts is high when you want to switch in 10 nanoseconds at 3GHz.

The "self-biasing" mechanism is exploited by deliberately making thin PIN diodes, as thin as 2 microns (about 0.1 mil). These work well as limiters; at an input of 100 watts R_s is driven under 1 ohm. Suffice it to say that for a high power switching application, extensive testing is necessary to establish proper bias conditions and to choose the right diode.

In the forward bias, or "shorted" mode, it is easier to assign some numbers to the problem. Negative RF current can pass through the PIN diode only because of the stored free charge in the I region. If too much charge is withdrawn during a half cycle, the impedance rises, and harmonics, loss and temperature rise with it.

The RF charge withdrawn, for a peak RF current Ip at frequency f, is:

$$Q_{rf} = I_p/\pi_f$$

Remembering that the total DC stored charge is:

$$Q_{dc} = I_{dc}T_L$$

we note that the fraction of charge withdrawn and the corresponding fractional increase in series resistance is:

$$\frac{Q_{rf}}{Q_{dc}} = \frac{I_p}{I_{dc}\pi f T_L} = \frac{\triangle R_s}{R_s}$$

For most microwave applications even megawatts of peak power can be handled without running into a problem from this mechanism.

The problem arises at low frequency, especially for attenuators, where the DC bias is restricted to small values and R_s is higher. The CATV industry has required development of a new family of PIN diodes characterized mainly by thick I regions and low lifetime. The thick I region allows the desired range of R_s to be met with adequate values of bias current. The low lifetime permits modulation of R_s at acceptable high frequencies.

The compromises required here are fairly delicate. You want the diode impedance to respond to a high frequency modulating signal, and you also want R_s to be independent of the carrier. The first requires a low lifetime thin diode, the second a long lifetime thick diode.

If your calculations on ΔR_s indicate a possible problem, make some harmonic measurements, for harmonics are a more sensitive aspect of this phenomenon than increased loss.

For those of you interested in high frequency modulation you should be aware that lifetime is a limiting factor, for R_S is a function of stored charge, not current.

Thus: $$id = \frac{d(Qd)}{dt} + \frac{Qd}{T_L}$$

which leads to $$Qd(W) = \frac{T_L id}{1 + j\omega T_L}$$

where $\omega = 2\pi$ times the modulating frequency.

VI. Switching Considerations

This section will not attempt to present a detailed discussion on switching. If further information is desired, see Reference 3.

Switching refers to changing the state of the I region from "no stored charge," high impedance, to "lots of stored charge," low impedance and vice versa. The PIN diode has its value over, say, a rotary vane attenuator, because the switching times can be as low as nanoseconds.

We will discuss the diode and driver circuitry together, for either can be the critical element in determining speed.

Consider a PIN diode and a typical driver circuit. When the system calls for a change in state, the logic command is applied to the driver. There is delay time in the driver, in the passive components as well as in the transistors, before the voltage at Point A (see Figure 12) begins to change. There is a further delay before that voltage has stabilized. Most diode switching measurements are measured with the time reference being the 50% point of the (Point A) command waveform.

The diode begins to respond immediately, but there is a delay before the RF impedance begins to change. It is the change in impedance that causes the RF state to switch.

In determining the proper design of driver and diode for your application, you must carefully consider the differences between delay and "RF switch" times.

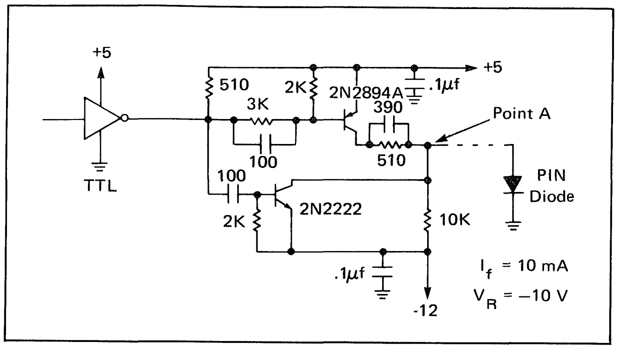


Figure 12. SPST Switch Driver for 10 ns

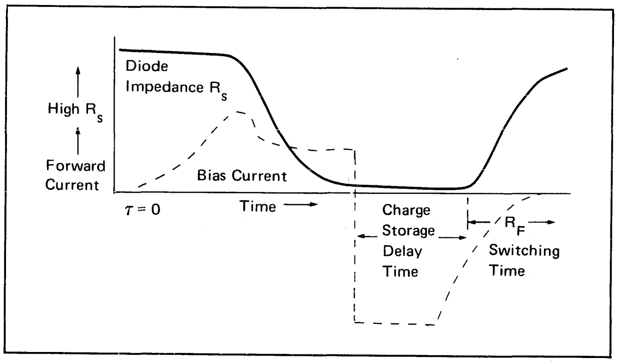


Figure 13. PIN Diode Switching Waveforms

Most data sheets refer to "RF switch" time only, but it is the total time that is important in many applications — including driver delay, driver rise time, PIN diode delay and, finally, PIN impedance switching time.

The PIN diode contributions can be understood by referring to Figure 13.

The command waveforms shown are required for the fastest total switching times and are delivered by drivers similar to the simple schematic shown in Figure 12.

REVERSE TO FORWARD

In the high impedance state the I-V characteristics are inductive. This can be considered a function of the fact that the I region must become flooded with stored charge before the current (and RF impedance) stabilizes. Accordingly, the driver must deliver a current spike with substantial overvoltage. The capacitor paralleling the output dropping resistor is called a "speed-up" capacitor and provides the spike.

Typical total switching time can be on the order of 2 to 10% of the specified diode lifetime and in general is much faster than switching in the other direction, from forward to reverse.

FORWARD TO REVERSE

In this mode the problem is to extract the stored charge rapidly. Once again the solution is a reverse current spike coupled with a moderately high reverse bias voltage, with reverse current on the order of 10 to 20 times forward bias,

I_f/I_r = .10 to .05 or less

The "charge storage delay" will be 5 to 10% of the lifetime. Additionally the actual "RF switching time" will be minimized by a large negative bias and/or by a low forward bias.

BIAS CIRCUITRY

It is advisable to design the bias circuit to have the same characteristic impedance as the RF line to minimize reflections and ringing. Extraneous capacitance, in the form of blocking and by-pass elements, must not be excessive. A typical 60 + pF bypass in a 50-ohm RF circuit produces a 3.0 nanosecond rise time. A few of these make it impossible to exploit the fastest PINs.

VII. Temperature Effects on Forward Resistance

GENERAL

Junction temperature plays an important role in determining diode reliability. However, diode electrical parameters are also influenced.

For example, at temperatures above 100°C, reverse leakage current begins to rise, and at 150°C a "10 nanoamp" reverse current becomes as high at 1 microamp.

Reverse bias loss increases with temperature, due to thermally induced generation of hole electron pairs in the I region. This loss can be significant above 150°C, especially at low reverse bias.

Carrier lifetime increases with temperature, owing to reduced charge mobility, and fewer recombinations.

Microwave capacitance changes only slightly, and due to thermal expansion (a few parts per million per °C) 1 MHz capacitance can change substantially, as much as + 1000 ppm/°C near zero bias, owing to a change in the junction contact potential, at the rate of – 2.3 mV/°C.

It is this change in contact potential which causes the most significant parameter change in a PIN diode. The forward voltage, V_f, corresponding to a fixed DC current I_f, decreases with temperature. Table 1 shows typical values of TC V_f (temperature coefficient of V_f) for a variety of PIN diodes. The coefficient varies with forward current: at very low current (density), the coefficient is near – 2.3 mV/°C; at high current (density), the coefficient approaches – 1.15 mV/°C.

Table 1. Typical Temperature Coefficients of V_f

Diode Type:	1000 volt 1.0 pf	500 volt .5 pf	200 volt .15 pf	60 volt .10 pf
TC V_f, at 1 mA mV/°C	– 2.3	– 2.0	– 1.8	– 1.5

An empirical estimate of TC V_f can be obtained from Figure 14, which shows TC V_f as an approximate function of V_t at 1 mA. For accurate work, a given diode type should be calibrated for TC V_f.

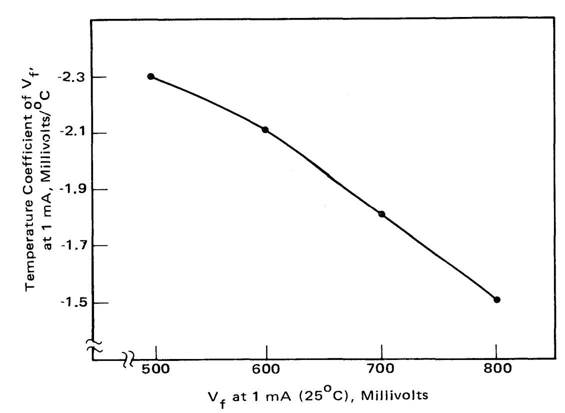


Figure 14. Empirical TCV_f as a Function of V_f of V_V

SERIES RESISTANCE

Figure 2 indicated typical curves of R_s as a function of I_f at constant current. Two conflicting mechanisms influence temperature behavior; first, as temperature rises, lifetime increases, allowing a greater carrier concentration, and lowering R_s. Secondly, however, at higher temperature charge mobility decreases, raising R_s. The net result of these competing phenomena is a function of diode design, bias current, RF power level, and frequency.

Figure 15 shows unlabelled curves of R_s vs. temperature with bias as a parameter.

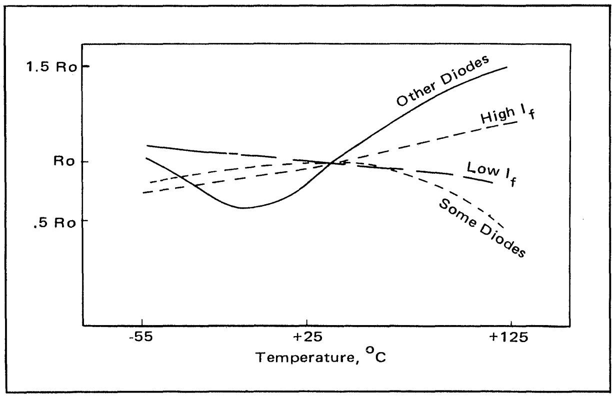


Figure 15. Series Resistance vs. Temperature

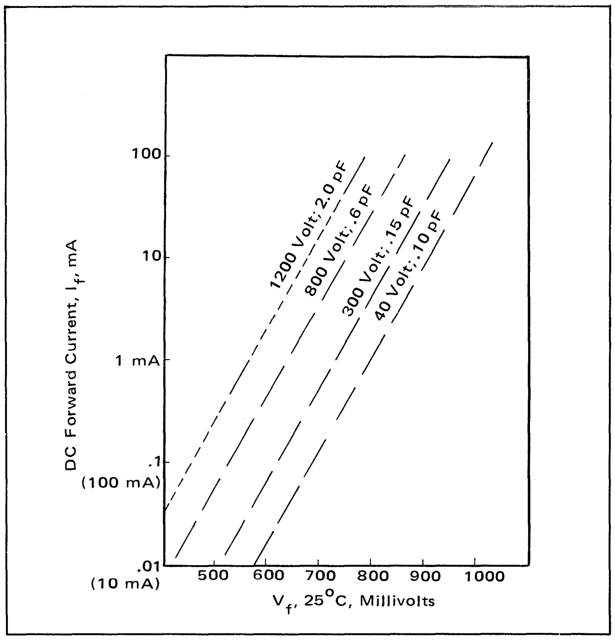


Figure 16. V_f vs. I_f for Various PIN Diodes

Notice that the curves do imply constant I_f — which is where the TC V_f comes in. If your bias supply is a low impedance circuit (in the direction of constant E_f), you will find that I_f increases rapidly with temperature, and R_s will decrease. This can be a problem in switches, especially at low temperatures and a disaster in attenuators, with fixed attenuation, which might imply fixed R_s at a relatively high value.

Figure 16 shows V_f vs. I_f for a variety of diodes, all at 25°C. Mentally superimpose a change in effective V_f of over $\pm$150 mV ($-2.0 \times \pm 75$°C), and you can see that I_f varies by orders of magnitude when constant V_f is applied. A typical fast switching diode (the 300 volt, 15 pF curve) will draw 10 mA at 850 mV at 25°C. At the same V_f, at -55°C it will draw about 500 microamp; at $+100$°C, I_f will be 200 mA.

VIII. Diode Selection/ Design Trade-Offs

The previous sections are summarized in part by Table 2 below which indicates the performance or design tradeoffs involved in selecting a PIN diode.

Table 2. Trade-Off Considerations

Diode Design Parameters	Fast Switching	Low Capacitance	Low Forward Resistance	Low Reverse Loss	Low Thermal Impedance	High Power
Lifetime	Low	—	High	—	—	High
I Layer Width	Thin	Thick	Thin	—	Thick	Thick
Area	Small	Small	Large	Large	Large	Large
Resistivity	High	High	—	High	—	—

None of the design parameters is totally independent of the others, but the chart is a moderately good overview of design possibilities. Typical of the independence is the lack of a "specification" for I layer width for low reverse loss; for low power, zero reverse bias applications a thin I layer is possible and desired. For high power a thick layer is mandatory.

Consider also that low capacitance is possible with large area thick diodes as well as with small area thin devices.

The requisites for fast switching and high power are mutually exclusive, as expected.

IX. Measurement of PIN Diode Parameters

RESISTANCE

It is well established that the resistance parameters of a PIN diode or chip cannot properly be measured at DC or submicrowave frequencies. There are several frequency dependent elements — contacts, undepleted I region, etc. — responsible for this fact. As a consequence suitable techniques for microwave frequency evaluation have been developed.

The most common technique uses slotted line measurements from 500 MHz to 9 GHz. It is quite accurate for all PIN and most silicon varactors (intrinsic losses in the line make it unsuitable for very high Q diodes, say fc above 350 GHz); it is easy to use, fast, economical, and when suitably maintained, quite reproducible and repeatable.

A description of the method requires first a model of a typical packaged diode, shown in Figure 17.

Here: R_C is a fixed "contact" resistance; R_s is a variable series resistance. C_J is the chip or junction capacitance; L_P and C_P are the package parasitics; L_J is the inductance of the bonding wire.

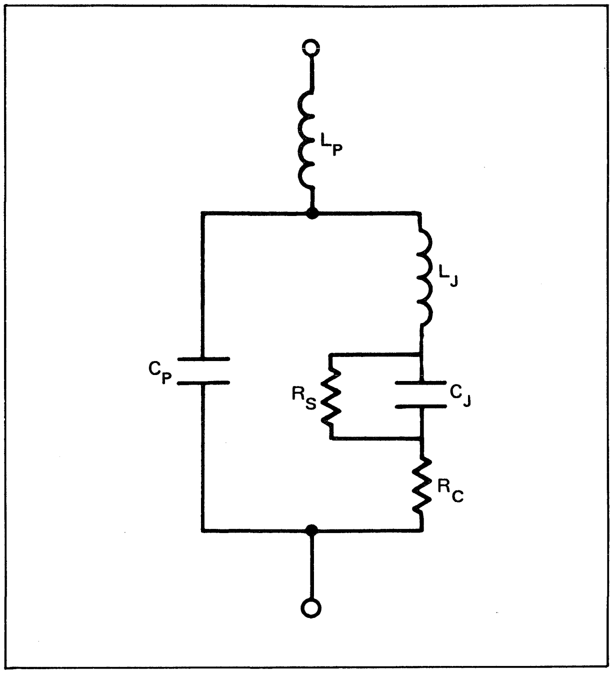


Figure 17. Packaged Diode Equivalent Network

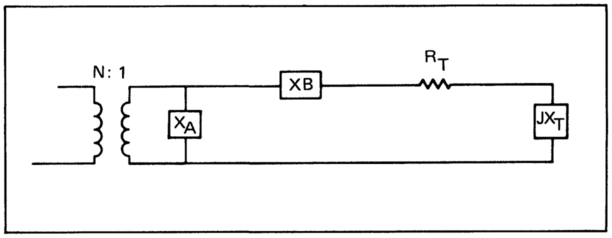


Figure 18. Equivalent Network for Slotted Line Holder

The chip parameters we wish to ascertain are R_c and R_s, or R and C_J, and we must do the measurements in the presence of L_P, L_J and C_P. Accordingly, we must allow for those parasitics.

It can be shown that any impedance Z_T terminating a coaxial line can be represented as shown in Figure 18.

By measuring diodes of known junction capacitance, we "calibrate" the diode holder by evaluating the constants of the transformation.

The equations relating the transformation constants and the terminating Z_T, and including line losses, are straightforward and ultimately reduce to a set of computer printouts which yield C_J and R, true junction parameters, when position of minimum and VSWR are known.

Measurements made at one microwave frequency can generally be extrapolated to other frequencies with fair accuracy.

a) C_J — quite accurately.

b) R_S — forward biased — from 500 MHz to 3 GHz, an increase of perhaps 0.1 to 0.2 ohm is common; from 3 to 10 GHz, a similar increase has been observed but is not felt to be universal. Some evidence says that there is no frequency dependence of R_S up to at least 20 GHz. It depends on the diode design.

c) R_V — reverse bias; at low values of bias below punch-through there is a substantial decrease in R_V with increasing frequency. This is the most frequency and power dependent element in a PIN, and it is advisable to make definitive loss-measurements under intended application conditions.

In general it is found that measurements at, say, 500 MHz or 3 GHz correlate with higher frequencies for the purpose of production tests, but this is not universally true, especially when the application is in Ku-band or above.

Finally, remember that the junction parameters are often signal level dependent, especially for thin I region diodes. A useful technique with a slotted line is to inject the signal into the probe with a mixer/detector on the other end of the line. This maximizes sensitivity while minimizing signal level at the diode; a signal level of about – 20 dBm is generally satisfactory.

CAPACITANCE

1 MHz capacitance at punch-through has been shown equal to microwave capacitance in numerous experiments. Thus, capacitance of a PIN in either chip or package is measured conveniently with Boonton meters or bridges at 1 MHz and voltage levels under 50–80 millivolts. For chips, a shielded cable connects the instrument to a probe which contacts the metallized junction. The bottom of the chip is grounded. The meter is nulled with the probe just removed from the junction to minimize error.

For packaged diodes two philosophies exist in the industry. Alpha uses grounded, shielded enclosures to minimize the fringing capacitance across the package and from package to ground. This yields a more rigorously correct "diode" capacitance, for it eliminates fringe capacitance which can differ substantially depending upon mounting procedures. The circuit designer must allow for fringing in his designs. Values are on the order of .02 to .05 pF.

The capacitance is measured over a range of bias voltage to determine the voltage at which the I layer reaches through and the capacitance bottoms out. Control of the resistivity of the I layer, or lack of it, is manifested by variation of the punch-through voltage.

LIFETIME

Inasmuch as we derived a stored charge number from a definition of lifetime, it follows that a measurement of stored charge should be sufficient to determine lifetime.

However, it has been found more useful to know the switching transient behavior of the diode, thereby measuring both lifetime and dynamic video resistance. The circuit of Figure 19 is used; the diode is forward biased, usually to 10 mA, and the negative current to 6 mA(I_f/I_r = 1.7). Internal recombination is a factor, and it can be shown that if T_R is the time required for the negative current to decrease to 3 mA (50% recovery), we have:

$$T_R = T_L \ell n(1 + I_f/I_r) = T_L$$

The current waveform is shown in Figure 19.

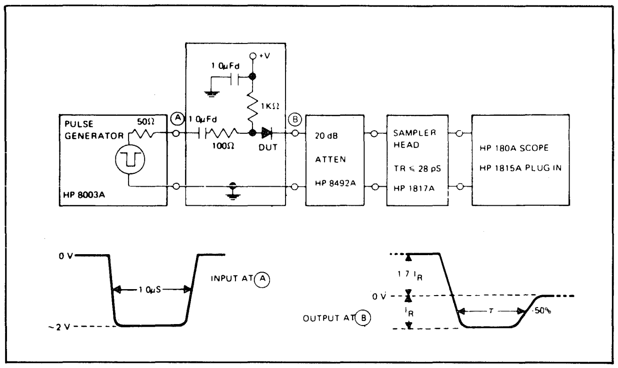


Figure 19. Minority Carrier Lifetime, τ_L Test Circuit

Often the "tail" of the waveform is so distorted that the 50% point is hard to determine accurately; nevertheless, it has been generally agreed in the industry that this method of measuring lifetime, to the extent that one observes the entire waveform, i.e., the 10%, 20%, 50%, 80%, and 90% recovery times, is a better way to predict diode behavior than stored charge alone.

If stored charge only is desired, a different method is employed. With a forward bias of 10 mA the reverse bias pulse voltage is adjusted for negative current of some 200 mA. The negative current is integrated and presented as a DC voltage, of dimensions "charge per unit time." Knowing the pulse rate, we derive:

$$T_L = \frac{Q_S}{(\text{P.R.F.})\,(10\text{ mA})}$$

With an I_f/I_r ratio of .05 the stored charge is removed in about .05 T_L, and internal recombination is negligible.

VOLTAGE BREAKDOWN, V_B

DC voltage breakdown is measured on standard curve tracers and is usually read at the 10 microamp point. Due to the possibility of thermally induced negative resistance, it is advisable to use a 100K to 1 Meg. limiting resistor located close to the diode. Also, incident light will cause increased leakage current.

The reverse I-V trace, exaggerated, looks like Figure 20.

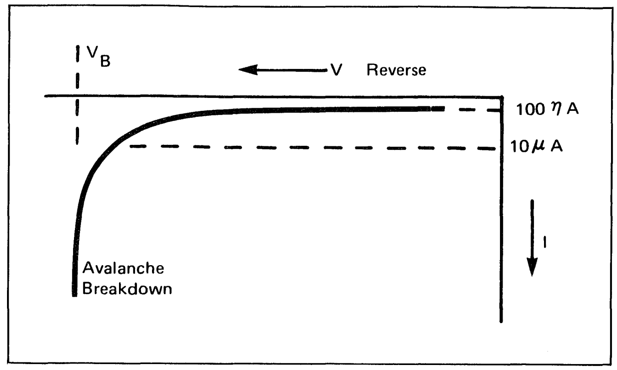


Figure 20. Reverse Current in PIN Diode, Exaggerated

A properly fabricated diode will exhibit almost no "leakage" current (at 25°C — typically less than 100 nanoamps) until within a few volts of breakdown. The "knee" from "low" to "high" leakage should be on the order of one or two percent of V_B. The knee will appear "sharp" and will also be stable; it will not "push out" to higher voltage or "pull-in" to lower. There will also be no hash or noise visible on the trace.

The breakdown curve will have low impedance and for low voltage (e.g., less than 500 volts) will be the true bulk breakdown of the I region. For high voltage PINs there can be extraneous current paths at the interface between junction and passivation or within the silicon. These are stable leakage paths which determine the catalog rating of the diode but which do not always determine the peak RF voltage that can be applied across the diode. Bulk (avalanche) breakdown, not always seen on a curve tracer, is the limiting parameter.

FORWARD VOLTAGE, V_F

V_F is rarely specified except in very loose fashion, primarily to provide another pre- and post-screening test. If we measure it, we use a curve tracer.

The V_f–I_f characteristics of PIN diodes vary substantially with design. Typical voltage for 1 mA current range from 600 millivolts for large area, high voltage diodes to 800 millivolts for thin, low voltage limiter diodes. Within a given design variation from wafer to wafer is typically ±25 millivolts and on a given wafer about ±15 millivolts. If your application involves DC-paralleled PIN diodes, and near equal values of R_s are required, implying near equal forward bias, you should make this a key point in your specification.

X. How To Specify a PIN Diode

Based on the material already presented in this application note, the following hints should help in specifying a PIN diode.

1. R_s, forward series resistance. If your design is frozen, ask for R_s to be measured at the intended bias level. In return, please accept 500 MHz as the measurement frequency. If the diodes are to be operated in DC-parallel, the specification should require a tight relationship between V_f and I_f, or even V_f and R_s. Be sure to consider temperature effects.
2. Capacitance — specify 1 MHz capacitance at punch-through, as this will be the "microwave" capacitance. Measurements at lower bias, or at zero bias, are of limited significance unless your application is at a very low frequency.
3. Reverse Bias Loss — specify measurement at 3 or 9 GHz, at your bias. This will be at low level, and the answer will be in form of equivalent parallel resistance. Do not ask for high power data, for such test stations are not normally available.
4. Voltage Breakdown — specify the 10 microamp point and some interim point, say 1 μA or 100 μA, at 80% of V_B. Also, specify I layer width, but after you have selected a diode and wish only to insure that the production units are similar.
5. Lifetime — if your switching requirements are severe and you have had difficulty in completing your driver design, you should tie down this parameter. Insist on recovery time measurement with a particular reverse current waveform. That is, specify the 20%, 50%, 80%, and 90% recovery times. The manufacturer will complain, but ultimately a compromise will be accepted that insures that production diodes are as required.
6. Thermal Impedance — if you properly control V_B, I layer thickness and junction capacitance, the pulsed impedance need not be measured. However, you must insure that on a packaged diode the chip is well soldered to the pedestal. You can do this by specifying the CW thermal impedance.
7. Forward Voltage — if DC parallel diodes are involved, you may need a tight V_f spec to insure similarity. Again, consider temperature.
8. For numerous situations it is expedient to ask us to make isolation and loss measurements in a suitable fixture. The best correlation will be achieved if we can use the circuit that you use in your system.

In all of the above testing we strive to include appropriate guard bands, etc. Realistically, there are always a few tenths of a dB, or so, variance between our measurements and yours.

XI. Simple Circuit Performance Charts

Figures 21 and 22 refer to chips shunt mounted in 50-ohm microstrip. Figure 23 refers to series mounted diodes. Figure 21 shows isolation as a function of diode series resistance R_s. Figure 22 shows isolation as a function of diode spacing for a shunt pair of 1.0 ohm diodes, and a series pair of diodes with $X_C = -j2500$. Figure 20 shows isolation vs. frequency and capacitance for a series diode. Here the advantage of the low capacitance (.02 pF) of Alpha beam-lead PIN diodes is quite apparent.

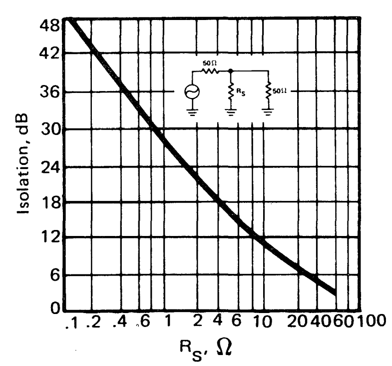


Figure 21. Shunt Diode Isolation vs. Forward Biased Resistance

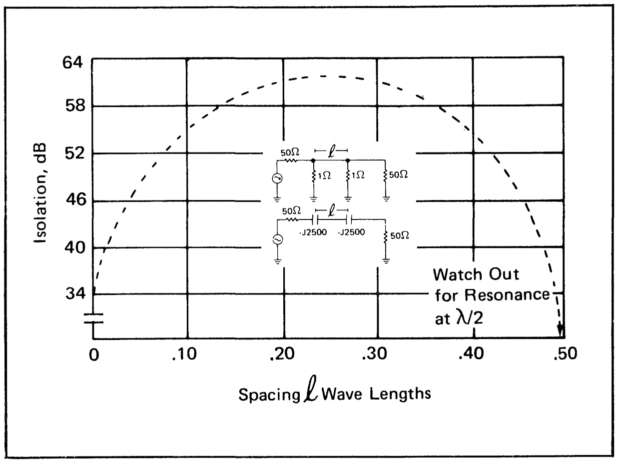


Figure 22. Isolation vs. Diode Spacing

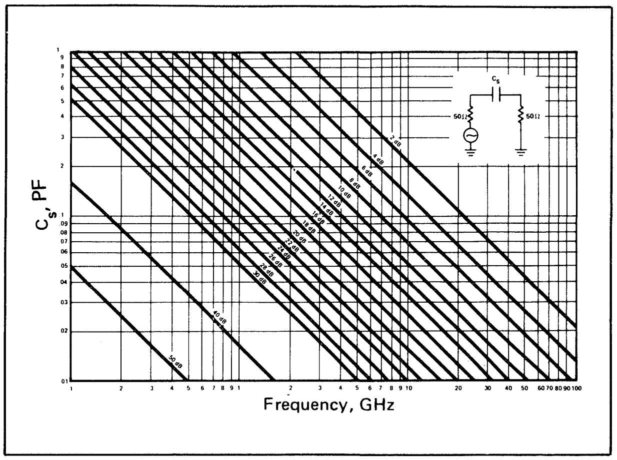


Figure 23. Isolation vs. Series Capacitance (C_S)

REFERENCES

1. Watson, "Microwave Semiconductor Diodes and their Circuit Applications," McGraw-Hill, 1969.
2. *Ibid.*
3. McDade and Schiavone, "Switching Time Performance of Microwave PIN Diodes," Microwave Journal, September 1974.

Application Note 80300: Characteristics of Semiconductor Limiter Diodes

I. Introduction

Microwave limiter diodes are used to prevent burnout in power sensitive components such as mixers, detectors and amplifiers. The limiter senses and then rejects power levels that would result in permanent damage to these devices. Some of the important characteristics of limiter diodes are low insertion loss, medium to high power handling capability, fast recovery time and solid state reliability. Limiter diodes are normally operated in the passive mode (no external bias) but can be biased for special applications such as raising or lowering the limiting threshold or for use as fast switches and STC attenuators. Another possible application is in leveling operations where the limiter is used to eliminate large RF amplitude fluctuations.

The purpose of this application note is to present a non-rigorous analysis of the operational characteristics of a semiconductor limiter diode and to show how and why these characteristics change with power requirements, frequency and temperature. It is hoped that the information presented in the following pages will assist the system engineer in designing limiters that will satisfactorily meet his requirements.

II. The PIN Limiter Diode

GENERAL CHARACTERISTICS

A forward biased PIN diode behaves like a variable resistor at microwave frequencies. This property is utilized for controlling RF power. Figure 1 shows typical R_s vs. bias data for a variety of PIN diode designs.

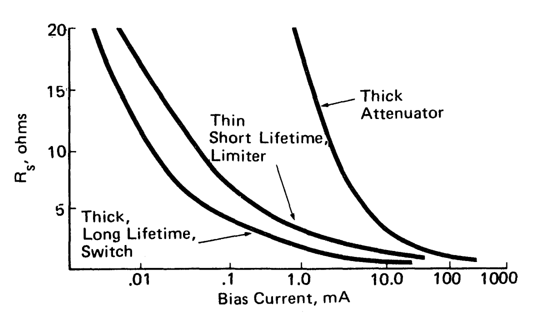


Figure 1. R_S vs. Bias Current for PIN Diodes

The limiter diode is an extremely fast responding silicon PIN diode that behaves as a variable resistance under large signal excitation. Through mechanisms of charge injection and charge storage in a thin intrinsic (high resistance) I region, the diode P-N junction controls the microwave resistance in response to the microwave signal level. Diodes with I regions of under 2 microns (.00008 inches) respond to input power on the order of 10 milliwatts. Thicker I region design produces limiters with high power dissipation capability, and combinations of diodes with different I regions are used to provide simultaneously high power handling and low level limiting.

Limiter diodes are available in chip form for use in wide-band microwave integrated circuits, as well as in a variety of stripline, glass and metal/ceramic packages.

A PIN limiter diode is a PIN diode with a very thin I region (low voltage breakdown) and very low minority carrier lifetime T_L.* These design features allow the diode to be driven into forward conduction by an incident RF signal and to develop its own "Bias Current" through processes akin to rectification. (A ground return is necessary to provide a current path). Thus, the diode can be used as a passive power limiter, whence it derives its name.

The limiter diode chip consists of a high resistivity region, the I layer, sandwiched between heavily doped low resistivity P^+ and N^+ contact regions.

There are two basic ways of making limiter diodes, and the simplified models described below will aid in further discussion of their properties.

The method of diode fabrication that Alpha feels is optimum for most applications is the Flat-Chip construction shown in Figure 2a. In this design, starting with a low resistivity N^+ contact, a high resistivity I layer is grown epitaxially. The doping density and thickness of this I region epi-layer are process variables that are used to develop the various types of limiters. On top of the I layer a small area is diffused with P^+ (anode) dopant to define the junction area and also establish a contact. The area of the P^+ region is a major design variable. A silicon-oxide silicon-nitride passivation layer covers the exposed surface of the I region, resulting in a high reliability product.

The second fabrication technique is the mesa construction shown in Figure 2b. The processes are quite similar to those used in the Flat-Chip approach, except that the volume of I region surrounding the junction as defined by the P^+ region is removed by etching. This results in lower fringe capacitance for the mesa diode but at the expense of higher transient thermal impedance, for in the Flat-Chip design some of the peak energy dissipated can flow quickly into the surrounding silicon, resulting in increased power handling. Silicon oxide passivation is used on mesa diodes.

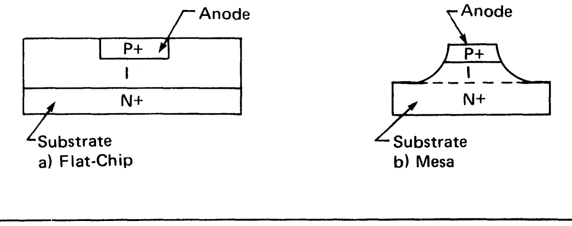


Figure 2. Flat-Chip Mesa Construction

*See Alpha Application Note 80200, "PIN Diode Basics."

Application Note 80300: Characteristics of Semiconductor Limiter Diodes

In addition to extra capacitance the Flat-Chip designs have higher series resistance (R_S) at lower bias currents due to fringing effects on current flow.

Alpha makes both type of limiters; we generally recommend Flat-Chip except where extremely low capacitance is absolutely essential.

Inasmuch as limiter applications range from milliwatt to kilowatt and from low to high microwave frequencies, a variety of diodes have been developed, optimized for each application.

In order to provide leakage power on the order of + 10 dBm or so, the limiter must have a very low threshold; that is, it must be able to respond to a milliwatt signal.

This requires a very thin I region, 1 to 2 microns. If we then add the requirement that this diode operates at 18 GHz, it must have a junction capacitance under 0.15 pF. Since capacitance is proportional to area and inversely proportional to I layer width, we need a very tiny junction, about .0015 inches in diameter. We now have a diode that limits well at the desired signal level, but it can't operate at high power. Even 200 watts incident for 1 microsec dissipates enough energy to raise the junction temperature considerably; consequently, for high power requirements the first consideration is thermal. We must have enough volume and area of silicon so that pulse heating is reasonable. For a given capacitance this requires thicker and thicker I regions and correspondingly larger area.

Diodes with I regions in the order of 1 and 2 mils have been used as limiters, but most applications require from 2 to 15 microns.

As the I region becomes larger, the ability of the diode to limit decreases, and threshold and leakage power increase. A 15 micron diode, for example, doesn't do anything until the incident power exceeds 100 milliwatts.

The inherent trade-off in diode design (high power handling ability causes high leakage power) necessitates the use of limiter diodes of each extreme — a thick input "coarse" diode to reflect most of the power, and a thin "clean-up" diode to provide the desired low leakage.

Table 1 lists some of the characteristics of typical limiter diodes.

SIMPLE LIMITER CIRCUITS

Consider a single limiter diode shunt-mounted on a microwave transmission line, with a ground return.

For power levels below the limiting theshold there is no rectification of the RF voltage, and the diode is in its zero bias state. This is the low loss condition of the diode. The junction capacitance of the diode is the significant factor that determines its maximum operating frequency. A capacitance shunting a transmission line is a one element low pass filter with a cutoff frequency that is dependent on the value of the capacitance. Figure 3 illustrates the VSWR vs. frequency response for three values of junction capacitance shunting a 50 ohm transmission line. As is shown, the uncompensated diode has a limited operating range.

This problem is compounded when more than one diode is used. To increase the usable frequency range of the diode the junction capacitance must be tuned.

Table 1. Typical Characteristics of Limiter Diodes

Base Width microns	Diameter inches	Voltage Breakdown(1) volts V_B	Capacitance(2) pf C_J	Peak Power(3) watts P	Threshold(4) dBm P_T	Leakage(5) dBm P_L
2	.0015	30	.15	100	+ 10	+ 22
2	.0025	30	.30	200	+ 10	+ 24
2	.0035	30	.50	400	+ 10	+ 25
4	.002	60	.15	150	+ 15	+ 28
4	.003	60	.30	300	+ 15	+ 30
4	.0045	60	.50	600	+ 15	+ 32
15	.003	150	.15	1kw	+ 20	+ 39
15	.004	150	.30	2kw	+ 20	+ 41
15	.005	150	.50	4kw	+ 20	+ 44

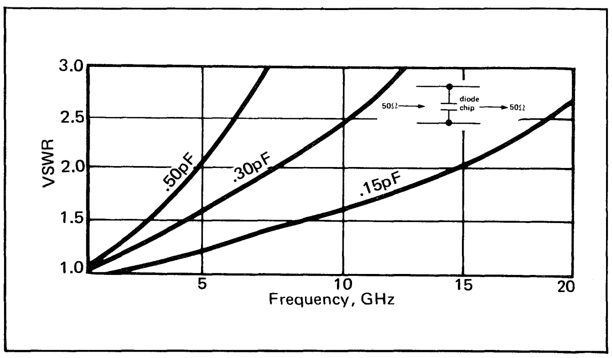


Figure 3. Typical VSWR For Untuned Shunt Diodes

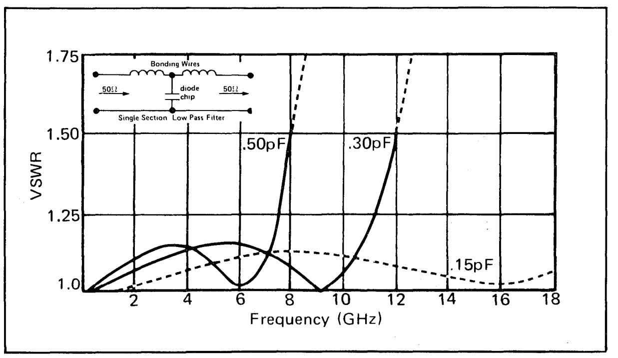


Figure 4. Typical VSWR for Low Pass Filters

This is done by adding series inductance to form a three element low pass filter. Figure 4 illustrates the VSWR vs. frequency response of such a filter using capacitances of .15, .30 and .50 pF.

1. Voltage breakdown is determined by I region thickness and the dielectric strength of silicon, about 400 volts per mil.

2. Junction capacitance is measured at 1 MHz; see section below on insertion loss.

3. 1 microsecond pulse, .001 duty.

4. Threshold is defined as the power input producing 1 dB extra loss above insertion loss.

5. Leakage power at maximum power input.

At power levels above the limiting threshold the diode responds to the RF voltage. During the positive half cycles of the voltage waveform charge is injected into the diode. If a low resistance DC return path is present, a self bias control current will be generated. When the voltage swing becomes negative, the diode discharges only some of the stored charge, maintaining the current flow. The accumulation of charge controls the effective RF resistance of the diode.

Experiments at X Band have demonstrated that the net accumulation of stored charge in the I region, and the consequent reduction in R_S, requires only a few RF cycles to reach saturation. At 10 watts incident a 30 volt device (I region approximately 2 microns) reaches 10 dB isolation (R_S about 10 ohms) in 1 nanosec and 20 dB (3 ohms) in 1.5 nanosec. Thicker I region diodes, designed for higher power handling capability, require more time, about 4 nanosec for a 60 volt, 4 micron diode, and 50 nanosec for a 150 volt, 15 micron diode.

As R_S is lowered, the transmitted signal is attenuated. A portion of this attenuated power is absorbed by the diode, and the remainder is reflected back toward the source. A semiconductor limiter is reflective by nature and has a high VSWR when in the limiting state. The percentage of incident power that is absorbed by the diode depends on the value of R_S and is a maximum when R_S is 25 ohms (in a 50 ohm system). The attenuation and percent of incident power dissipated for a PIN diode as a function of its effective RF resistance are shown in Figure 5.

LIMITING THRESHOLD AND LEAKAGE POWER

Limiting threshold is defined as the input power at which a limiter has 1 dB additional insertion loss over its 0 dBm value (1 dB compression). The threshold power level is dependent on the RF frequency and the thickness of the I region. It can be significantly controlled by application of positive or negative bias to the diode.

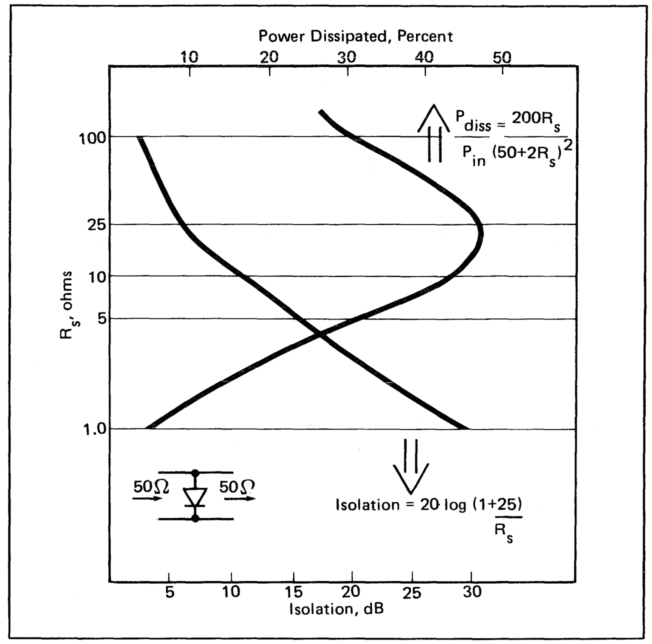


Figure 5. Isolation and Percentage Power Dissipated vs. Diode Resistance

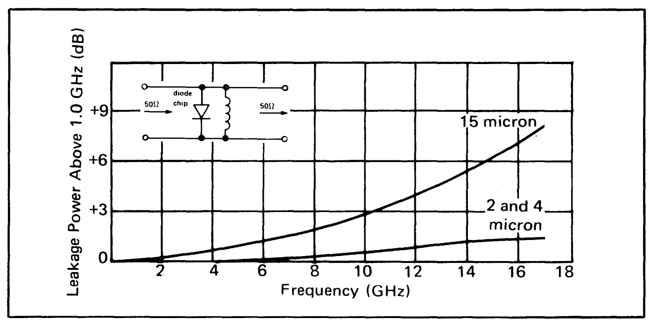


Figure 6a. Leakage Power vs. Frequency

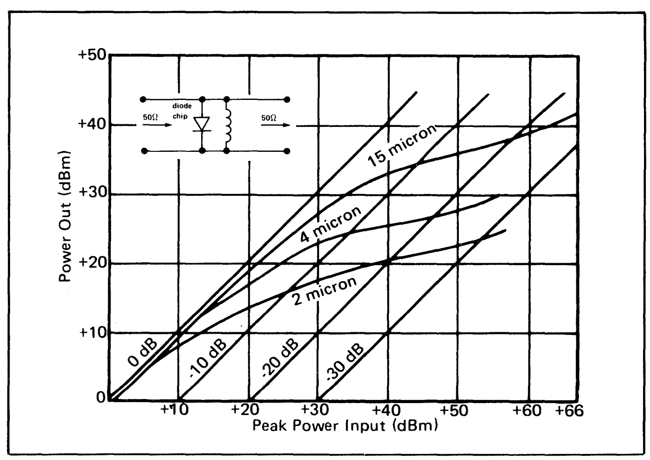


Figure 6b. Typical Peak Leakage Power at 1 GHz

Application Note 80300: Characteristics of Semiconductor Limiter Diodes

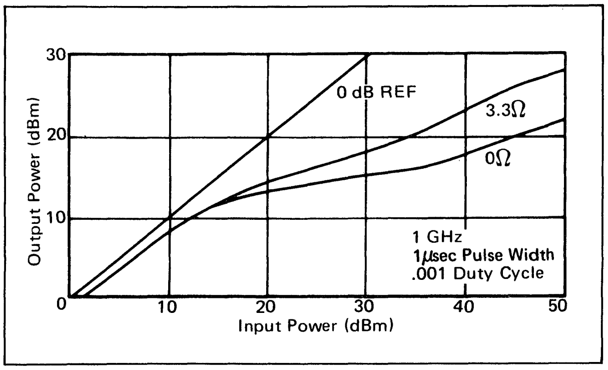


Figure 7. Typical Limiting Characteristics vs. Resistance of DC Return

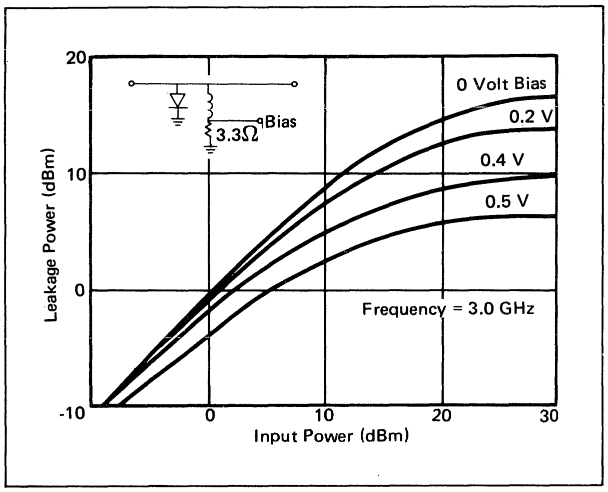


Figure 8. Leakage Characteristics vs. Forward Bias, 30 Volt Limiter Diode

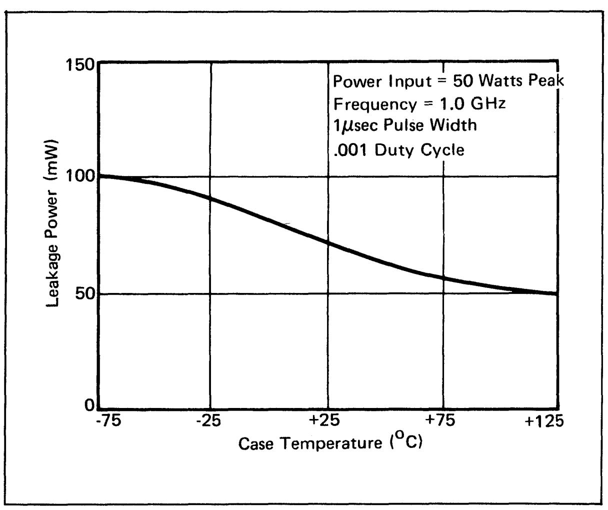


Figure 9. Leakage Power vs. Temperature for 50 Watts Peak Input Power, 30 Volt Limiter Diode

As the incident power level is increased above the limiting threshold, more charge is injected into the diodes, which results in a lower effective RF resistance. Essentially, the limiter behaves like a power sensitive variable attenuator that adjusts its attenuation level to keep the output power relatively constant.

Figures 6a and 6b show typical leakage power curves for various diodes.

Proper design of the DC return is essential. An ideal DC return path has no appreciable resistance. Excess resistance will increase the leakage power. This effect is shown in Figure 7 for a resistance of 3.3 ohms. Good RF-choke ground returns may be made using magnet wire (about 2 mils diameter), with about 20 to 40 turns wound on a 20–30 mil diameter. Resonances can occur but can generally be eliminated by minor adjustment. Excess inductance in this choke can delay current flow in the diode and produce a leakage spike.

There are applications where resistance in the DC return is required, such as when an external bias supply applies a small forward voltage across the diode terminals (Figure 8). This results in a lower theshold power at the expense of insertion loss. Negative bias can be used to raise the threshold and reduce insertion loss. The threshold RF voltage increases rapidly with negative bias, as does the leakage power. I region width is a key variable in predicting the effects of bias; experimentation is necessary.

Increased ambient temperatures will produce an increase in attenuation and a subsequent decrease in leakage power. Figure 9 demonstrates a typical leakage power change over temperature.

INSERTION LOSS

In addition to any reflective loss that might arise from the chip or diode loading of the circuit there is dissipative loss within the chip itself. This loss is caused by essentially constant contact resistance at the top and bottom of the chip and package plus dielectric losses in the I region. Typical zero bias loss at X-Band is under 0.2 dB.

If we refer to a simple physical picture of the active portion of the chip, Figure 10, we see the I region sandwiched between P^+ and N^+ heavily doped low resistance contacts.

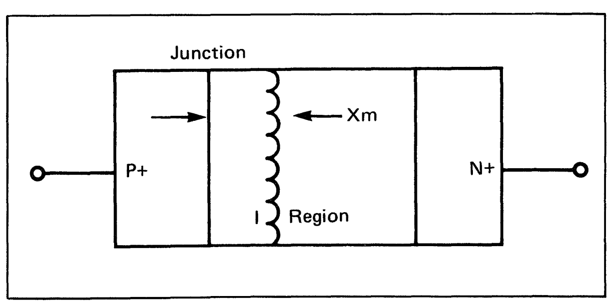


Figure 10. Idealized Limiter Structure

Application Note 80300: Characteristics of Semiconductor Limiter Diodes

Within the I region, built-in "contact voltage" at the junction establishes a so-called depletion width, X_m, which is usually not as wide as the total I region. Within the depleted zone there are no free charges, and that volume is essentially a lossless capacitor. In the undepleted zone there can exist free carriers which contribute to a volume resistivity of the I layer, typically more than 100 ohm/cm.

At low frequency, say the 1 MHz at which junction capacitance is measured, the reactance of the capacitance of the undepleted zone is effectively shunted by conductance, and only the capacitance of the depleted zone is measured. Inasmuch as the width X_m increases with negative bias, the "1 MHz" capacitance decreases. Figure 11 shows typical C-V plots. The lowest value of C_J occurs where X_m equals the width W of the I region.

At the microwave frequencies, especially above the dielectric relaxation frequency of the undepleted I region (where $2\pi f C_u = \frac{1}{R_u}$), the total capacitance is C_d and C_u in a series with some loss caused by R_u. It can be shown that

$$C_J = C_d\, C_u / C_d + C_u \propto \frac{1}{W}$$

for any value of X_m the chip junction capacitance tends to be constant, independent of bias.

The subscripts "u" and "d" correspond to "undepleted" and "depleted" zones. A good limiter diode has a zero punch-through, which means that X_m at zero bias is equal to the width of the I region. When this is true, the I region contributes no loss. Good limiter diodes achieve zero punch-through by a combination of high resistivity, so that X_m at zero bias is large, and a very thin I region, so that W is less than X_m. In practice punch-through is never achieved at zero but at − 1 or − 2 volts.

Although the I region Q is an increasing function of frequency, fixed contact resistances produce increasing loss with frequency. Figure 12 shows typical zero bias loss, including reflective loss, for a variety of limiter chips. Application of one or two volts negative bias reduces the loss by some 10 or 20% (in dB).

A good measure of a low loss chip is a ratio of junction capacitance at zero bias to the minimum capacitance at punch-through. Thus, $C_{JO}/C_{JPT} < 1.3$ is an indicator of high resistivity, low loss processing. Another measure is the equivalent parallel resistance, R_P, measured at S-band using slotted line techniques. Zero bias loss is increased at temperatures above 100°C, typically doubling at 150°C.

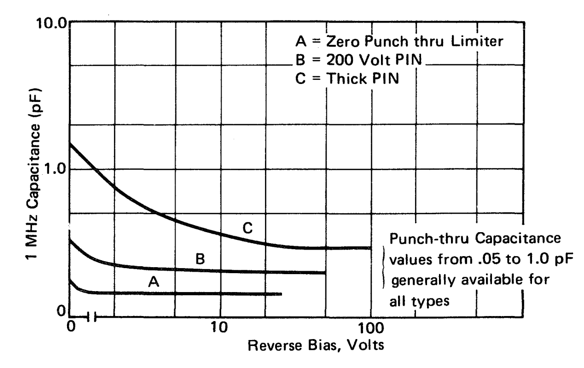


Figure 11. Typical C-V Curves 1 MHz

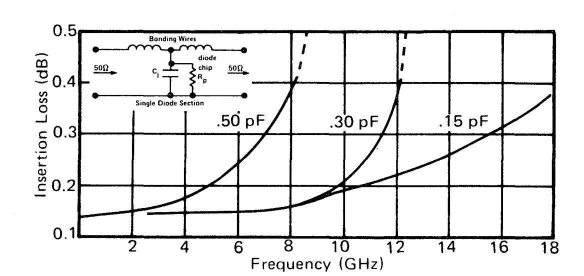


Figure 12. Typical Diode Insertion Loss vs. Frequency, Zero Bias, − 10 dBm Input

POWER HANDLING CAPABILITY

The primary cause of failure of semiconductor devices is temperature, and the limiter diode is no exception. Due to irreversible changes along the silicon/passivation interfaces or in the contact metal/silicon interfaces, junction temperatures in excess of 250°C are to be avoided. For pulsed applications the peak pulse temperature can reach as high as 300°C with no apparent degradation over extended periods, but exceptions like this must be established experimentally for each application.

The junction temperature is dependent upon peak and average power dissipated, the thermal impedance of the chip and the heat sink interfaces and the ambient temperature. A conservative equation for junction temperature is:

$$T_J = \hat{P}_d\, \hat{\theta}p + \bar{P}_d\, \bar{\theta}d + \bar{P}_d\, \bar{\theta}hs + T_A$$

where $\hat{P}_d$ and $\hat{P}_d$ are peak and average power dissipation; $\hat{\theta}p$ is the transient thermal impedance of the chip at maximum pulse length; $\bar{\theta}d$ and $\bar{\theta}hs$ are the CW or average thermal impedances of the chip, heat sink and all interfaces, and T_A is the heat sink temperature.

(This equation is of marginal utility unless you can obtain a good estimate of power dissipated in the junction — not in the circuit or contacts to the diode.)

Application Note 80300: Characteristics of Semiconductor Limiter Diodes

Pulsed thermal impedance is readily calculated, and data for various chips are presented in Figure 13. CW impedance is rather easy to measure; see Alpha Application Note 80200, "PIN Diode Basics."

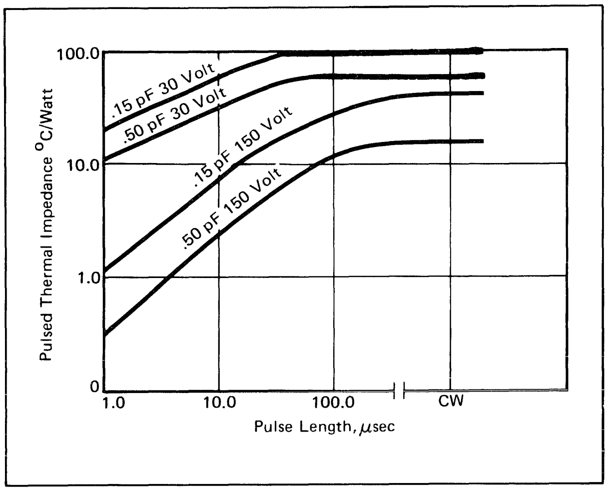


Figure 13. Pulsed Thermal Impedance

For very short pulses the energy dissipated is confined to the I region volume, and the temperature rises linearly with time. Thus, θp, the transient thermal impedance, rises linearly with pulse length. At some greater pulse length the energy has time to diffuse out of the I region into the contacts on top and bottom and, in the case of Flat-Chip construction, into the silicon surrounding the junction. In this mode — or "Time Regime" — the temperature rises as the square root of time; θ_p increases as the square root of pulse length. Finally, at some time when the energy has diffused to the metal and to the heat sink, a limiting (maximum) value of temperature is obtained. This corresponds to the CW or average thermal impedance, θ.

The pulse lengths corresponding to the various regimes depend upon I region design, primarily thickness.

For a 2 micron 30 volt limiter the linear regime is under 200 nanosec, and the CW thermal impedance is reached near 10 microsec. For a 15 micron, 150 volt limiter the linear regime exists up to some 10 microsec, and CW is reached in about 1 millisec.*

Because of uncertainties in the calculation of peak temperature it is always advisable to experiment slowly and carefully to determine the limiting and/or power handling capability of any limiter diode you wish to use. A good design has a "guaranteed to burn-out" level that is at least 3 dB above system requirements.

For best reliability design for peak junction temperature under 250°C, even 200°C, and average junction temperature under 150°C. Instant failure will occur at around 350°C.

*For reference, relevant properties of silicon are: density 2.3 gm/cm^3; specific heat .72 joules/gm/°C thermal conductivity at 25°C is 1.5 watt/cm^2/cm/°C.

Thermal conductivity drops rapidly with temperature: at 100°C, K = 1.08, and at 300°C it is 0.65. Thus, thermal runaway is always a possibility.

MORE COMPLICATED LIMITER CIRCUITS

Multiple Diodes For Higher Power Handling

If in the intended application the combination of peak power and pulse length exceeds the rated limitations for a given diode, immediate possible solutions are to use two or more similar chips in parallel (parallel here means specifically at the same electrical plane, see Figure 14) or to use a single chip of greater capacitance.

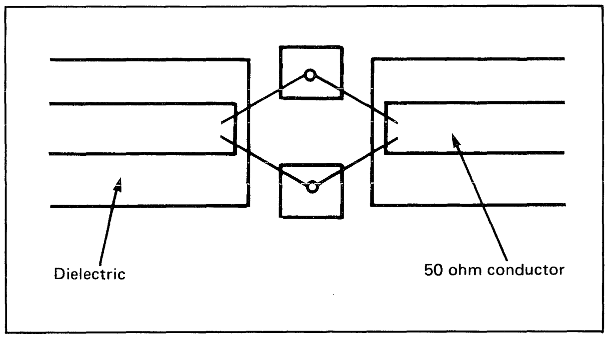


Figure 14. Chips in Parallel

Under low level insertion loss conditions the two options are more or less interchangeable. Under high power, however, two parallel chips will always yield a lower temperature, or higher power handling, than will a single chip of twice capacitance. This is because the series resistance and pulsed thermal impedance of the larger chip are not related to capacitance (area) but are more closely related to diameter (periphery), as most of the electrical and thermal resistance of the chips lies in the "spreading resistance" at the interface between the very tiny active I region and the heavily doped substrate.

Thus, doubling capacitance by doubling area reduces R_s and θp by the square root of 2. As a consequence the division of RF current by using two chips is the dominating advantage. Power handling increases by a factor of 4.

In using multiple chips there is always the question of RF impedance under high power conditions. How well do the diodes share the current? Due to inherent variables in processing no two chips can ever truly be identified as "identical" except by actual test. The most practical way out of this dilemma is to use chips from the same wafer, with voltage breakdown and capacitance as equal as possible.

Dissimilar Diodes in Cascade

We pointed out earlier that limiter chips designed for high power have inherently high leakage power. To obtain low leakage with high power input capability, it is necessary to use chips of each extreme.

Figure 15 shows a typical 3 chip limiter using chips of 3 different I regions. With .15pF chips this design will handle 1kw peak, 1 microsec, with about 20–60 mW leakage from 2.0 to 18 GHz.

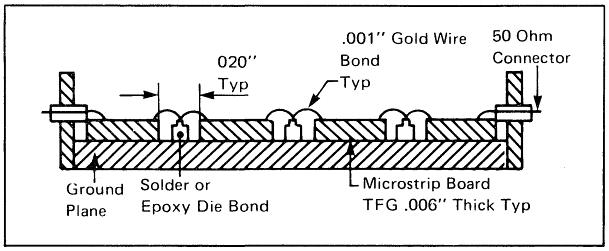


Figure 15a. Typical Microstrip Design (side view)

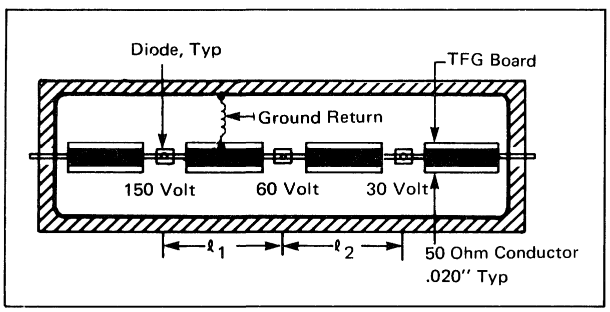


Figure 15b. Typical Microstrip Design (top view)

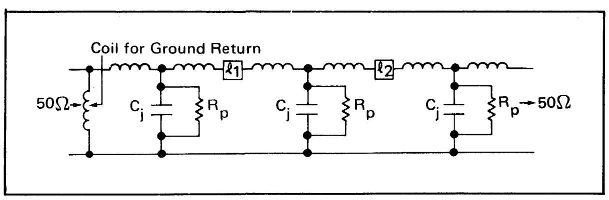


Figure 15c. Low Level Equivalent Circuit

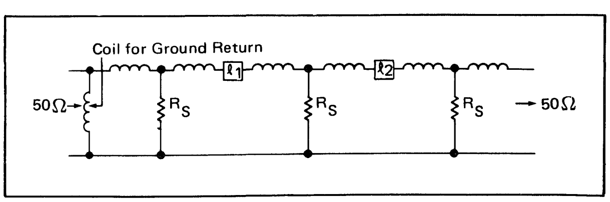


Figure 15d. High Power Equivalent Circuit

During the rise time of the incident pulse the diodes behave in the following manner. The 30 volt chip, due to its thin I region, is the first to change a low impedance. Experiments indicate that this chip reaches the 10 dB isolation point in about 1 ns and 20 dB in 1.5 ns with an incident power of 10 watts. The 60 volt takes about 4 ns, and the 150 volt about 50 ns. Consequently, the 30 volt provides protection during the initial stages of pulse rise time, with the thicker diodes progressively "turning on" as the power increases. With proper spacing (L_1 and L_2) the "on" diodes reflect high impedance to the upstream diodes, reducing the turn-on time for those diodes and insuring that essentially all of the incident power is reflected by the input diode, preventing burnout of the thinner diodes.

The spacings between diodes, while not critical, must be carefully considered, for they tend to determine the variation of leakage with frequency, the VSWR of the circuit and the power handling.

This can readily be seen from inspection of Figure 16, showing isolation vs. spacing for a pair of 1 ohm diodes. At zero or $\lambda/2$ spacing the diodes are in parallel, the net R_s is 0.5 ohm, and 34 dB of isolation results. At $\lambda/4$ spacing the high impedance produced by the second diode, at the plane of the first diode, adds another 28 dB of isolation.

In terms of RF current sharing, at zero or $\lambda/2$ spacing each diode gets half the current; at $\lambda/4$ the input diode gets all of the current.

In the case of passive limiters, where the R_S of the diode is dependent upon the magnitude of RF (power) impressed upon it, the situation is more complex. If the input diode is a 150 volt high power unit, the second diode is a 30 volt clean-up unit, and the spacing is zero or $\lambda/2$, the thin diode turns on long before the thick diode. This causes a voltage minimum to occur at the thick diode and prevents the thick diode from ever turning on. With a 1kw signal the second diode will fail quickly. With $\lambda/4$ spacing the 30 volt diode turns on during the pulse rise time and reflects a voltage maximum at the 150 volt diode, enhancing turn on of the input diode. By the time the input reaches 1kw, the input diode is fully on, and "all" of the current and energy is reflected by the input.

Figure 16 indicates that moderately adequate spacing is between .05λ and .45λ. This allows almost a decade in band width, and 2–18 GHz devices are common.

Detector Driven Limiters

In some applications the lowest leakage power that can be obtained using the thinnest possible limiters is too high. This essentially comes from the fact that we are asking the diode to perform two functions: 1) to "detect" or "rectify" a low level signal and 2) to use the rectified current to drive itself to a low R_S. These functions are inherently incompatible, and in order to

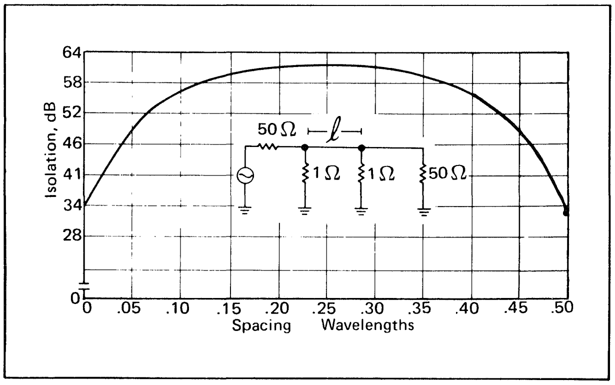


Figure 16. Isolation vs. Spacing for 1 ohm Diodes

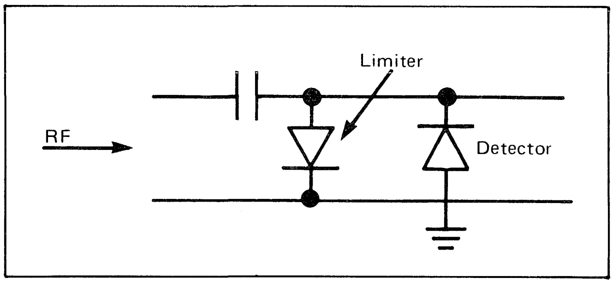


Figure 17. Detector Driven Limiter

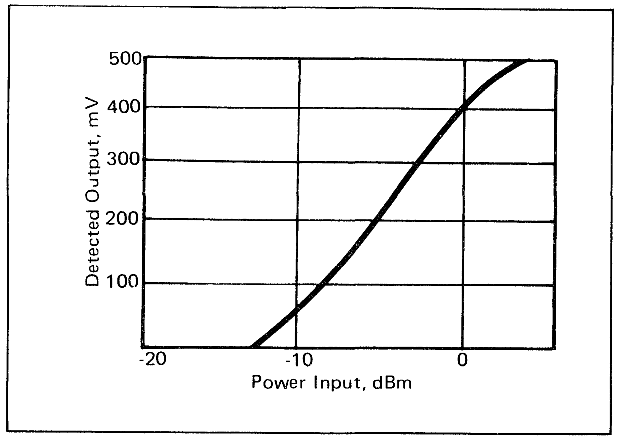


Figure 18. Typical Detector Output, 1000 ohm Load

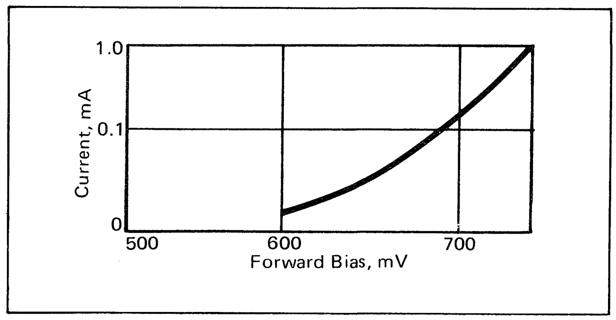


Figure 19. Typical $V_f - I_f$ Curve for Limiter Diode

get limiting to, say, 0 to 10 dB dBm, it is necessary to separate the functions by using diodes optimized for each.

We thus have the circuit shown in Figure 17.

The detector chip can be incorporated into the transmission line, using the same L-C network designs, or it can be decoupled from the line as desired. In either case the detector develops voltage and current which forward bias the limiter to low R_S. When the detector is "on-line," isolation is provided not only by the limiter but also by the detector, which at 0 dBM has an R_S on the order of 10–25 ohms. (At receive signal levels, e.g., – 40 dBm, the detector is a good low loss capacitor, with good VSWR and low insertion loss.)

A typical voltage output curve for Schottky barrier and point contact diodes is presented in Figure 18, for a load impedance of 1,000 ohms.

Typical limiter diodes have $V_f - I_f$ characteristics as shown in Figure 19. Series resistance at 1.0 mA is on the order of 3 ohms for limiter diodes.

The bias supplied by the detector provides isolation in two ways: 1) by lowering the measured small signal R_S of the limiter and 2) by enhancing the ability of the limiter to generate its own bias. (See Figures 1 and 8.)

If the detector is decoupled from the line, and the RF power detected is too low (e.g., – 10 dBm), the leakage power may increase over the level possible with passive operation with a ground return. This is because of the high R_S of the detector which reduces the "rectified" current in the limiter.

Quasi-Active Limiters

The limiters discussed thus far are entirely passive, in the sense that no external source of control power is involved. Another form of limiter utilizes external power, but the operation is still entirely controlled by the incoming RF, which justifies the term "quasi-active". A "fully-active" limiter controlled by external logic is a switch.

Active limiters can be used to provide leakage power levels that are beyond the threshold capability of passive devices.

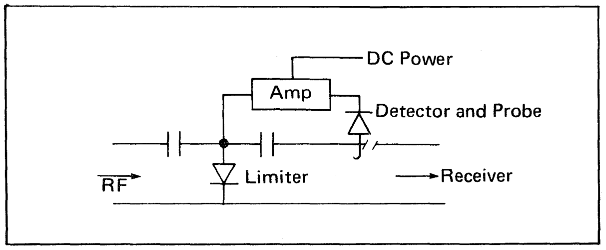


Figure 20. Quasi-Active DC Driven Limiter

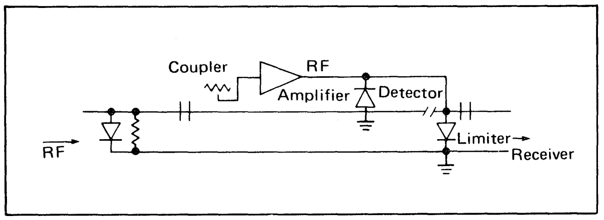


Figure 21. Off-Line RF Amplifier Quasi-Active Limiter

Figure 20 shows one form of quasi-active limiter using a video amplifier to provide limiter bias current. This approach is limited in response time, but does find some applications.

A better approach is to use an Off-Line RF amplifier. (See Figure 21.) The RF amplifier, which has the full system bandwidth and perhaps 40 dB gain, does not have to be low noise, linear, or expensive. Depending on the application there are circuit problems associated with this approach, but they are not insurmountable.

To provide normal receiver protection a conventional limiter precedes this active limiter; the high VSWR of this pre-limiter, interacting with the low-level limiter, can produce flatness problems in wide band systems, especially for leveling rather than protection circuits. An alternate approach puts the directional coupler after the final limiter.

STC Attenuator — Limiters

For various applications a limiter diode can be used to provide passive receiver protection and STC attenuator function simultaneously, as indicated in Figure 22. The Schottky diode provides a low impedance return, and the shunt resistor R_R minimizes recovery time, as will be explained in the following section.

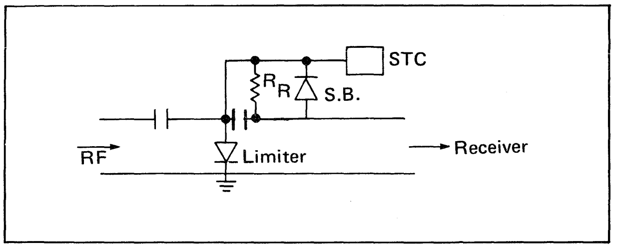


Figure 22. Passive Limiter-Dual STC Function

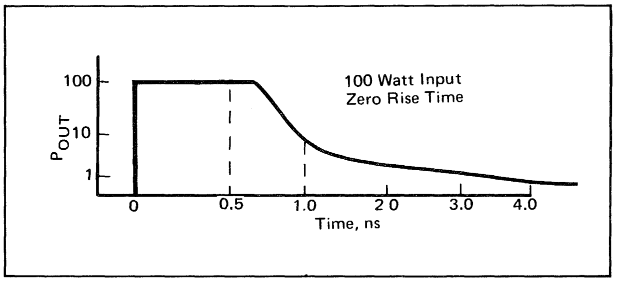


Figure 23. Generalized Response of Limiter Diode

SPIKE LEAKAGE, FLAT LEAKAGE, RECOVERY TIME

Leakage

a) SINGLE DIODE

Consider Figure 23, which is a generalized sketch of the output response of a limiter as a function of time, assuming a zero rise time input of 100 watts in the case of a 30 volt (2 micron) limiter chip.

The limiter diode does have spike leakage, the period at the beginning of the pulse when the diode is changing from a high impedance to a low resistance. During this time the output is very nearly equal to the input. The thin diode, processed optimally for fast response, begins to have appreciable isolation in less than 0.5 nanosec and at 1 nanosec provides over 10 dB isolation. At perhaps 1.5 nanosec the isolation is 20 dB. In 2 or 3 nanosec CW conditions are reached, about 28 dB isolation.

In this unrealistic example, the "spike amplitude" is 100 watts; the "spike duration," 3 dB width, is less than 1 nanosec; the "spike energy" is 1 erg. The "flat leakage" is the leakage power of the CW or steady state condition, about 150 milliwatts.

Spike amplitudes of 100 watts will burn out any kind of low noise receiver.[1] The diode limiter as described will not be satisfactory. Each of the following three steps may be taken to try to alleviate this problem.

- Be more realistic in your appraisal of the expected rise time of the input pulse. Transmitter rise times of less than one nanosecond are rare, yet even this rise time will allow the limiter diodes to respond sufficiently to limit the spike amplitude to 10 watts.

[1]Anand & Moroney — Microwave Mixer and Detector Diodes — Proc IEEE-Vol. 59, No. 8, August 1971.

Application Note 80300: Characteristics of Semiconductor Limiter Diodes

- Try to obtain even thinner diodes. I regions as thin as .4 microns can be made, but due to small area they are very hard to handle as chips; they can be mounted into standard low parasitic metal ceramic packages.
- Try a high voltage Schottky Barrier diode by itself in the transmission line. Due to high series resistance flat isolation will not be high, but the Schottky will respond faster than the limiter. Two Schottkies of opposite polarity but with a ground return are appropriate.[2]

b) TWO DIODE LIMITER

The curve of Figure 24 can be used to describe the behavior of a 2 diode limiter consisting of a "coarse" 15 micron diode followed by a thin 2 micron diode 0.1λ downstream, with an input of 1 kw and with a 50 nanosec rise time.

In the first 5 nanosec the thin diode does all the work. With an input (at that moment) of 100 watts the thin diode is almost fully "on," and the leakage is about 1 watt; at 10 nanosec the input has risen to 200 watts, and if the thin diode were alone, the leakage would rise to about 2 watts. However, the thick diode is finally waking up, and the leakage will reach a maximum on the rough order of 2 watts. At 50 nanosec the input diode is fairly saturated, and the leakage drops to some 500 milliwatts. At 100 nanosec both diodes are saturated, and the final flat leakage is about 100 milliwatts.

Figure 25 shows flat leakage for two such diode limiters.

In case 1 the input diode may be too thick or the line spacing too small, and the input diode does not contribute isolation at a low enough input; thus the "overshoot." In case 2 the input is optimally chosen.

At sufficiently high input power both diodes are saturated to the lowest R_S, and output power rises linearly. Burn-out may be imminent.

For pulses with finite rise and fall times an overshoot can appear as a "spike" on the leading and trailing pulse edges (see Figure 26).

Because of these considerations it is necessary to specify the flat leakage response of a multi-diode limiter at all input power levels from zero to the system maximum, not just at the maximum.

Recovery Time

Following the incident RF pulse there is a finite measurable period of time during which the limiter chips are returning to the high impedance, low loss state. The "free charge" which accumulated in the I region and was responsible for lowering the resistance must be totally removed.

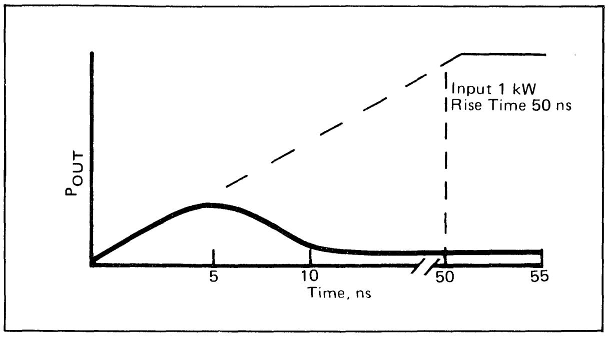


Figure 24. Generalized Response of Two Diode Limiter

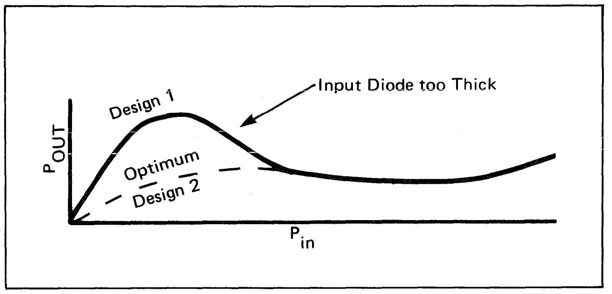


Figure 25. Generalized Output of Two Diode Limiter

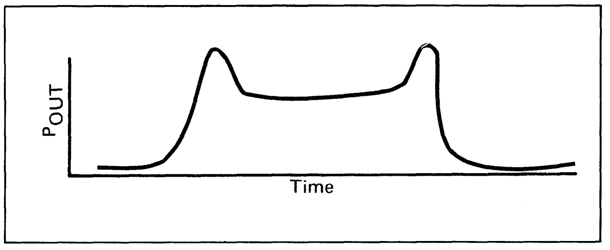


Figure 26. Effects of Overshoot on Pulse Edges

Within the I region, in the absence of external drive, internal recombination of the holes and electrons takes place at a rate reciprocal to the minority carrier lifetime. A limiter diode has a lifetime on the order of 5 to 100 nanosec depending upon thickness, capacitance and processing. This mechanism for recovery is quite slow, and for the charge to decay to 1% of the charge present under high power conditions takes about 4.5 lifetimes. Since 1% still corresponds to perhaps 100 ohm R_S, loss is still excessive, and since 4.5 lifetimes for a thick diode is about 450 nanosec, recovery is lengthy if internal recombination alone is involved.

[2]Design of Schottky Diode Limiters — Kurihara et al; Electronics & Communications in Japan, Vol. 57B, No. 5, 1974.

Fortunately, a second, much faster, mechanism exists — discharge through a return current path. With a zero ohm ground return, recovery time (measured to 1 dB excess loss) is about 1 lifetime, and with a 100 ohm return, recovery time is about 2 lifetimes.

If the limiter circuit employs a Schottky, either as a "limiter" or as a "ground return," the Schottky recovers almost instantly, and the PIN limiter does not have a ground return — recovery time will be long. A resistor in shunt with the Schottky (Figure 22) solves this problem at the expense of either Schottky current or bias current. Design compromise may be necessary in establishing the value of this resistor. The inductance of the ground return, as mentioned earlier, influences both spike leakage and recovery time. For minimum spike the time constant (RL) of the ground return-limiter circuit must be less than the pulse rise time.

Moreover, when the inductance is high, voltage impulses generated by the inductance when the RF power ceases will tend to forward bias the limiter diode and delay recovery time.

If the application involves fixed pulse lengths, the circuit of Figure 22 can be modified by replacing R_R with a large inductance, with RL (Schottky R) roughly equal to the pulse length. Initially, all Schottky current flows to the limiter and the spike is minimized; during the pulse some Schottky current flows through the choke, raising leakage power only marginally; at the end of the pulse the Schottky ceases to supply current, and the choke develops a negative $L \frac{\Delta i}{\Delta t}$ impulse which helps to withdraw the charge stored in the limiter.

When the limiter diode junction temperature exceeds 150°C, the low level insertion loss increases noticeably. At 200°C an additional 1 dB or so may be seen. Consequently, in high power limiter applications where the diodes are being stressed thermally, temperature rise constitutes another increase in recovery time; insertion loss is not minimized until the junction cools.

The junction thermal time constant, for the bulk of the cooling curve, is about 100 nanosec for 2 micron, 400 nanosec for 4 micron, and 5 microsec for 15 micron limiter diodes. Clearly, temperature can be the dominating factor in recovery time in high power limiters, which prompts another simple experiment to be done during development of any limiter circuit. Measure recovery time as a function of input power; these data, plus measurements of burn-out power, will give excellent reference points from which you can estimate junction temperature and infer diode reliability.

HARMONICS

Even an externally biased PIN diode generates harmonics, if the bias current or the frequency is low or the RF power high. This is caused by "partial recovery" of the diode during the reverse cycle of the RF current. "Negative" current can flow through the junction only by extracting some of the free charge that was injected by the bias and/or by the positive RF current.

For a PIN diode with long minority carrier lifetime and external bias, harmonic 60 to −80 dBc are possible even at 20 MHz. The limiter diode, on the other hand, has low lifetime and consequently low stored charge; harmonics are greater. Figure 27 shows harmonic generation for a pair of 30 volt limiters at 2 GHz. At higher power levels the diode becomes more saturated, and the harmonics drop off.

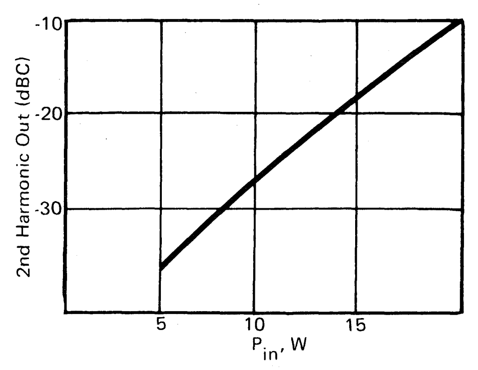


Figure 27. Typical Harmonic Generation of Limiter Diode

DESIGN EXAMPLE

To complete this note we shall design a solid state limiter that is needed by the marine radar market — 5 kilowatt peak, 1.5 micro-second, .001 Duty, X Band. (Although the market would probably want waveguide, we will use coax, since the microwave circuitry is easier to understand.)

Looking at Table 1 we note that no single diode listed will work. On the other hand it appears that a 0.3 pF 15 micron diode can handle 2 kw for 1 microsec. If we use two of these in parallel, we raise this to 8 kw for 1 microsec or 4 kw for 2 microsec. Unfortunately, this totals 0.6 pF, which is too much for 10 GHz even with a narrow band restriction. These diodes could be used, not in parallel, but λ/2 apart. However, current division might impose too much of a strain on the input diode. We thus put two 0.15 pF diodes in the input and two more from the same lot at the half wave point down stream. The .15 pF 15 micron chip can handle 1 kw for 1 microsec. Assuming perfect current division 4 diodes raise power handling by 16, or 8 kw for about 2 microsec. There now appears to be an adequate safety margin.

Application Note 80300: Characteristics of Semiconductor Limiter Diodes

Insertion loss of these 4 diodes will be about 0.4 dB and flat leakage power about 50 watts. We now add clean-up limiters down stream, $\lambda/4$ from the second stage of high power input diodes. A pair of 60 volt .15 pF chips will probably be needed to handle the spike that gets by the input, perhaps 2 kw for 100 nanosec.

Finally, we put one 2 micron diode to handle the spike that gets by the 60 volt diode, perhaps 1 kw for 5 nanosec, and keep the flat leakage down to about 100 mw.

We thus wind up with 7 chips, about .7 dB diode loss, and we are ready for high power test.

The first thing we discover is that thin microstrip is not ideal for high power. We need about 20 mil thick duroid to avoid arcing and reduce circuit losses.

Next, we find that the voltage maxima upstream of the input diodes correspond to 20 kw peak, and our transitions and connectors begin to arc. This can be handled by using HN connectors and half-inch coax.

Once we learn how to use packaged diodes in waveguide, using tuned chokes as sketched in Figure 28, we find that we can obtain a zero to 5 percent band, using the same complement of 7 chips in standard metal ceramic packages. Achieving close spacing is difficult due to choke dimensions, and this restricts bandwidth. Thus, this limiter has not yet been developed.

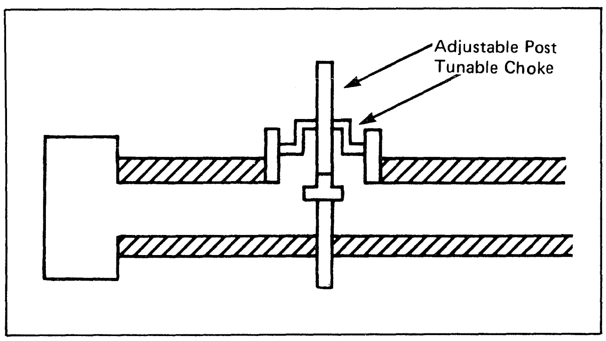


Figure 28. Typical Waveguide Mount, Packaged Limiter Diode

Hints:

1. Could anything be done at high power using Fin-Line?
2. Two .15 pF chips can be assembled in one package.

Let's calculate the temperature rise of the 4 input diodes; again, assume we are in 50 ohm microstrip, so that we know the chip current. At 5 kilowatts assume peak line current is

Each diode gets 8 amperes. If each chip is driven to an R_S of 2.0 ohms (not fully saturated), it will dissipate

The peak thermal impedance for 1 microsec is tabulated at 1.2°C/watt. For the 1.5 microsec pulse, θp is 1.8°C/watt. Thus, the peak junction temperature is 64 (1.8) = 115°C. The average power dissipation at .001 Duty is 64 milliwatts.

With an ambient temperature of 60°C we find a peak junction temperature of 175°C. In view of the conservative assumptions, this sounds reasonable.

3. Once we begin working in waveguide, we discover that we can use a junction capacitance as high as 0.7 pt, and still cover the marine radar band. This solves the handling problem.
4. It is possible to use thick PIN diodes, with breakdown voltages over 500 volts, as coarse limiters. The spike energy is low enough for medium power limiters, and peak power input of over 20 kilowatts can be tolerated.

Chip Electrical Parameters

Model Number	+ V_B Typ (V)	C_{J0} Typ (pf)	C_{J6} Max. (pf)	R_S Typ @10 mA (Ω)	R_S Typ @1.0 mA (Ω)	R_P (2) Typ (Ω)	θ_P (3) Typ (°C/W)	θ_{CW} (°C/W)	τ_L Typ (ns)
CLA3131-01	20–45	0.20	0.15	1.5	5.0	2000	20	100	5
CLA3131-02		0.50	0.30	1.2	4.5	1000	12	80	10
CLA3131-03		0.70	0.50	1.0	4.0	1000	10	55	10
CLA3132-01	45–75	0.20	0.15	1.5	4.0	2000	15	80	10
CLA3132-02		0.50	0.30	1.2	3.5	1000	10	60	15
CLA3132-03		0.70	0.50	1.0	3.0	1000	6	40	20
CLA3133-01	120–180	0.20	0.15	1.5	3.5	2000	1.2	40	50
CLA3133-02		0.60	0.30	1.0	3.0	1000	0.5	20	50
CLA3133-03		0.80	0.50	0.5	3.0	1000	0.3	15	100
CLA3134-01	15–30	0.12	0.10	2.0	4.0	3000	30	120	5
CLA3134-02		0.20	0.15	1.5	3.0	2000	20	80	5
CLA3135-01	30–60	0.12	0.10	2.0	4.0	3000	20	100	7
CLA3135-02		0.20	0.15	1.5	4.0	2000	15	70	7

Application Note 80300: Characteristics of Semiconductor Limiter Diodes

Limiter Performance Ratings

Model Number	Peak P_{in} Max. @1.0 μs (dBm)	Threshold[4] Typ (dB)	Leakage[4] P_{out} Typ (dBm)	Insertion Loss[2] Typ (dBm)	CW[5] Power In Max. (W)	Recovery[6] Time, Typ (ns)
CLA3131-01	+50	+10	+22	0.1	2	10
CLA3131-02	+53	+10	+24	0.2	3	10
CLA3131-03	+56	+10	+25	0.2	4	10
CLA3132-01	+53	+15	+27	0.1	3	20
CLA3132-02	+56	+15	+29	0.2	4	20
CLA3132-03	+59	+15	+31	0.2	5	20
CLA3133-01	+60	+20	+39	0.1	5	50
CLA3133-02	+63	+20	+41	0.2	10	50
CLA3133-03	+66	+20	+44	0.2	15	50
CLA3134-01	+47	+7	+19	0.1	2	5
CLA3134-02	+50	+7	+22	0.1	3	5
CLA3135-01	+47	+12	+24	0.1	3	10
CLA3135-02	+50	+12	+27	0.1	4	10

NOTES:

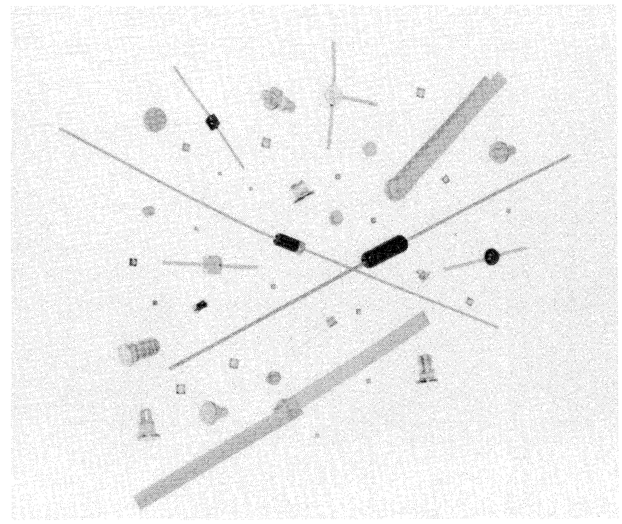
1. Series resistance measured at 500 MHz.
2. Chip loss can be represented as a resistance in shunt with the junction capacitance.
   Data shown are for 10 GHz for 0.15 and 0.30 pf chips, 5 GHz for 0.50 pf chips. Reflective loss is shown in Figure 3, and is included. Loss is measured at −10 dBm input.
3. Pulsed thermal impedance is given for a 1 μs pulse. Figure 5 shows typical variation for longer pulse lengths. CW thermal impedance presumes infinite heat sink.
4. Threshold input power produces 1 dB increase in insertion loss.
   Figure 6 shows typical leakage power curves. Data taken for 1.0 GHz.
   Figure 7 shows typical variation with frequency.
5. Note that CW power and average power are not synonymous. Power ratings are computed in terms of a peak junction temperature of 200°C, for short pulses, an average junction temperature of 125°C, and an ambient of 25°C. Duty factor 0.001 assumed for maximum pulse power input.
6. Recovery time is measured with ground return (less than 1.0 ohm) to 1 dB excess loss.

Silicon Tuning Diode Selection Guide

In general, high capacitance tuning diodes (either abrupt or hyperabrupt) are characterized by low Q's, which limit them to operation at below microwave frequencies. The following is meant to be a rough guide for the design engineer. Please consult the factory for more detailed information.

Device Family	Frequency of Operation				
	100–500 MHz	500 MHz–3.5 GHz	3.5 GHz–5 GHz	5–7 GHz	7–10 GHz
Hyperabrupt — 6510 Series	X				
Hyperabrupt — 6520 Series	X				
Hyperabrupt — 6530 Series	X				
Hyperabrupt — DKV4105 & 4109 Series	X	X			
Hyperabrupt — 6550 Series		X	X		
Abrupt — 90 volt, DVH6790-07 through DVH6790-20 Series	X				
Abrupt — 90 volt, DVH6790-03 to 05	X	X			
Abrupt — 60 volt, DVH6760-03 through 17		X	X		
Abrupt — 60 volt, DVH6760-17 through 25	X	X			
Abrupt — 45 volt, DVH6740-01 through 19	X	X	X		
Abrupt — 30 volt, DVH6730-01 through 19			X	X	X
Abrupt — 30 volt, DVH6730-19 through 27	X	X			

Microwave Tuning Diodes and Chips



Features

- Highest Q Values Available
- Widest Range of Capacitance, Voltage, and Package Styles
- Low Post-Tuning Drift
- High Stability, Low Leakage
- Meet All MIL-STD-750 Requirements

Types

- DVH6700 Series
- CVH2000 Series

Description

Alpha abrupt-junction tuning varactors are of the epitaxial, mesa design and have a high density silicon dioxide passivation. This passivation, in conjunction with other processes, results in high reliability, low leakage current, and low post-tuning drift. To minimize series resistance and provide chips capable of being bonded in a wide variety of packages using conventional bonding techniques, tightly controlled metallization on the top and back surfaces of the chip is utilized.

Variations from square law are minimized while maintaining high tuning ratios and highest Q by a careful selection of epitaxial silicon and by anode diffusions that are computer controlled. All diodes are available in a wide selection of packages or in chip form. See Section 8 for a complete selection of standard packages.

Applications

Tuning diodes are offered in a large selection of capacitance ranges. Alpha also has hyperabrupt tuning diodes for those applications requiring larger capacitances, wider tuning ranges and linear frequency versus voltage tuning at slightly lower Q. For tuning applications above Ku-band Alpha has a series of GaAs tuning diodes with exceptionally high Q.

Silicon abrupt junction tuning varactors are ideally suited for frequency tuning applications through Ku-band. They may also be used for tuning filters, phase shifters, oscillators, up-converters and low order multipliers. Typical C_T (Total Capacitance — includes package) and C_J (Junction Capacitance) curves are shown on Figures 1 and 2.

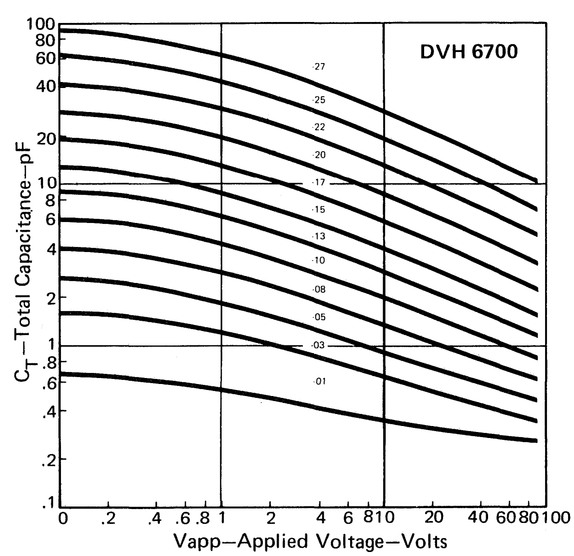


Figure 1. Total Capacitance vs. Applied Voltage

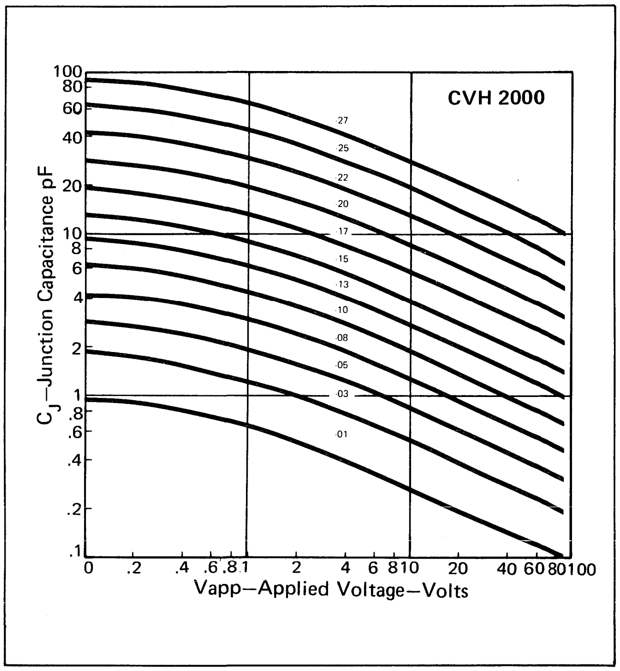


Figure 2. Junction Capacitance vs. Applied Voltage

Diode Q is dependent on several factors. Highest Q is obtained from low breakdown voltage and low capacitance diodes; Q decreases as either breakdown voltage or capacitance is increased. In addition, Q, being an inverse function of capacitance and series resistance, increases with reverse bias. Typical Q vs. reverse bias curves for several diodes of different C_T values are shown in Figure 3. A typical schematic representation of a packaged High Q tuning varactor is shown in Figure 4. Usually the L_s (package series inductance) and C_p (package parallel capacitance) can be designed into most circuits. The junction capacitance of abrupt junction diodes is given by the following equation.

$$C_j(V) = \frac{Co}{(1 + \frac{V}{\varphi})^n}$$

Where:

$C_j(V)$ = Junction capacitance at reverse voltage, V
Co = Junction capacitance at V = 0
V = Applied reverse voltage
φ = Contact potential of the diode = 0.8 V
n = Slope of C – V curve when plotted on log-log paper;
n ≅ .47 for actual devices: n = .50 for the ideal case.

The total capacitance of a packaged diode is thus
$C_T(V) = C_P + C_j(V)$

where C_P is the package stray capacitance.

If $C_j(V)$ is large compared with C_P, no degradation of the diode tuning ratio due to package parasitics is observed. However, if C_P and $C_j(V)$ are of the same order, a substantial decrease in tuning ratio will occur. This is clearly seen by comparing the C_j and C_T vs. voltage curves in Figures 1 and 2.

See Application Note 80000 in Section 7 for suggested handling and bonding procedures for diode chips.

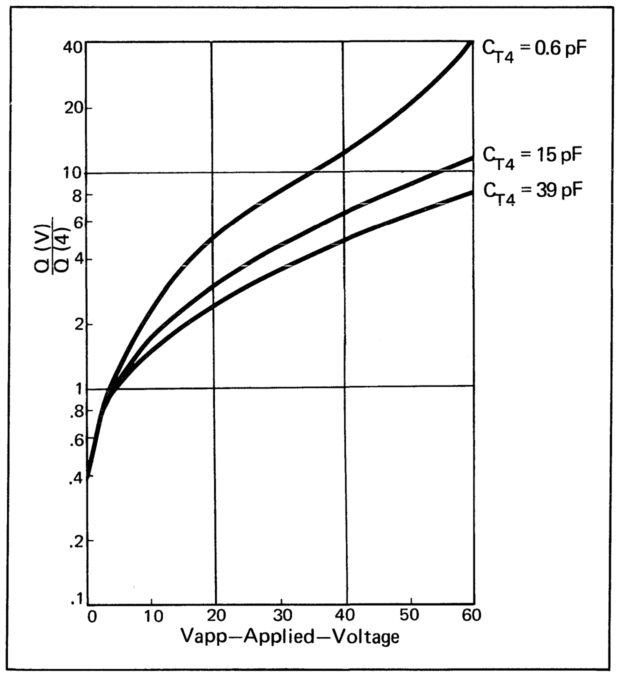


Figure 3. Typical Q vs. Applied Voltage Abrupt Junction Tuning Diode Q Normalized to Q at V = 4 Vdc

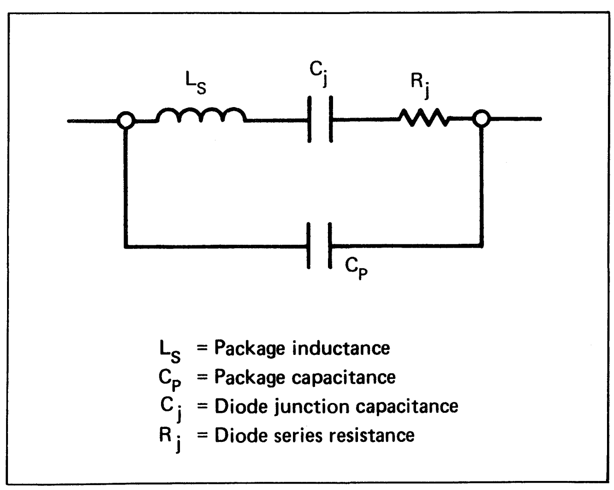


Figure 4. Typical Schematic Representation of a Packaged Tuning Varactor

Extra High Q DVH6700 Series

Maximum Ratings
Operating Temperature Range T_{OP} −65°C to +125°C
Storage Temperature Range T_{SLG} −65°C to +175°C
Reverse Voltage V_R same as rated V_B

Ordering Information
6700 Series
Example:
Desired Device Specification
V_{BR} = 45 V C_{T4} = 3.3 pF Pkg. = 135
Resultant Type Number DVH6742-11

		30 Volt Series		45 Volt Series		60 Volt Series		90 Volt Series	
DVH6700 EXTRA HIGH Q		DVH6730 099-001 Pkg DVH6731 023-001 Pkg DVH6732 135-001 Pkg DVH6733 168-001 Pkg DVH6734 168-801 Pkg		DVH6740 099-001 Pkg DVH6741 023-001 Pkg DVH6742 135-001 Pkg DVH6743 168-001 Pkg DVH6744 168-801 Pkg		DVH6760 099-001 Pkg DVH6761 023-001 Pkg DVH6762 135-001 Pkg DVH6763 168-001 Pkg DVH6764 168-801 Pkg		DVH6790 099-001 Pkg DVH6791 023-001 Pkg DVH6792 135-001 Pkg DVH6793 168-001 Pkg DVH6794 168-801 Pkg	
C_{T4}(pF)[1]	Suffix Number	C_{TO}/C_{T30}	Q_{-4}[2] 50 MHz	C_{TO}/C_{T45}	Q_{-4}[2] 50 MHz	C_{TO}/C_{T60}	Q_{-4}[2] 50 MHz	C_{TO}/C_{T90}	Q_{-4}[2] 50 MHz
0.4	01	2.2	5000	2.3	3000				
0.6	02	2.7	5000	2.8	3000				
0.8	03	3.2	4800	3.3	2800	3.8	2100	4.2	1000
1.0	04	3.5	4800	3.9	2800	4.3	2100	4.7	1000
1.2	05	3.8	4600	4.3	2600	4.6	2100	5.2	900
1.5	07	4.0	4400	4.6	2400	5.1	2000	5.7	900
1.8	08	4.1	4200	4.9	2300	5.4	2000	6.2	900
2.2	09	4.1	4000	5.1	2200	5.6	2000	6.5	850
2.7	10	4.2	3800	5.2	2200	5.8	1900	6.8	850
3.3	11	4.2	3600	5.3	2100	6.0	1800	7.1	850
3.9	13	4.2	3400	5.4	2000	6.2	1700	7.3	800
4.7	14	4.2	3200	5.4	2000	6.4	1600	7.5	800
5.6	15	4.3	3000	5.5	1900	6.6	1500	7.7	800
6.8	16	4.3	2800	5.6	1800	6.7	1400	7.8	750
8.2	17	4.3	2600	5.7	1700	6.8	1300	7.9	750
10	19	4.4	2400	5.8	1600	6.8	1200	8.0	750
12	20	4.4	2200			6.9	1100	8.1	700
15	21	4.4	2000			7.0	1000	8.2	700
18	22	4.4	1800			7.0	1000		
22	23	4.5	1600			7.0	950		
27	25	4.5	1400			7.0	950		
33	26	4.5	1400						
39	27	4.5	1200						

Notes:
1. Capacitance tolerance is ±10% except ±20% for 0.4 and 0.6 pF. 099 package diodes measured in shielded holder, $C_{pkg} \cong 0.07$ pF.
2. Q specified V_R = 4 V, 50 MHz equivalent from 1 GHz or 100 MHz measurement.
3. Minimum V_{BR} (Breakdown Voltage) at $I_R = 10\mu A$.

Microwave Tuning Diodes and Chips

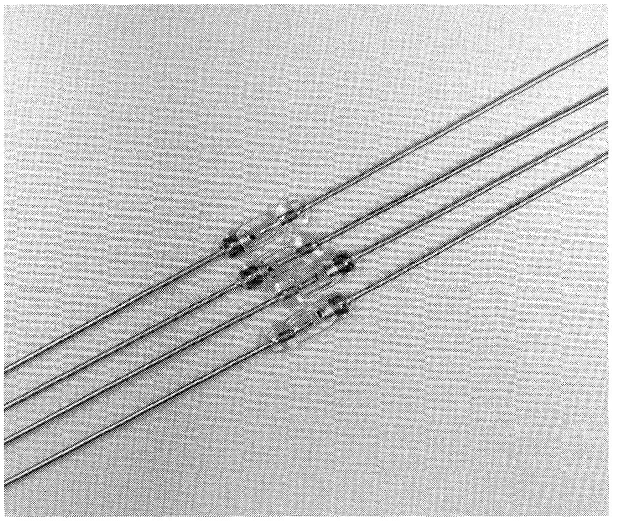
Extra High Q CVH2000 Series Chips

Maximum Ratings
Operating Temperature Range T_{OP} −65° to +125°C
Storage Temperature Range T_{SLG} −65° to +175°C
Reverse Voltage V_R same as rated V

Ordering Information
2000 Series
Example:
Desired Chip Specification
C_j – 4 Volts = 8.2 pF V_{BR} = 60 Volts
Resultant Part Number CVH-2060-17

		TYPE CVH2030		TYPE CVH2045		TYPE CVH2060		TYPE CVH2090	
CVH2000 Extra High Q Chips		30 Volt Series(3) tuning ratio(4) 4.5:1 min		45 Volt Series(3) tuning ratio(4) 6:1 min		60 Volt Series(3) tuning ratio(4) 7.5:1 min		90 Volt Series(3) tuning ratio(4) 8.7:1 min	
C_J – 4V (pF)(1)	Suffix Number	Chip Style	Q_{-4}(2)	Chip Style	Q_{-4}(2)	Chip Style	Q_{-4}(2)	Chip Style	Q_{-4}(2)
0.4	01	150-801	5000	150-801	3000				
0.6	02	150-801	5000	150-801	3000				
0.8	03	150-801	4800	150-801	2800	150-801	2100	150-801	1000
1.0	04	150-801	4800	150-801	2800	150-801	2100	150-801	1000
1.2	05	150-801	4600	150-801	2600	150-801	2100	150-801	900
1.5	07	150-801	4400	150-801	2400	150-801	2000	150-802	900
1.8	08	150-801	4200	150-801	2300	150-801	2000	150-802	850
2.2	09	150-801	4000	150-801	2200	150-802	2000	150-802	850
2.7	10	150-801	3800	150-802	2200	150-802	1900	150-802	850
3.3	11	150-802	3600	150-802	2100	150-802	1800	150-802	850
3.9	13	150-802	3400	150-802	2000	150-802	1700	150-802	800
4.7	14	150-802	3200	150-802	2000	150-802	1600	150-802	800
5.6	15	150-802	3000	150-802	1900	150-802	1500	150-802	800
6.8	16	150-802	2800	150-802	1800	150-802	1400	150-802	750
8.2	17	150-802	2600	150-802	1700	150-802	1300	150-803	750
10	19	150-802	2400	150-802	1600	150-802	1200	150-803	750
12	20	150-802	2200			150-803	1100	150-803	700
15	21	150-803	2000			150-803	1000	150-803	700
18	22	150-803	1800			150-803	1000		
22	23	150-803	1600			150-803	950		
27	25	150-803	1400			150-803	950		
33	26	150-803	1400			150-805	900		
39	27	150-803	1200			150-805	900		

Notes:
1. Capacitance tolerance is ± 10% except ± 20% for 0.4 and 0.6 pF.
2. Q specified V_R = 4 V, 50 MHz equivalent from 1 GHz or 100 MHz measurement.
3. Minimum V_{BR} (Breakdown Voltage) at 10µA.
4. Tuning ratio equals the capacitance at 0 Volts divided by the capacitance at the specified breakdown voltage.



Features

- High Q
- Large Tuning Range
- Standard Capacitance Tolerances — 10%, 5%, 2%
- Computer Matched for Tracking (optional)
- Low Leakage Current
- Meet All MIL-STD-750 Requirements

Types

- 30 Volt Series
  (1N5461A,B,C — 1N5476A,B,C)
  (1N5441A,B,C — 1N5456A,B,C)
- 60 Volt Series
  (1N5139 — 1N5148)
  (1N5139A — 1N5148A)

Description

Alpha VHF-UHF tuning diodes are diffused epitaxial planar-passivated devices housed in the standard Alpha 099-001 glass package (DO-7). Low leakage current is inherent in this process. Shallow diffusions combined with a high degree of control of epitaxial layer doping uniformity results in devices with near abrupt junctions. High Q is maintained by optimizing active layer resistance and by careful control of the metallization process. The devices are also available in chip form and are suitable for mounting into circuits using Au-Sn solder. The top contact can be readily bonded with gold wire or ribbon using conventional thermocompression bonding techniques.

Applications

These devices are designed for electronic tuning applications in the VHF-UHF region to replace mechanical tuners. They can also be used for other frequency control applications or for low power harmonic generation applications. The devices can be matched for capacitance at several bias voltages using computer-aided testing and supplied in multi-unit matched sets.

Maximum Ratings

Parameter	Symbol	Value	Units
Reverse Voltage	V_R	Same as V_{BR}	Volts
Device Dissipation @ T_A = 25°C		400	mw
Derate above 25°C	P_D	2.67	mw/°C
Junction Temperature	Tj	175	°C
Storage Temperature Range	Tstg	− 65 to + 200	°C

30 Volt Series

Electrical Characteristics (T_A = 25°C or as noted)

Parameter	Test Conditions	Symbol	Min	Max	Units
Reverse Breakdown Voltage	I_R = 10μAdc	V_{BR}	30	—	Vdc
Reverse Leakage Current	V_R = 25 Vdc. T_A = 25°C V_R = 25 Vdc. T_A = 150°C	I_R	— —	0.02 20	μAdc
Diode Capacitance Temperature Coefficient	V_R = 4.0 Vdc. f = 1.0 MHz	TC_c	—	400	ppm/°C

60 Volt Series

Electrical Characteristics (T_A = 25°C or as noted)

Parameter	Test Conditions	Symbol	Min	Max	Units
Reverse Breakdown Voltage	I_R = 10μAdc	V_{BR}	60	—	Vdc
Reverse Leakage Current	V_R = 55 Vdc. T_A = 25°C V_R = 55 Vdc. T_A = 150°C	I_R	— —	0.02 20	μAdc
Diode Capacitance Temperature Coefficient	V_R = 4.0 Vdc. f = 1.0 MHz	TC_c	—	300	ppm/°C

VHF-UHF Tuning Diodes

30 VOLT SERIES

Device	C_T, Diode Capacitance[1] $V_R = 4.0$ Vdc, f = 1.0 MHz pF	TR, Tuning Ratio C_{T2}/C_{T30} = 1.0 MHz		Q[3] $V_R = 4.0$ Vdc f = 50 MHz
	Nom ± 10%	Min	Max	Min
1N5461A	6.8	2.7	3.1	600
1N5462A	8.2	2.8	3.1	600
1N5463A	10.0	2.8	3.1	550
1N5464A	12.0	2.8	3.1	550
1N5465A	15.0	2.8	3.1	550
1N5466A	18.0	2.9	3.1	500
1N5467A	20.0	2.9	3.1	500
1N5468A	22.0	2.9	3.2	500
1N5469A	27.0	2.9	3.2	500
1N5470A	33.0	2.9	3.2	500
1N5471A	39.0	2.9	3.2	450
1N5472A	47.0	2.9	3.2	400
1N5473A	56.0	2.9	3.3	300
1N5474A	68.0	2.9	3.3	250
1N5475A	82.0	2.9	3.3	225
1N5476A	100.0	2.9	3.3	200
1N5441A	6.8	2.5	3.1	450
1N5442A	8.2	2.5	3.1	450
1N5443A	10.0	2.6	3.1	400
1N5444A	12.0	2.6	3.1	400
1N5445A	15.0	2.6	3.1	400
1N5446A	18.0	2.6	3.1	350
1N5447A	20.0	2.6	3.1	350
1N5448A	22.0	2.6	3.2	350
1N5449A	27.0	2.6	3.2	350
1N5450A	33.0	2.6	3.2	350
1N5451A	39.0	2.6	3.2	300
1N5452A	47.0	2.6	3.2	250
1N5453A	56.0	2.6	3.3	200
1N5454A	68.0	2.7	3.3	175
1N5455A	82.0	2.7	3.3	175
1N5456A	100.0	2.7	3.3	175

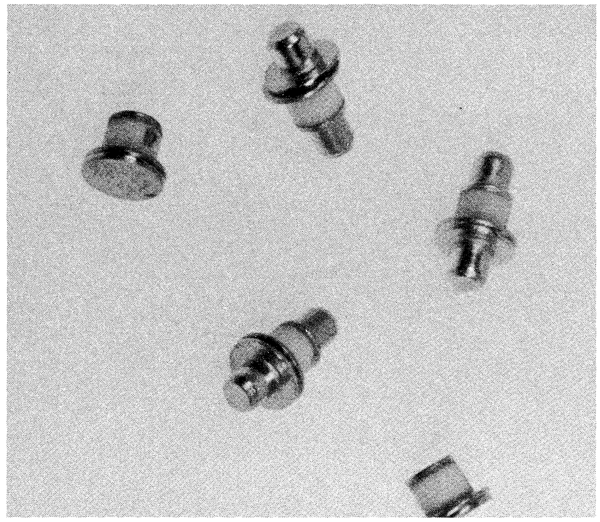
60 VOLT SERIES

Device	C_T, Diode Capacitance $V_R = 4$ Vdc, f = 1 MHz pF	TR, Tuning Ratio C_{T4}/C_{T60} f = 1 MHz		Q $V_R = 4$ Vdc. f = 50 MHz
	Nom	Min	Typ	Min
1N5139	6.8	2.7	2.9	350
1N5140	10.0	2.8	3.0	300
1N5141	12.0	2.8	3.0	300
1N5142	15.0	2.8	3.0	250
1N5143	18.0	2.8	3.0	250
1N5144	22.0	3.2	3.4	200
1N5145	27.0	3.2	3.4	200
1N5146	33.0	3.2	3.4	200
1N5147	39.0	3.2	3.4	200
1N5148	47.0	3.2	3.4	200

Notes:
1. Substitute subscript B for ± 5% or C for ± 2% tolerance on C_{T4}.
2. Add subscript A for ± 5% tolerance on C_{T4}.
3. Q is calculated from values of C and G measured on Boonton 33A admittance bridge using the formula

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

Microwave Hyperabrupt Tuning Diodes
DKV6550 Series



Features

- Octave Frequency Tuning from 0 to 10 Volts
- ±1.5% Linearity for a 1.7:1 Tuning Ratio without Compensation Network

Type

- DKV 6550 Series

Description

Alpha microwave hyperabrupt diodes are designed for linear wideband tuning of microwave filters, resonators and local oscillators. Linear tuning, not possible with conventional abrupt-junction tuning diodes, is accomplished by maintaining an accurate silicon doping profile using ion-implantation precision control techniques.

The DKV6550 series hyperabrupt diodes offer wide bandwidth linear tuning with low bias voltage. For example a 20-volt hyperabrupt diode can provide the same tuning variation as a 90-volt abrupt-junction diode, as illustrated in Figure 3.

When capacitance and tuning ratio values are equal, a hyperabrupt diode will have a Q (measured at −4 volts, 50 MHz) approximately ½ to ⅓ that of an abrupt-junction diode. This inherent Q reduction is often outweighed by the advantages of linearity and low bias requirements of hyperabrupt diodes.

These diodes are available in most of the Alpha ceramic and glass packages. They can be supplied in chip form or mounted on a variety of chip carriers. All chips are passivated with silicon dioxide for high reliability, low leakage current and low post tuning drift.

The characteristics of the model DKV6550 diodes in the standard Alpha 023-001 ceramic package (C_P = 0.17 pF) are shown in Figures 1, 2 and 3.

Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
VR	Reverse Voltage	22	Volts
I_F	Forward Current	50	mAdc
P_D	Power Dissipation (T_A = 25°C)	250	mW
T_J	Junction Temperature	−55 to +125	°C
T_{STS}	Storage Temperature	−55 to +175	°C

Electrical Characteristics at 25°C (Package Outline 023-001)

Symbol		V_{BR}	I_R	C_T				Q
Parameter		Reverse Breakdown Voltage	Reverse Leakage Current	Diode Capacitance (Cp = 0.17pF)				Figure of Merit
Unit		V_{DC}	nA_{DC}	pF				
Test Condition		$I_R = 10\mu$Adc	V_R = 20 Vdc	f = 1 MHz, V_R = 4 Vdc		f = 1 MHz, V_R = 20Vdc		f = 50 MHz V_R = 4 Vdc
Type Number for 023 Package	Type Number for 150-801 Chip	Min.	Max.	Min.	Max.	Min.	Max.	Min.
DKV6550A	CKV2010-19	22	50	.90	1.10	.35	.45	500
DKV6550B	CKV2010-20	22	50	1.35	1.65	.45	.55	500
DKV6550C	CKV2010-21	22	50	1.80	2.20	.55	.70	400
DKV6550D	CKV2010-22	22	50	2.70	3.30	.70	.90	400
DKV6550E	CKV2010-23	22	50	4.50	5.50	1.00	1.30	400

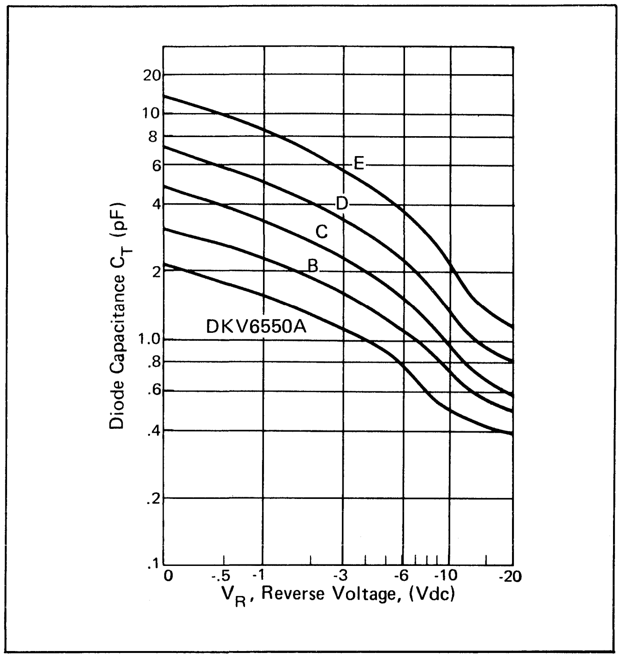


Figure 1. Typical Diode Capacitance vs. Tuning Voltage

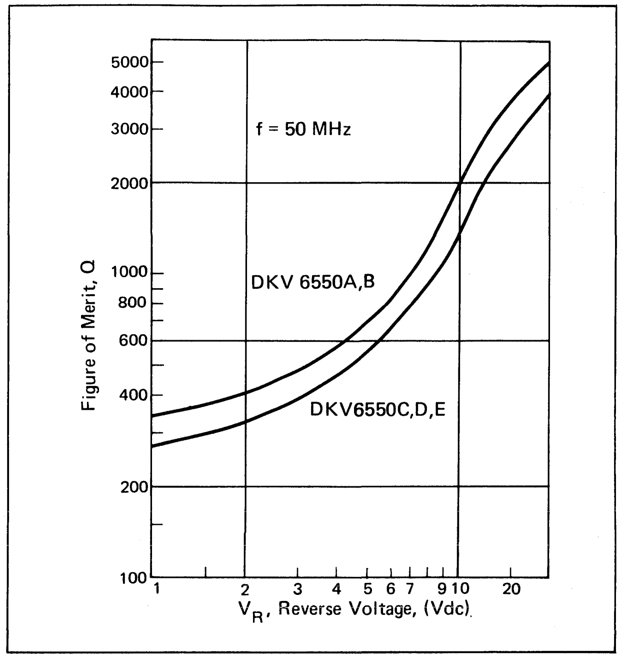


Figure 2. Typical Q vs. Tuning Voltage

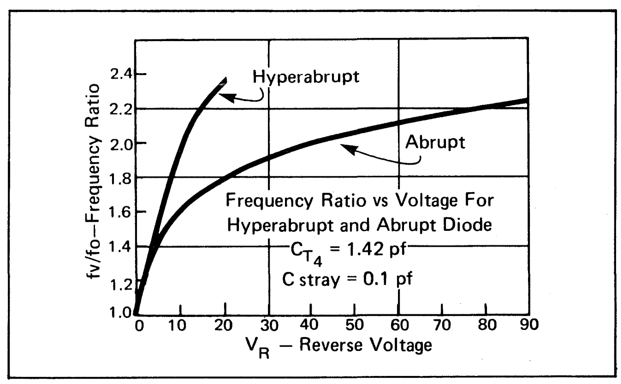
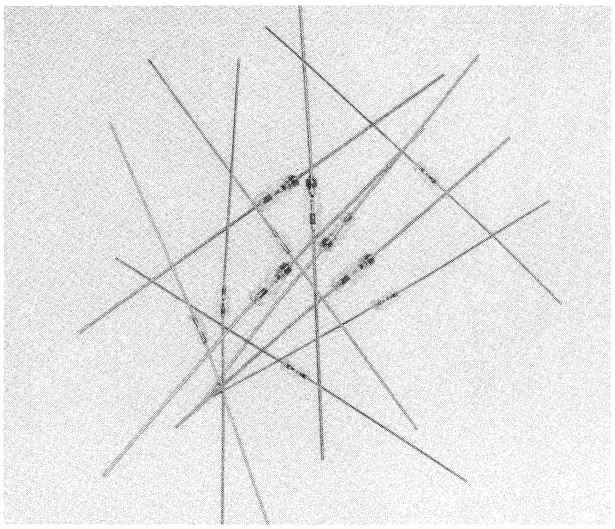


Figure 3.

Hyperabrupt Tuning Varactors, DKV6510 Series



Features

- Medium to High Frequency Operation
- Guaranteed 10:1 Tuning Ratio from 2 to 10 Volts
- Q of 800 at 1 MHz Typical

Description

Alpha uses ion implantation to provide this series of hyperabrupt tuning diodes with closely controlled characteristics. The highly reproducible capacitance versus voltage behavior of this family permits Alpha to supply matched sets and also assures the customer of long-term availability of parts having uniform electrical properties. Passivated, hermetically sealed construction allows their use under the most adverse conditions, both in commercial equipment and in high reliability space and military applications.

Applications

Designer oriented families offer types selected and tested with each customer's application in mind. Premium units DKV6510B and DKV6515B through DKV6518B tune up to 30 MHz with frequency ratios as high as 4 to 1 and can be used up to 300 MHz in oscillators. Alpha's DKV6510A and DKV6515A through DKV6518A diodes tune over 4 to 1 frequency ratios up to 10MHz and are also ideal for wide deviation voltage-tuned crystal oscillators. The DKV6510 and DKV6515 through DKV6518 series are suited to applications where economy is a prime consideration and may be used as replacements for devices which are not ion-implanted, with, in most cases, performance advantages. Low frequency oscillators, voltage-tuned filters, VCXO/TCXO modules, and frequency/phase modulators using Alpha's DKV6510 series achieve new levels of frequency swing and linearity.

Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
V_R	Reverse Voltage	Same as V_{BR}	
I_F	Forward Current	50	mAdc
P_D	Power Dissipation ($T_A = 25°C$)	250	mW
T_J	Junction Temperature	−55 to +125	°C
T_{stg}	Storage Temperature	−55 to +175	°C

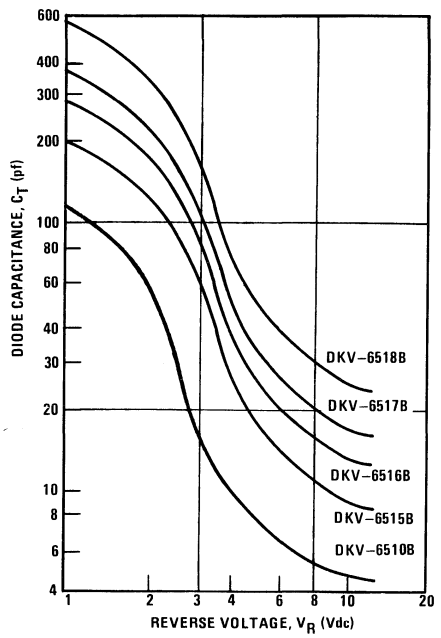


Figure 1. Typical Capacitance vs. Tuning Voltage (T_A = 25°C)

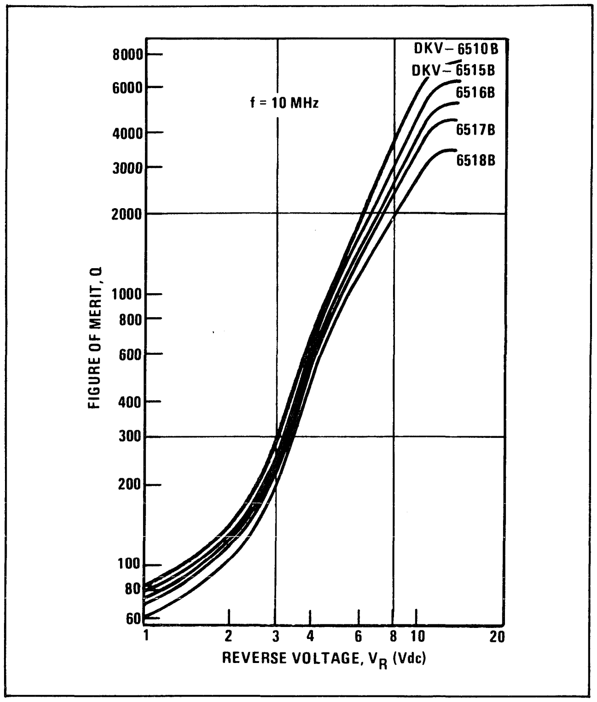


Figure 2. Typical Q vs. Tuning Voltage ($T_A = 25°C$)

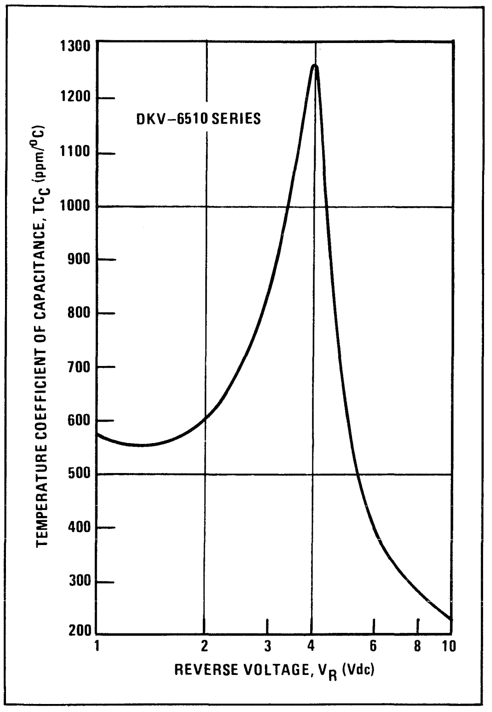


Figure 3. Temperature Coefficient of Capacitance vs. Tuning Voltage ($T_A = 25°C$)

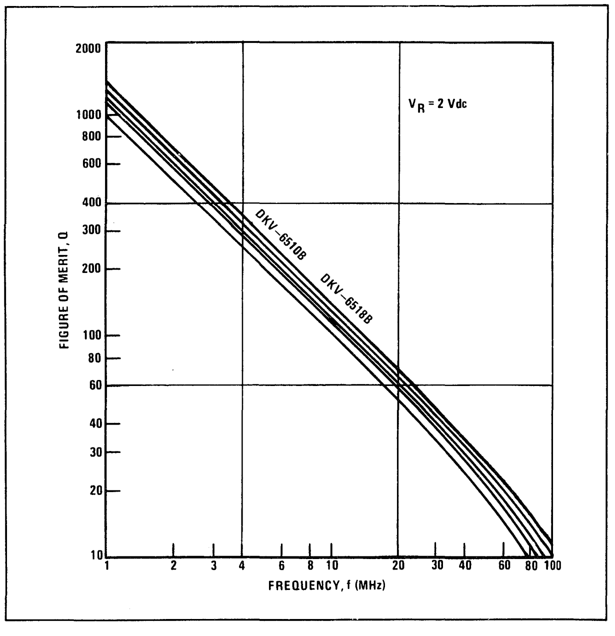


Figure 4. Typical Q vs. Frequency ($T_A = 25°C$)

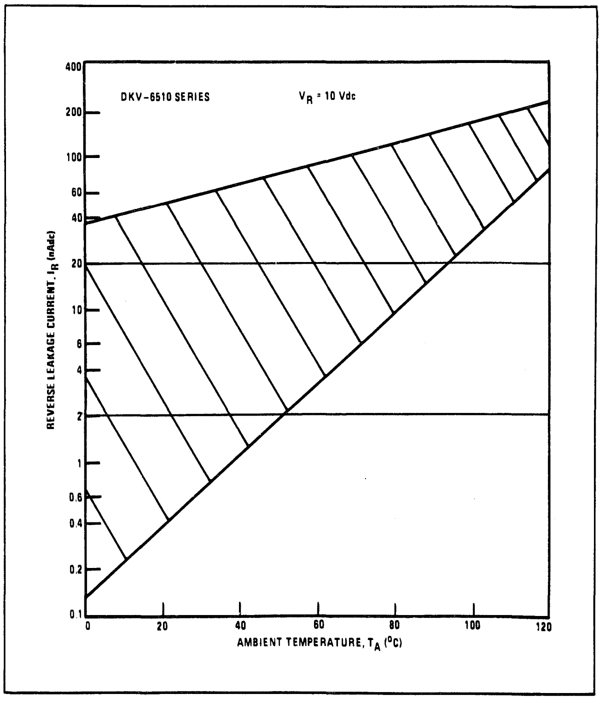


Figure 5. Reverse Leakage Current vs. Ambient Temperature

Hyperabrupt Tuning Varactors, DKV6510 Series

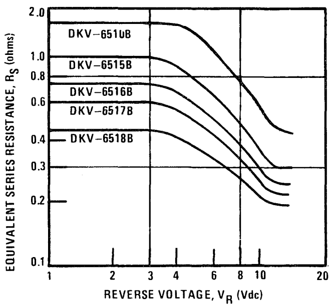


Figure 6. Equivalent Series Resistance vs. Tuning Voltage ($T_A = 25°C$)

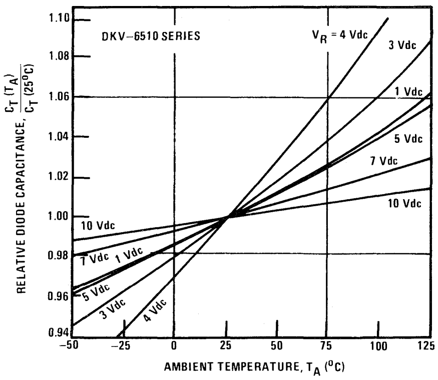


Figure 7. Capacitance vs. Ambient Temperature

Electrical Characteristics ($T_A = 25°C$)

DKV6510 SERIES

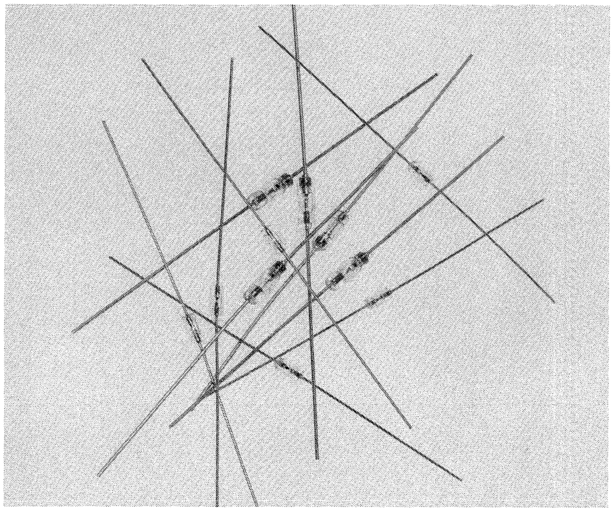
Symbol		V_{BR}	I_R	C_T								T_R			
Parameter		Reverse Breakdown Voltage	Reverse Leakage Current	Diode Capacitance								Tuning Ratio			
Unit		Vdc	nAdc	pf											
Test Conditions		$I_R = 10\mu$ Adc	$V_R = 10$ Vdc	f = 1 MHz								f = 1 MHz			
				$V_R = 1.25$ Vdc		$V_R = 2$ Vdc		$V_R = 7$ Vdc		$V_R = 10$ Vdc		C(1.25v)/C(7v)		C(2v)/C(10v)	
Type Number for 099 Package	Type Number for Chip(1)	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
DKV6510	CKV2020-01	12	1000			45				4				10	
DKV6510A	CKV2020-02	12	100			45	75			4	7			10	17
DKV6510B	CKV2020-03	12	50			45	75			4	7			10	17
DKV6515	CKV2020-04	12	1000			100					13			10	
DKV6515A	CKV2020-05	12	100			100	150			8	13			10	17.5
DKV6515B	CKV2020-06	12	50			100	150			8	13			10	17.5
DKV6516	CKV2020-07	12	1000			140					18			10	
DKV6516A	CKV2020-08	12	100			140	210			11	18			10	17
DKV6516B	CKV2020-09	12	50			140	210			11	18			10	17
DKV6517	CKV2020-10	12	1000			180					22			10	
DKV6517A	CKV2020-11	12	100			180	270			14	22			10	17
DKV6517B	CKV2020-12	12	50			180	270			14	22			10	17
DKV6518(2)	CKV2020-13	12	2000	450					40			12			
DKV6518A	CKV2020-14	12	200	450	550			25	40			12	20		
DKV6518B	CKV2020-15	12	100	450	550			25	40			12	20		

Symbol		Q		Package
Parameter		Figure of Merit		
Unit		f = 1 MHz		
Test Conditions		$V_R = 1.25$ Vdc	$V_R = 2$ Vdc	
Type Number for 099 Package	Type Number for Chip(1)	Min.	Min.	
DKV6510	CKV2020-01		500	099
DKV6510A	CKV2020-02		500	099
DKV6510B	CKV2020-03		750	099
DKV6515	CKV2020-04		200	099
DKV6515A	CKV2020-05		200	099
DKV6515B	CKV2020-06		500	099
DKV6516	CKV2020-07		200	099
DKV6516A	CKV2020-08		200	099
DKV6516B	CKV2020-09		500	099
DKV6517	CKV2020-10		200	099
DKV6517A	CKV2020-11		200	099
DKV6517B	CKV2020-12		500	099
DKV6518(2)	CKV2020-13	150		287
DKV6518A	CKV2020-14	150		287
DKV6518B	CKV2020-15	300		287

Notes:

1. Chip styles
   CKV2020-01 through 06 are 149-803
   CKV2020-07 through 12 are 149-804.
2. DKV6518 seies are in 287-001 outline.

Hyperabrupt Tuning Varactors, DKV6520 Series



Features

- High to Very High Frequency Operation
- Capacitance Values of 20 pF to 200 pF at 4 Volts
- Octave Tuning from 4 to 20 Volts
- Linear Frequency vs. Voltage Characteristics

Description

Alpha uses ion implantation to provide this series of hyperabrupt tuning diodes with closely controlled characteristics. The highly-reproducible capacitance versus voltage behavior of this family permits Alpha to supply matched sets and also assures the customer of a long-term availability of parts having uniform electrical properties. Passivated, hermetically sealed construction allows their use under the most adverse conditions, both in commercial equipment and in high reliability space and military applications.

Applications

Designer oriented families offer types selected and tested with each customer's application in mind. Premium units DKV6520B through DKV6525B, and their corresponding close-tolerance units having a "D" suffix, are ideal for octave tuning up to 500 MHz. When tuned from 8 to 20 volts of reverse bias, they offer very high Q values and excellent large signal handling capabilites, along with a 2 to 1 capacitance ratio. Alpha's DKV6520A through DKV6525A, and the close-tolerance versions having a "C" suffix, give superior straight line frequency versus voltage characteristics when tuning wide deviation crystal circuits or when varying LC tanks over a 1.5 to 1 frequency ratio. They excel as frequency or phase modulators, for which purpose the customers can also substitute the DKV6520 through DKV6525 series when minimum cost is of prime importance. All devices typically handle one-volt rms signals at intermodulation/cross-modulation distortion levels of 1% or less.

Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
V_R	Reverse Voltage	Same as V_{BR}	
I_F	Forward Current	50	mAdc
P_D	Power Dissipation ($T_A = 25°C$)	250	mW
T_J	Junction Temperature	−55 to +125	°C
T_{stg}	Storage Temperature	−55 to +175	°C

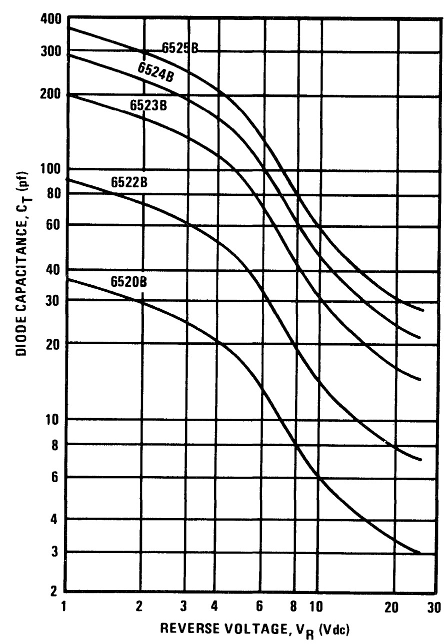


Figure 1. Typical Capacitance vs. Tuning Voltage (T_A = 25°C)

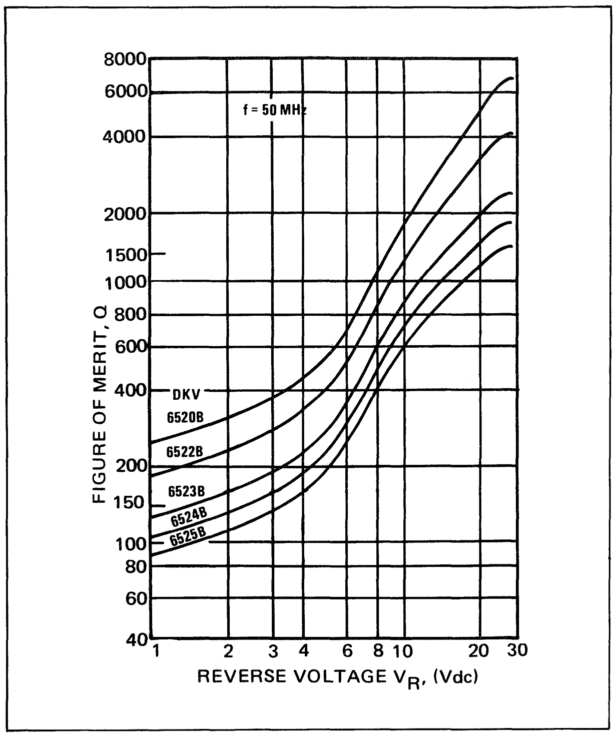


Figure 2. Typical Q vs. Tuning Voltage ($T_A = 25°C$)

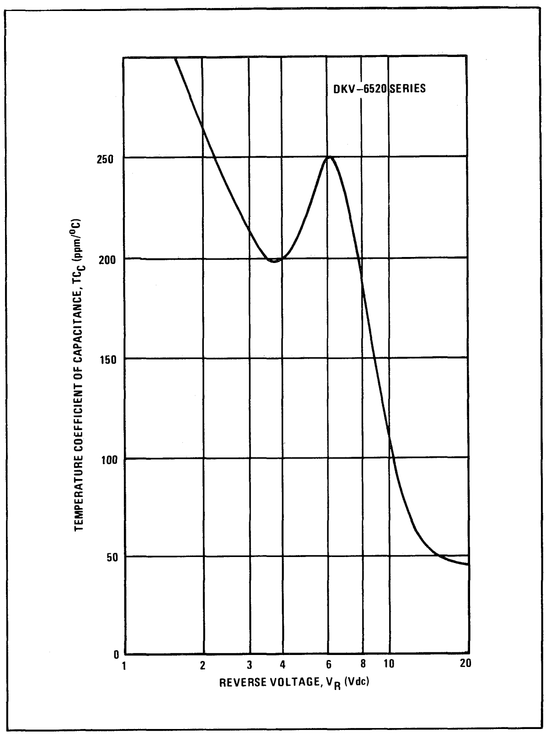


Figure 3.
Temperature Coefficient of Capacitance vs. Tuning Voltage ($T_A = 25°C$)

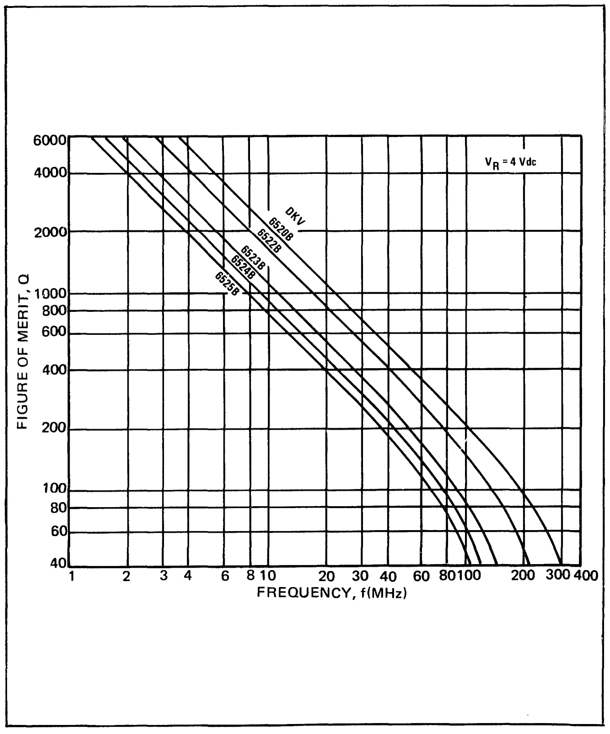


Figure 4. Typical Q vs. Frequency ($T_A = 25°C$)

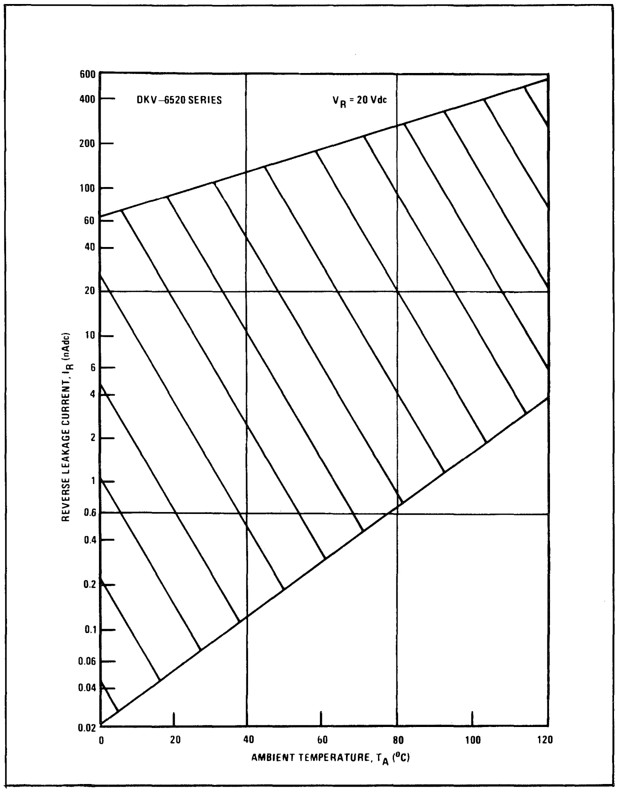


Figure 5. Reverse Leakage Current vs. Ambient Temperature

Hyperabrupt Tuning Varactors, DKV6520 Series

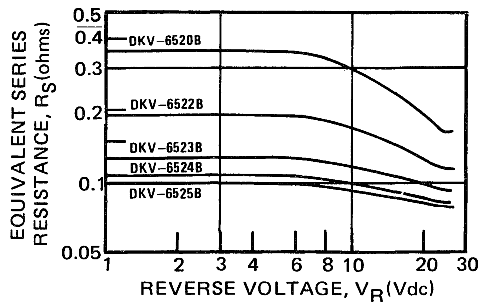


Figure 6. Equivalent Series Resistance vs. Tuning Voltage ($T_A = 25°C$)

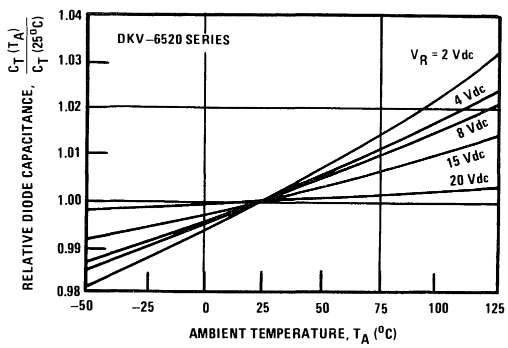


Figure 7. Capacitance vs. Ambient Temperature

Electrical Characteristics ($T_A = 25°C$)

DKV6520 SERIES

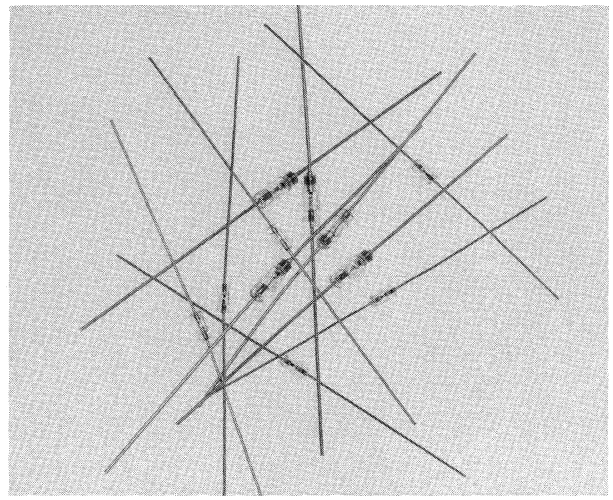
Symbol		V_{BR}	I_R			C_T								T_R			
Parameter		Reverse Breakdown Voltage	Reverse Leakage Current			Diode Capacitance								Tuning Ratio			
Unit		Vdc	nAdc			pF											
Test Conditions		$I_R = 10\mu$ Adc	$V_R = 6$ Vdc	$V_R = 10$ Vdc	$V_R = 20$ Vdc	f = 1 MHz, $V_R = 2.5$ Vdc		$V_R = 4$ Vdc		$V_R = 8$ Vdc		$V_R = 20$ Vdc		f = 1 MHz, C(4v)/C(8v)		C(4v)/C(20v)	
Type Number for 099 Package	Type Number for Chip(1)	Min.	Max.	Max.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
DKV6520	CKV2020-16	8	250			25	29	18	22								
DKV6520A	CKV2020-17	15		100				18	22	7.5	10.5			1.7	2.9		
DKV6520B	CKV2020-18	22			100			18	22	7.5	10.5	3.1	3.9			4.6	7.1
DKV6520C	CKV2020-19	15		100				19	21	7.8	9.2			2.0	2.7		
DKV6520D	CKV2020-20	22			100			19	21	7.8	9.2	3.1	3.9	2.0	2.7	4.8	6.8
DKV6522	CKV2020-21	8	250			62	72	45	55								
DKV6522A	CKV2020-22	15		100				45	55	18	25			1.8	3.1		
DKV6522B	CKV2020-23	22			100			45	55	18	25	7.3	9.2			4.9	7.5
DKV6522C	CKV2020-24	15		100				47.5	52.5	18.4	21.6			2.2	2.8		
DKV6522D	CKV2020-25	22			100			47.5	52.5	18.4	21.6	7.3	9.2	2.2	2.8	5.2	6.9
DKV6523	CKV2020-26	8	250			135	160	100	120								
DKV6523A	CKV2020-27	15		100				100	120	39	55			1.8	3.1		
DKV6523B	CKV2020-28	22			100			100	120	39	55	16	20			5.0	7.5
DKV6523C	CKV2020-29	15		100				104.5	115.5	41.4	48.6			2.15	2.8		
DKV6523D	CKV2020-30	22			100			104.5	115.5	41.4	48.6	16	20	2.15	2.8	5.2	7.3
DKV6524	CKV2020-31	8	500			195	225	140	170								
DKV6524A	CKV2020-32	15		500				140	170	55	80			1.7	3.1		
DKV6524B	CKV2020-33	22			500			140	170	55	80	22.5	28			5.0	7.6
DKV6524C	CKV2020-34	15		500				147	163	59.8	70.2			2.1	2.8		
DKV6524D	CKV2020-35	22			500			147	163	59.8	70.2	22.5	28	2.1	2.8	5.2	7.2
DKV6525	CKV2020-36	8	500			250	290										
DKV6525A	CKV2020-37	15		500				180	220	70	105			1.7	3.1		
DKV6525B	CKV2020-38	22			500			180	220	70	105	29	36			5.0	7.6
DKV6525C	CKV2020-39	15		500				190	210	78	92			2.0	2.7		
DKV6525D	CKV2020-40	22			500			190	210	78	92	29	36	2.0	2.7	5.3	7.3

Symbol		Q	Package
Parameter		Figure of Merit	
Unit			
Test Conditions		f = 50 MHz, $V_R = 4$ Vdc	
Type Number for 099 Package	Type Number for Chip(1)	Min.	
DKV6520	CKV2020-16	150	099
DKV6520A	CKV2020-17	300	099
DKV6520B	CKV2020-18	300	099
DKV6520C	CKV2020-19	300	099
DKV6520D	CKV2020-20	300	099
DKV6522	CKV2020-21	100	099
DKV6522A	CKV2020-22	200	099
DKV6522B	CKV2020-23	200	099
DKV6522C	CKV2020-24	200	099
DKV6522D	CKV2020-25	200	099
DKV6523	CKV2020-26	65	099
DKV6523A	CKV2020-27	125	099
DKV6523B	CKV2020-28	125	099
DKV6523C	CKV2020-29	125	099
DKV6523D	CKV2020-30	125	099
DKV6524	CKV2020-31	50	099
DKV6524A	CKV2020-32	100	099
DKV6524B	CKV2020-33	100	099
DKV6524C	CKV2020-34	100	099
DKV6524D	CKV2020-35	100	099
DKV6525	CKV2020-36	45	099
DKV6525A	CKV2020-37	90	099
DKV6525B	CKV2020-38	90	099
DKV6525C	CKV2020-39	90	099
DKV6525D	CKV2020-40	90	099

Note:

1. Chip styles
   CKV2020-16 through 25 are 149-802
   CKV2020-26 through 30 are 149-803
   CKV2020-31 through 40 are 149-804.

Hyperabrupt Tuning Varactors, DKV6530 Series



Features

- VHF to UHF Operation
- Guaranteed Minimum Q Values
- Octave Tuning from 3 to 20 Volts
- Linear Frequency vs. Voltage Characteristics

Description

Alpha uses ion implantation to provide this series of hyperabrupt tuning diodes with closely controlled characteristics. The highly-reproducible capacitance versus voltage behavior of this family permits Alpha to supply matched sets and also assures the customer of a long-term availability of devices having uniform electrical properties. Passivated, hermetically sealed construction allows their use under the most adverse conditions, both in commercial equipment and in high reliability space and military applications.

Applications

Designer oriented families offer types selected and tested with each customer's application in mind. Premium units DKV6533C and DKV6534C, and their corresponding close-tolerance units having an "F" suffix, are ideal for octave tuning up to 800 MHz. When tuned from 8 to 20 volts of reverse bias, they offer a 2 to 1 capacitance ratio, very high Q values, and excellent large signal handling capabilities. Diodes DKV6533B, E and DKV6534B, E are suitable for similar applications up to 500 MHz. Alpha's hyperabrupt tuning diodes are ideal for straight line frequency versus voltage applications in crystal or LC tuned circuits as well as for frequency or phase modulators, for which the customer may substitute the DKV6533 or DKV6534 devices when minimum cost is of prime importance. All devices typically handle one-volt rms signals with less than 1% intermodulation or cross-modulation distortion.

Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
V_R	Reverse Voltage	Same as V_{BR}	
I_F	Forward Current	50	mAdc
P_D	Power Dissipation ($T_A = 25°C$)	250	mW
T_J	Junction Temperature	−55 to +125	°C
T_{stg}	Storage Temperature	−55 to +175	°C

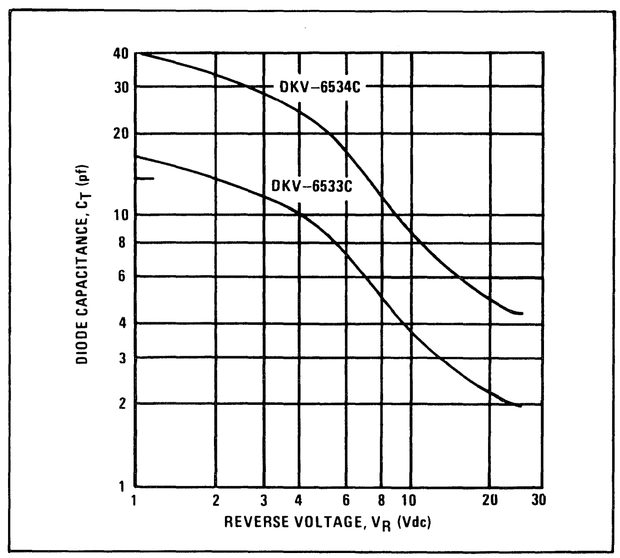


Figure 1. Typical Capacitance vs. Tuning Voltage ($T_A = 25°C$)

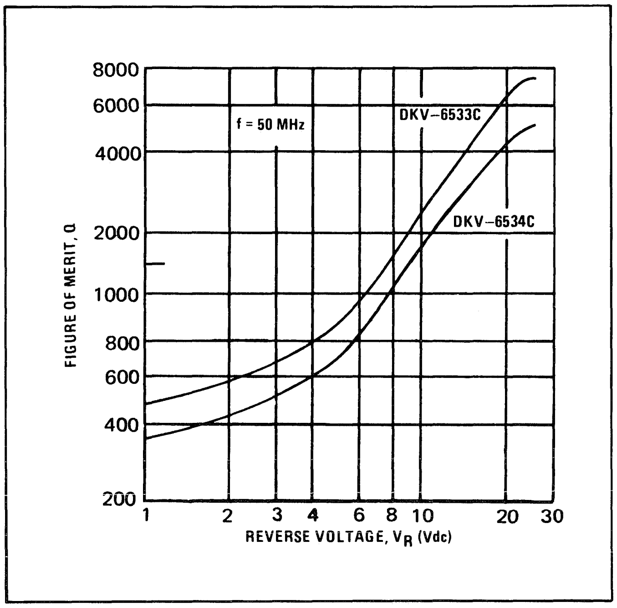


Figure 2. Typical Q vs. Tuning Voltage ($T_A = 25°C$)

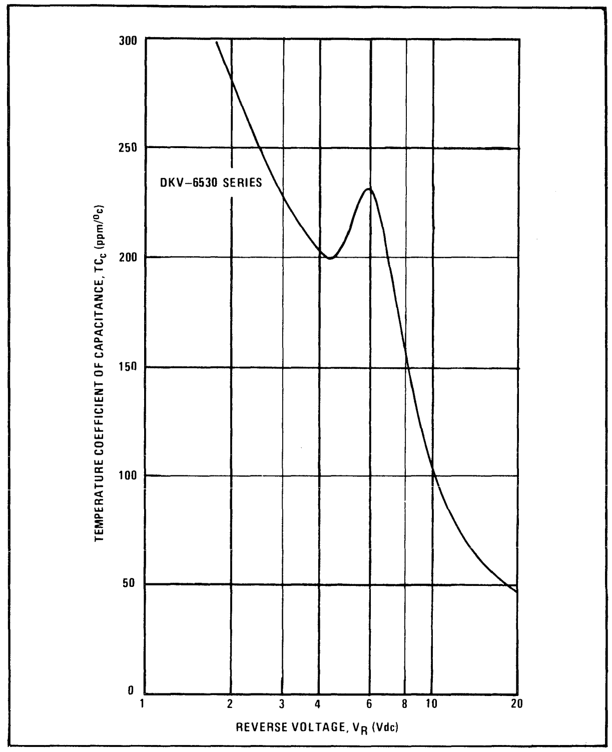


Figure 3. Temperature Coefficient of Capacitance vs. Tuning Voltage ($T_A = 25°C$)

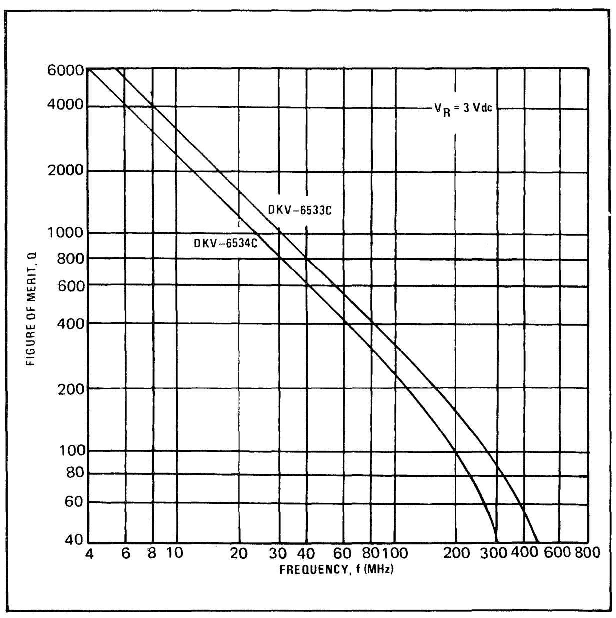


Figure 4. Typical Q vs. Frequency ($T_A = 25°C$)

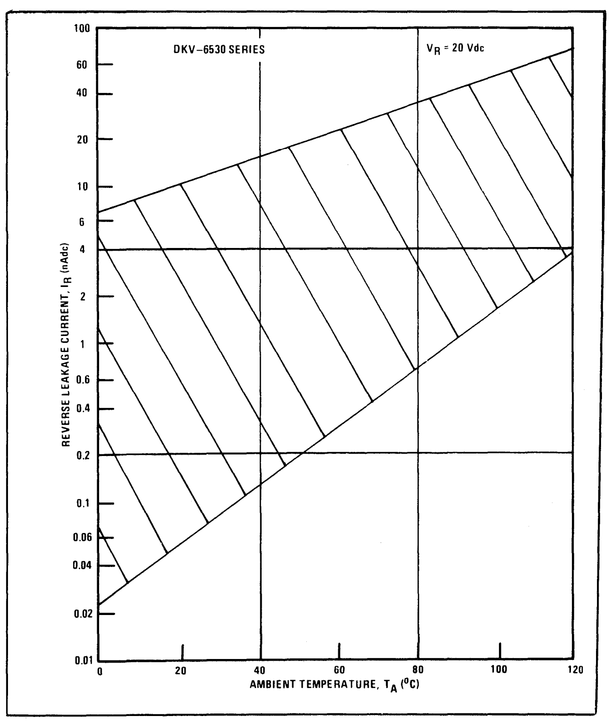


Figure 5. Reverse Leakage Current vs. Ambient Temperature

Hyperabrupt Tuning Varactors, DKV6530 Series

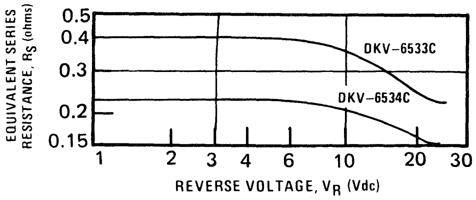


Figure 6. Equivalent Series Resistance vs. Tuning Voltage (T_A = 25°C)

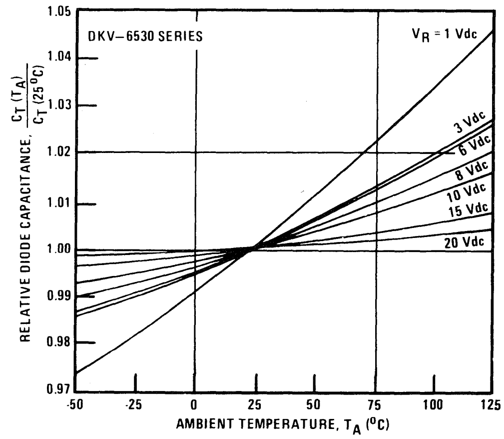


Figure 7. Capacitance vs. Ambient Temperature

Electrical Characteristics (T_A = 25°C)

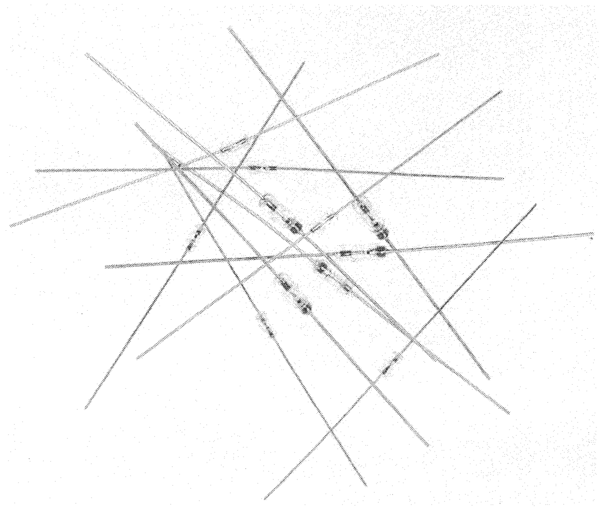
DKV6530 SERIES

Symbol		V_{BR}	I_R			C_T							
Parameter		Reverse Breakdown Voltage	Reverse Leakage Current			Diode Capacitance							
Unit		Vdc	nAdc			pF							
Test Conditions		I_R = 10µ Adc	V_R = 6 Vdc	V_R = 10 Vdc	V_R = 20 Vdc	f = 1 MHz V_R = 1.25 Vdc		V_R = 3 Vdc		V_R = 8 Vdc		V_R = 20 Vdc	
Type Number for 099 Package	Type Number for Chip(1)	Min.	Max.	Max.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.
DKV6533	CKV2020-41	8	250			14	17.5	10.5	12.5				
DKV6533A	CKV2020-42	15		100				10.5	12.5	4.3	5.7		
DKV6533B	CKV2020-43	22			100			10.5	12.5	4.3	5.7	2.0	2.4
DKV6533C	CKV2020-44	22			100			10.5	12.5	4.3	5.7	2.0	2.3
DKV6533D	CKV2020-45	15		100				10.9	12.5	4.6	5.4		
DKV6533E	CKV2020-46	22			100			10.9	12.1	4.6	5.4	2.0	2.4
DKV6533F	CKV2020-47	22			100			10.9	12.1	4.6	5.4	2.0	2.3
DKV6534	CKV2020-48	8	250			34	42	25	31				
DKV6534A	CKV2020-49	15		100				25	31	10	13.5		
DKV6534B	CKV2020-50	22			100			25	31	10	13.5	4.5	5.3
DKV6534C	CKV2020-51	22			100			25	31	10	13.5	4.5	5.1
DKV6534D	CKV2020-52	15		100				26.5	29.5	11	13		
DKV6534E	CKV2020-53	22			100			26.5	29.5	11	13	4.5	5.3
DKV6534F	CKV2020-54	22			100			26.5	29.5	11	13	4.5	5.1

Symbol		T_R				Q	Package
Parameter		Tuning Ratio				Figure of Merit	
Unit							
Test Conditions		f = 1 MHz C(3v)/C(8v)		C(3v)/C(20v)		f = 50 MHz V_R = 3 Vdc	
Type Number for 099 Package	Type Number for Chip(1)	Min.	Max.	Min.	Max.	Min.	
DKV6533	CKV2020-41					200	099
DKV6533A	CKV2020-42	1.8	2.9			300	099
DKV6533B	CKV2020-43			4.4	6.3	300	099
DKV6533C	CKV2020-44			4.6	6.3	450	099
DKV6533D	CKV2020-45	2.0	2.6			300	099
DKV6533E	CKV2020-46	2.0	2.6	4.5	6.1	300	099
DKV6533F	CKV2020-47	2.0	2.6	4.7	6.1	450	099
DKV6534	CKV2020-48					150	099
DKV6534A	CKV2020-49	1.8	3.1			200	099
DKV6534B	CKV2020-50			4.7	6.9	200	099
DKV6534C	CKV2020-51			4.9	6.9	300	099
DKV6534D	CKV2020-52	2.0	2.7			200	099
DKV6534E	CKV2020-53	2.0	2.7	5.0	6.6	200	099
DKV6534F	CKV2020-54	2.0	2.7	5.2	6.6	300	099

Note:
1. Chip styles CKV2020-41 through 54 are 149-802.

Hyperabrupt Tuning Varactors DKV4105 & 4109 Series



Features

- Direct Replacement for Motorola, Siemens, and ITT BB105 & MV109 Types
- Highest Q Possible
- Reproducible C vs. V Characteristics
- Available in All Standard Packages
- Available in Many Capacitance Ranges

Description

Alpha uses ion implantation to provide this series of hyperabrupt tuning diodes with closely controlled characteristics. The highly-reproducible capacitance versus voltage behavior of this family permits Alpha to supply matched sets and also assures the customer of a long-term availability of devices having uniform electrical properties. Passivated, hermetically sealed construction allows their use under the most adverse conditions, both in commercial equipment and in high reliability space and military applications.

Applications

Alpha's DKV4105 and 4109 units are high reliability, glass encapsulated replacements for the Motorola, Siemens, and ITT BB105 & MV109 type units. Alpha's devices use low cost, high reliability glass instead of plastic, which is commonly used in these other devices. Alpha's hyperabrupt tuning diodes are ideal for straight line frequency vs. voltage applications in crystal or LO tuned circuits as well as for frequency or phase modulators.

Absolute Maximum Ratings

Symbol	Parameter	Value	Unit
V_R	Reverse Voltage	30	Volts
I_F	Forward Current	200	mA
P_D	Power Dissipation ($T_A = 25°C$)	400	mW
T_J	Junction Temperature	− 55 to + 125	°C
T_{STS}	Storage Temperature	− 55 to + 175	°C

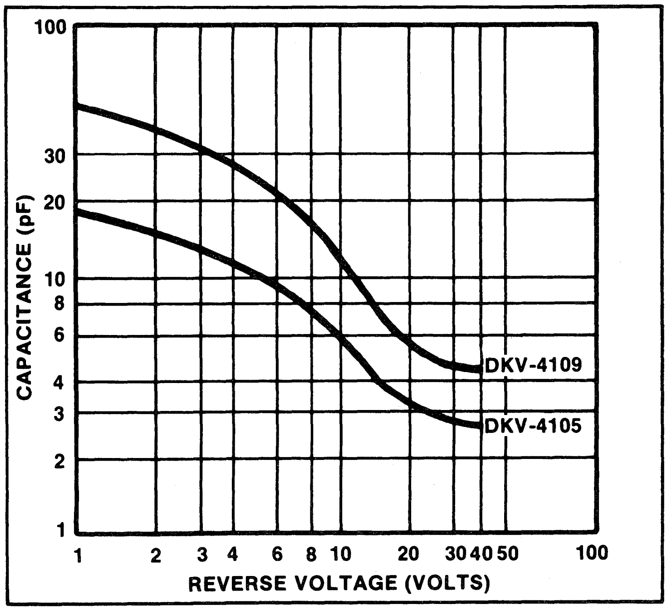


Figure 1. Typical Capacitance vs. Tuning Voltage ($T_A = 25°C$)

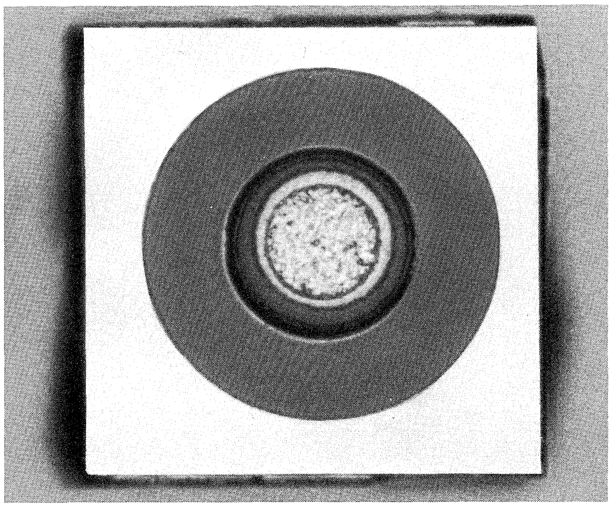
Electrical Characteristics ($T_A = 25°C$)

DKV4105 & 4109 Series

Parameter	DKV-4105	DKV-4109
Capacitance (−25V)	1.8 to 2.8pF	5.0 to 6.0pF
Capacitance Ratio $\frac{C_T(3V)}{C_T(25V)}$	4.0 to 6.0pF	5.0pF Min.
Reverse Breakdown Voltage (I_R = 10μA)	30V Min.	30V Min.
Reverse Leakage Current (V_R = −28V)	50nA Max.	50nA Max.
Temperature Coefficient of Capacitance (V_R = 3V, f = 1MHz)	400ppm Max.	400ppm Max.
Diode Q (V_R = 3V, f = 50MHz)	300 Min.	300 Min.
Series Inductance (L_{pkg})	5.0nH Max.	5.0nH Max.

NOTE: Corresponding chip styles are CKV 2105 for DKV 4105, and CKV 2109 for DKV 4109. A, B and G versions, which are grouped by ranges of the $\frac{C_T(3V)}{C_T(25V)}$ ratio, are available from Alpha on special order. Call the factory for details.

High-"Q" GaAs Tuning Diode Chips



Features

- High "Q" — 4,000 to 15,000
- Wide Tuning Capacitance Variation:4/1 and 6/1 Typical
- Low Leakage — Nitride-Oxide Passivated
- X through Ka-Band

Types

- CVE7800 (25 Volt Series)
- CVE7900 (45 Volt Series)

Description

Alpha now offers passivated abrupt gallium arsenide tuning diodes in chip form. The passivation, in conjunction with other processes, results in high reliability and leakage currents less than 10 nanoamps. Variations from square law are minimized while maintaining high tuning ratios and highest Q by a careful selection of epitaxial GaAs, and by anode diffusions that are tightly controlled.

Mechanical Details

All chip lots are characterized for Q_{-4} in our 023-001 package. They are also put on burn-in to check the reliability of the lot. During assembly the diodes are tested for die shear and strap pull strength. The die have bondable gold contacts on both sides. Special barrier underlying metals are used to prevent gallium migration and subsequent oxidation of the anode bond surface. Pull strengths meet MIL-STD-750. Mesa sizes vary from 1.6 to 4.5 mil diameter depending on the capacitance. Anode bond diameters vary from 1.4 to 3.5 mils. Die size is .010″ nominal. Epoxy or gold-germanium solder is the recommended die attach technique.

For strap bonding a thermocompression bond should be made. The passivation is nitride-oxide deposited by the latest plasma techniques. This passivation extends over the top surface of the mesa (see Figure 1). Care must be taken to use a strap bond tool smaller than the passivation opening to avoid cracking the dielectric. Note that the gold surface will be brighter in the anode bond area. See Table I for suggested bond force and temperature.

Ultrasonic bonding may be used on the larger diameter high capacitance diodes. For further details on bonding see Application Note 80000 in Section 7.

Chips can also be offered with various straps attached. They also may be mounted on various metal or ceramic carriers for some microstrip applications. Consult factory for more information.

Applications

These GaAs chips are ideally suited for frequency tuning applications from X through Ka band. They may be used to tune filters, phase shifters, Gunn-Impatt-transistor oscillators, upconverters, and low order multipliers.

Elimination of the package parasitics allows a lower breakdown voltage and a higher Q diode to be used for a given bandwidth specification. This will result in less insertion loss and lower noise operation. For very high frequency application, i.e., Ka-band and above, a chip is essential for all but the narrowest band specifications.

For circuits in U, V, and W band, beam-lead varactors may be offered in the future. Consult the factory for more information.

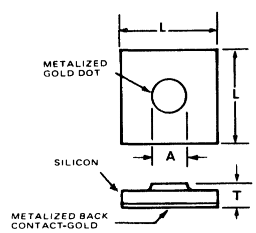
High-"Q" GaAs Tuning Diode Chips

Model Number

Model Number			CVE 7800	CVE 7900
GaAs Abrupt High "Q" Chips			25 Volt Series[1] C_0/C_{VB}[3] = 3.7/1	45 Volt Series[1] C_0/C_{VB}[3] = 6/1
Suffix Letter	C_0	C_{-4}	Q_{-4}(50 MHz)[4]	Q_{-4}(50 MHz)[4]
A	.4-.6	.20	15,000	10,000
B	.6-.8	.35	13,000	9,000
C	.8-1.0	.45	12,000	8,000
D	1.0-1.5	.60	10,000	7,000
E	1.5-2.0	.90	7,500	6,000
F	2.0-2.5	1.10	6,500	5,500
G	2.5-3.0	1.40	5,500	5,000
H	3.0-4.0	1.75	4,300	4,200

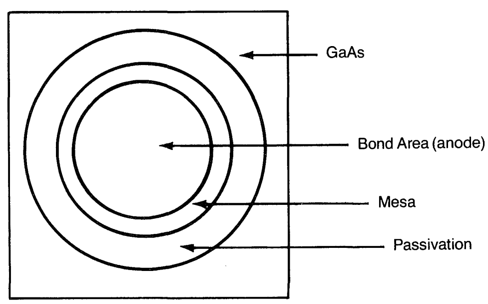
Notes:
Add suffix letter to Alpha Model Number to specify desired Electrical Characteristics.
[1]Voltage breakdown is specified at 10 µA. Higher voltage breakdown is available on request.
[2]A 10% capacitance tolerance is standard. Specify goal capacitance if different limits are needed when ordering. Tighter tolerances are available on request.
[3]C_0/C_{VB} is the typical capacitance ratio when the chip is biased from zero volts to the breakdown voltage.
[4]The Q of the chip lot is characterized at − 4 volts using a resonant cavity between 1-2GHz. The Q is then extrapolated down to 50MHz assuming a constant series resistance.

Outline Drawing

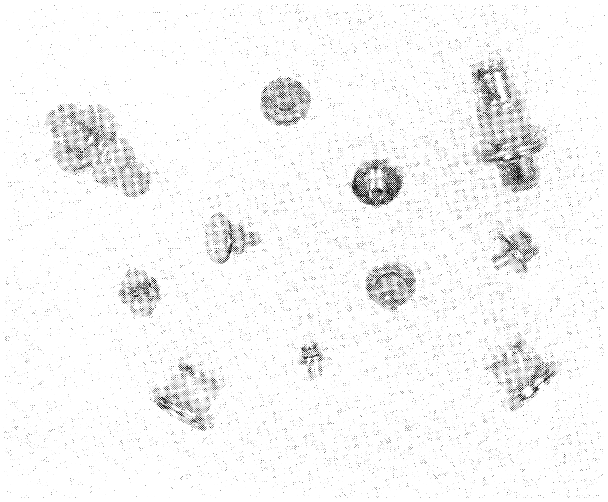


Chip Style	Inches			MM		
	Dim A Min.	Dim L Nom.	Dim T Nom.	Dim A Min.	Dim L Nom.	Dim T Nom.
150-808	.0012	.010	.005	.030	.25	.13

Figure 1



High-"Q" GaAs 25 Volt Series Tuning Diodes



Features

- 50% Higher "Q" Than Comparable Silicon Diodes
- Wide Tuning Ratio
- High Reliability and Space Qualified

Types

- DVE4550 Series
- DVE4570 Series

Description

The Alpha line of gallium arsenide tuning diodes offers the circuit designer expanded capability. The extremely high-Q and superior tuning ratio of these diodes allow tunable oscillators and filters to be built with lower loss and broader bandwidth. The diodes are particularly useful for tuning Gunn and Impatt oscillators.

The diode Q is measured in a well characterized high-Q cavity with an unloaded cavity Q of 1500 in the 1 to 2 GHz range. A block diagram of the test set-up is shown in Figure 1. The test cavity is shown in Figure 2.

A plot of Q_{-4} at 1.0 GHz versus C_{T-4} in Figure 3 compares the Alpha gallium arsenide diodes with available silicon diodes.

All packaged Alpha gallium arsenide tuning varactors are electrically burned-in prior to final measurement. A special variation of this diode family is the only space-qualified, high-reliability varactor available today and is used in the ESRO European satellite program.

Environmental Capability

Thermal Shock	– 195.8°C to + 100°C
Centrifuge	20,000 G
Gross Leak Test	10^{-5} atm – cc/sec
Fine Leak Test	10^{-8} atm – cc/sec
High Temperature Storage	200°C
High Temperature Power Burn-In	100°C, I_{pk}50 mA, 16 hrs.
Reverse Leakage Current	50 nA

Electrical Characteristics Min ($V_B^{(1)}$ = 25 Volts)

$C_{TO}^{(2)}$ (pF)	$C_{TO}^{(3)}/C_{TVB}$	$Q_{-4}^{(4)}$ @50 MHz	Q_{-4} @1 GHz	Suffix Letter
0.4–0.6	1.5	15,000	750	A
0.6–0.8	1.85	13,000	650	B
0.8–1.0	2.15	12,000	600	C
1.0–1.5	2.35	10,000	500	D
1.5–2.0	2.85	7,500	375	E
2.0–2.5	2.95	6,500	325	F
2.5–3.0	3.1	5,500	275	G
3.0–4.0	3.3	4,300	215	H

Model Number

Alpha Model Number	Package Style
DVE4551	023-001
DVE4552	168-001
DVE4575	320-001
DVE4576	350-001
DVE4555	290-001

Note: Add suffix letter to Alpha Model Number to specify desired Electrical Characterisitics

Notes:

1. Voltage breakdown is specified at 10µA. Higher voltage breakdowns are available on request.
2. A 10% capacitance tolerance is standard. Specify goal capacitance when ordering. Tighter tolerances are available on request.
3. $\frac{C_{TO}}{C_{TVB}}$ is the minimum total capacitance ratio which includes the package capacitance that is normally 0.2 pF. The ratio for diode model DVE4554 may be somewhat lower than specified due to the higher stray capacitance of the 092 package. A typical capacitance versus voltage plot appears in Figure 4.
4. Extrapolated down to 50 MHz.
5. Model DVE6956 is used when ordering diodes in a package style not listed in the table. Using the Alpha diode catalog as a reference, you can order these diodes in the 048-001, 067-001, 084-001, 093-001, 082-001, 092-001, 135-001, 158-001, 168-001, 237-001, 247-001, 304-001 and 305-001 package styles. See ORDERING INFORMATION.

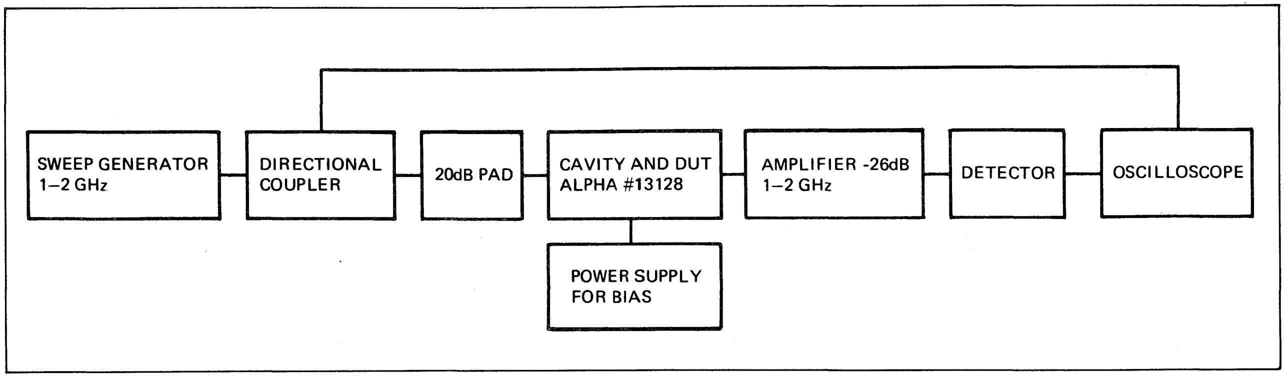


Figure 1. Quality Factor "Q" Test Set-Up.

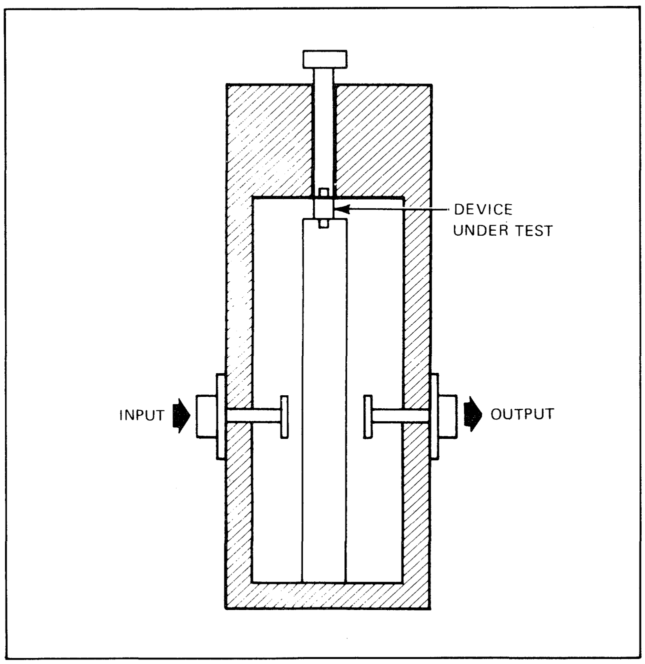


Figure 2. Test Cavity

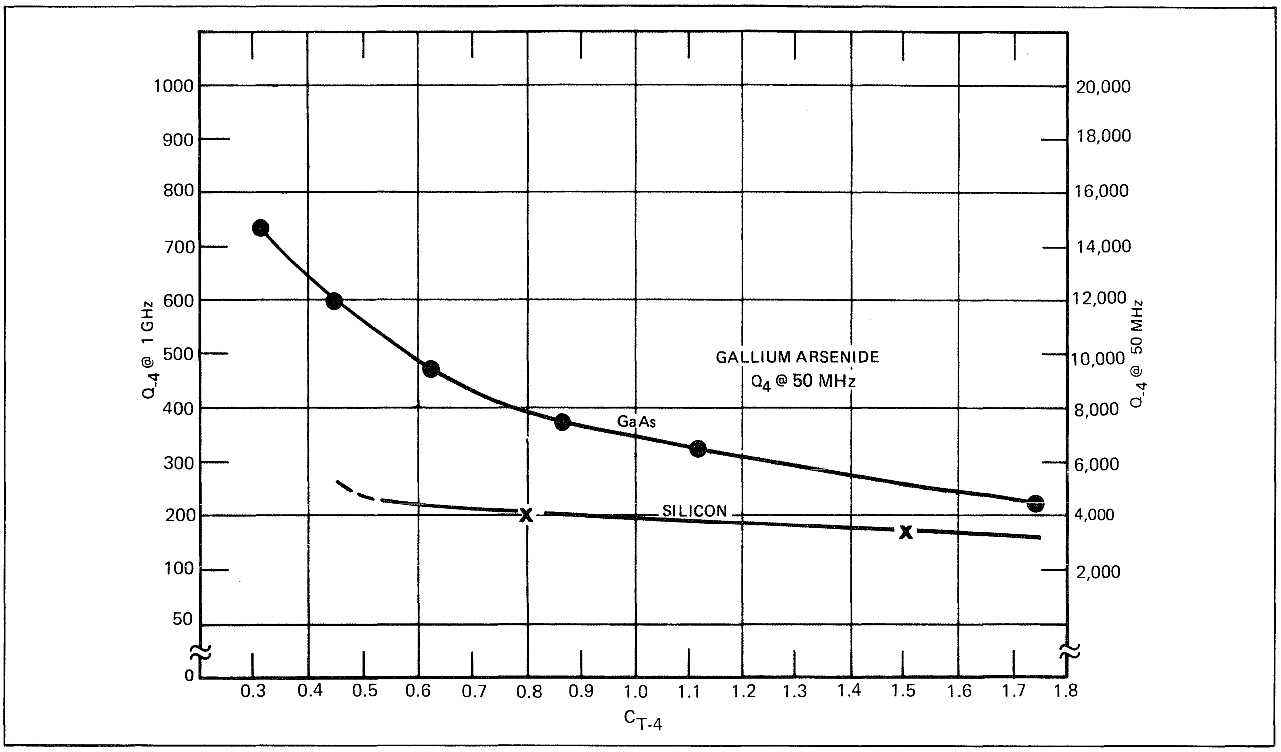


Figure 3. Q_{-4} vs. C_{T-4}

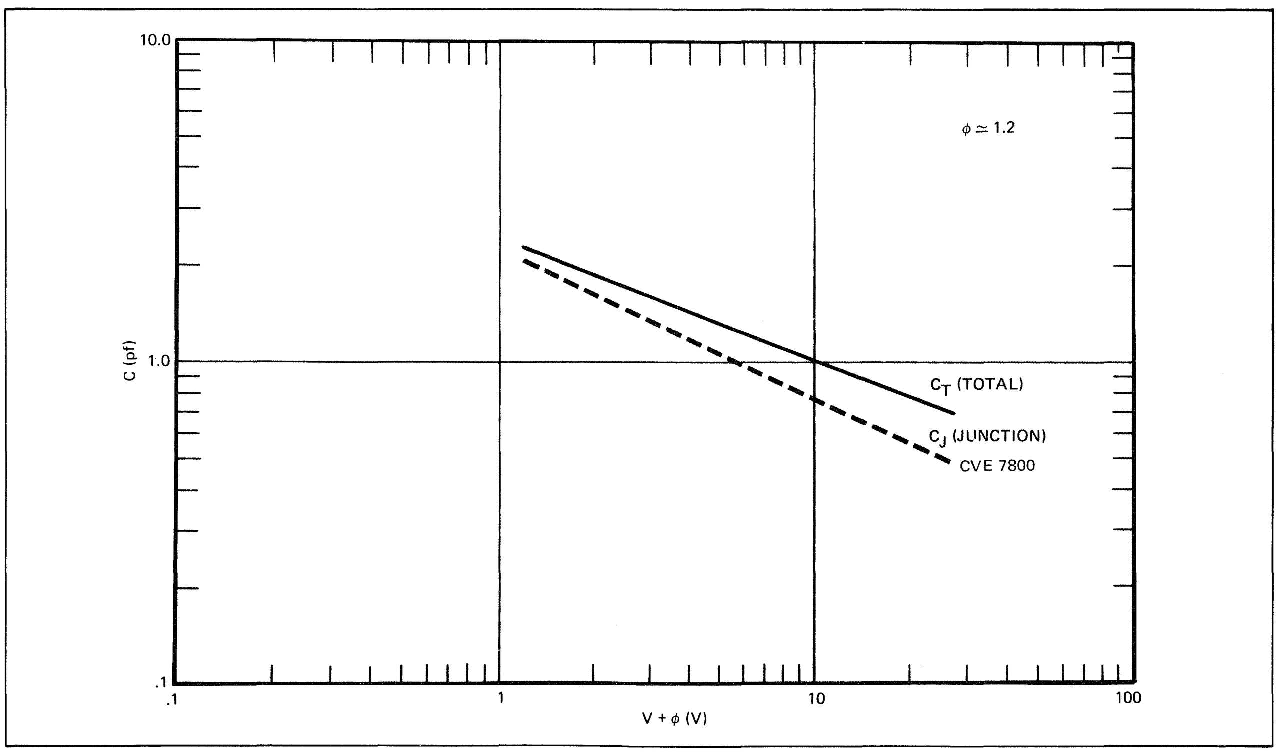
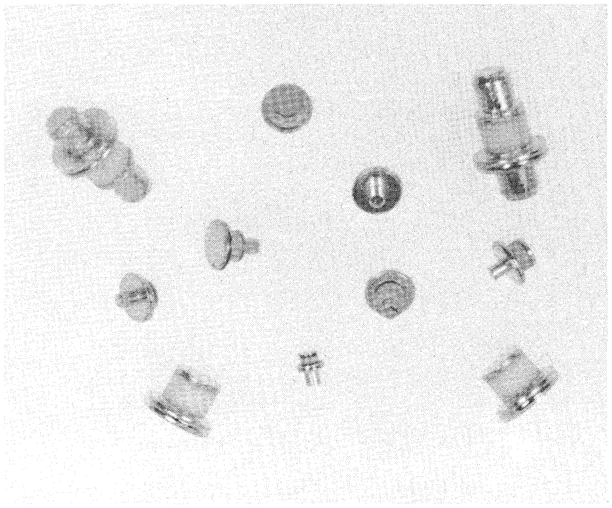


Figure 4. Typical Capacitance vs. Voltage

High-"Q" GaAs 45 Volt Series Tuning Diodes

Features

- 100% Higher "Q" Than Comparable Silicon Diodes
- Wide Tuning Ratio
- High Reliability and Space Qualified



Type

- DVE6950 Series

Description

The Alpha line of gallium arsenide tuning diodes offers the circuit designer expanded capability. The extremely high-Q and superior tuning ratio of these diodes allow tunable oscillators and filters to be built with lower loss and broader bandwidth. The diodes are particularly useful for tuning Gunn and Impatt oscillators.

The diode Q is measured in a well characterized high-Q cavity with an unloaded cavity Q of 1500 in the 1 to 2 GHz range. A block diagram of the test set-up is shown in Figure 1. The test cavity is shown in Figure 2.

A plot of Q_{-4} at 1.0 GHz versus C_{T-4} in Figure 3 compares the Alpha gallium arsenide diodes with available silicon diodes.

Electrical Characteristics Min (V_B(1) = 45 Volts)

C_{TO}(2) (pF)	C_{TO}(3) / C_{TVB}	Q_{-4}(4) @50 MHz	Q_{-4} @1 GHz	Suffix Letter
0.4–0.6	2.0	10,000	500	A
0.6–0.8	2.3	9,000	450	B
0.8–1.0	2.7	8,000	400	C
1.0–1.5	3.0	7,000	350	D
1.5–2.0	3.5	6,000	300	E
2.0–2.5	3.9	5,500	275	F
2.5–3.0	4.25	5,000	250	G
3.0–4.0	4.30	4,500	225	H
4.0–5.0	4.35	4,300	215	J
5.0–6.0	4.40	4,000	200	K

All packaged Alpha gallium arsenide tuning varactors are electrically burned-in prior to final measurement. A special variation of this diode family is the only space-qualified, high-reliability varactor available today and is used in the ESRO European satellite program.

Environmental Capability

Thermal Shock	– 195.8°C to + 100°C
Centrifuge	20,000 G
Gross Leak Test	10^{-5}atm – cc/sec
Fine Leak Test	10^{-8}atm – cc/sec
High Temperature Storage	200°C
High Temperature Power Burn-In	100°C, I_{pk}50 mA, 16 hrs.
Reverse Leakage Current	50 nA

Model Number

Alpha Model Number	Package Style
DVE6951	023-001
DVE6952	168-001
DVE6953	320-001
DVE6954	350-001
DVE6955	290-001
DVE6956	Various(5)

Note: Add suffix letter to Alpha Model Number to specify desired Electrical Characterisitics

Notes:
1. Voltage breakdown is specified at 10µA. Higher voltage breakdowns are available on request.
2. A 10% capacitance tolerance is standard. Specify goal capacitance when ordering. Tighter tolerances are available on request.
3. $\frac{C_{TO}}{C_{TVB}}$ is the minimum total capacitance ratio which includes the package capacitance that is normally 0.2 pF. The ratio for diode model DVE4554 may be somewhat lower than specified due to the higher stray capacitance of the 092 package. A typical capacitance versus voltage plot appears in Figure 4.
4. Extrapolated down to 50 MHz.
5. Model DVE6956 is used when ordering diodes in a package style not listed in the table. Using the Alpha diode catalog as a reference, you can order these diodes in the 048-001, 067-001, 084-001, 093-001, 082-001, 092-001, 135-001, 158-001, 168-001, 237-001, 247-001, 304-001 and 305-001 package styles. See ORDERING INFORMATION.

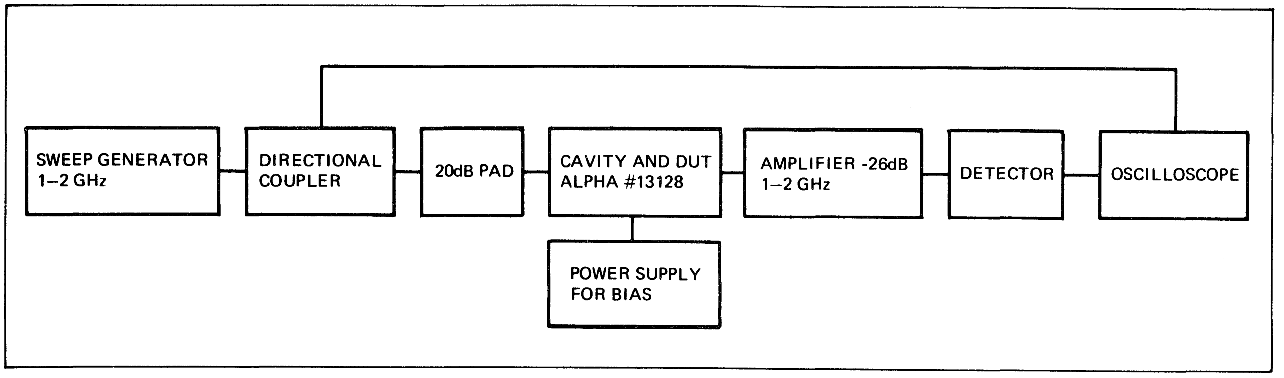


Figure 1. Quality Factory "Q" Test Set-Up

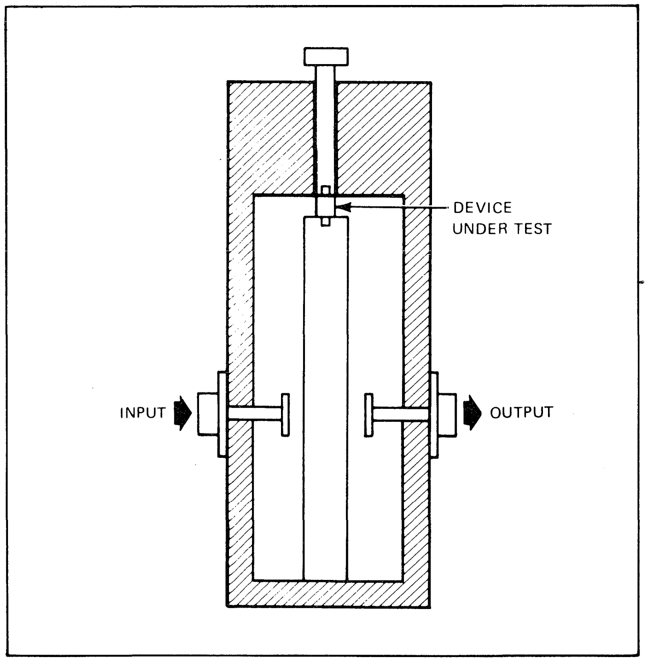


Figure 2. Test Cavity

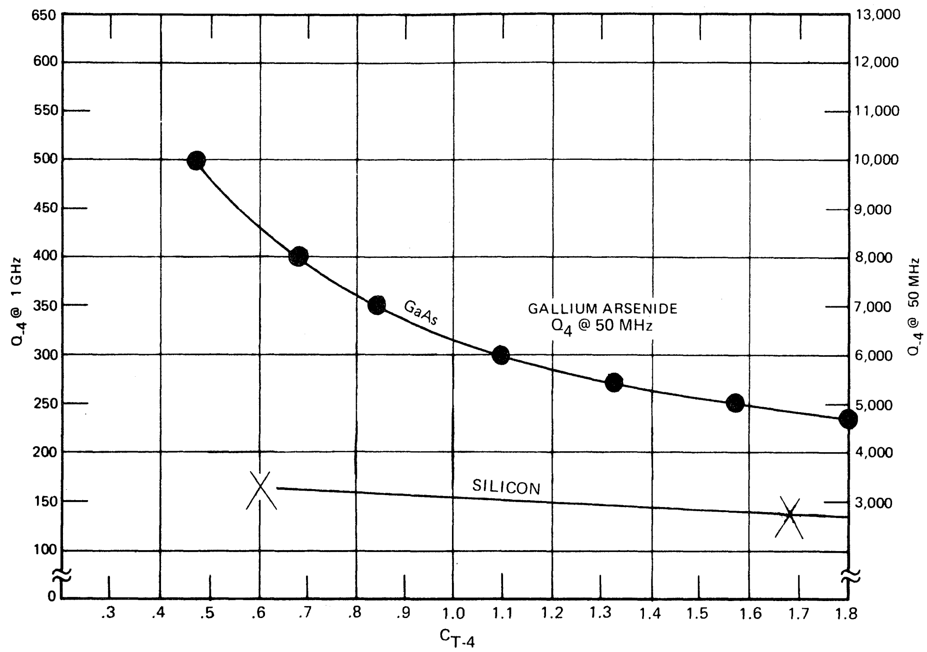


Figure 3. Q_{-4} vs. C_{T-4}

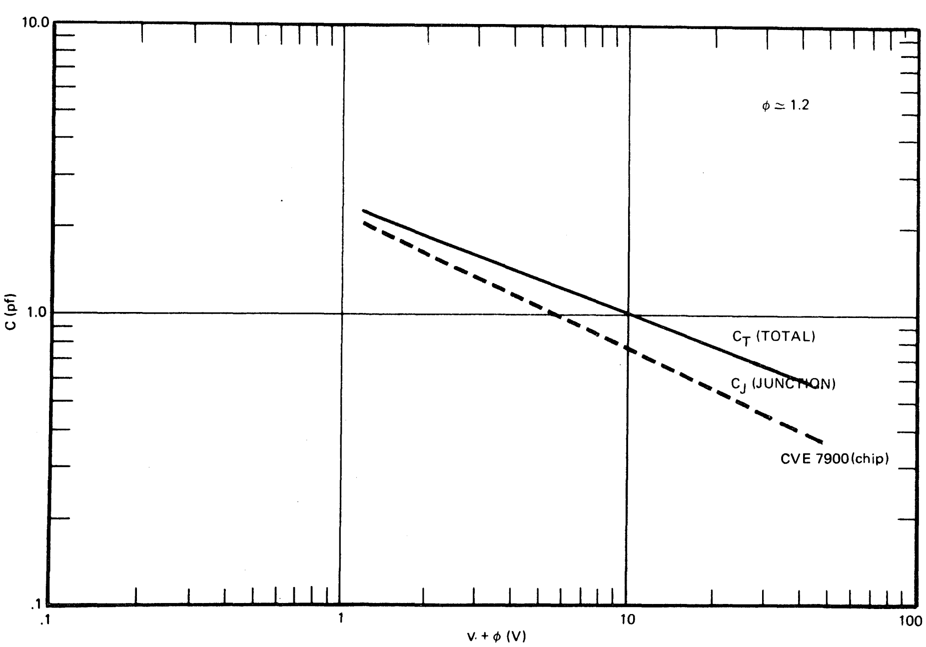


Figure 4. Typical Capacitance vs. Voltage

Application Note 80500: Tuning Diodes

I. Introduction

In recent years continuous development of tuning varactors — voltage controlled capacitors — together with increased commercial and military use has led to substantial improvement in Q, reproducibility and reliability. Concurrently, new techniques for producing and controlling a hyperabrupt dopant profile in the semiconductor permit the capacitance-voltage law to be much faster than the classical square root or cube root behavior.

Current tuning varactor materials include silicon and gallium arsenide; silicon is favored for lower cost and lower Q applications from HF through microwave frequencies. Hyperabrupt varactors, also of silicon, are finding large application in commercial television tuner applications, where their high tuning ratios, linear tuning and low cost are needed. New developments include low capacitance hyperabrupts for microwave applications.

Gallium arsenide is used when high operating frequency dictates the highest Q possible, as in parametric amplifiers and millimeter multipliers.

This application note will acquaint the reader with tuning varactors: how they work, and what they can or cannot be expected to do in an electronic circuit. The basic properties of a tuning diode will be described in terms of the parameters that manufacturers use in characterizing them. The following topics will also be addressed:

a) Capacitance ratio with respect to voltage and voltage breakdown;

b) Q as a function of design and operating conditions;

c) Stability — leakage current, temperature coefficient, and Post Tuning Drift;

d) Distortion Products;

e) Packaging Parasitics;

f) Applications — Suggestions on how to specify a varactor.

II. Device Physics

INTRODUCTION

All junction diodes are made up of the same physical parts: a P-N junction, a carefully controlled epitaxial layer and a very low resistance substrate. These parts are shown in Figure 2-1. No matter what type of junction device we are discussing — a tuning diode, a step recovery diode or a PIN diode — these parts are all present; the main difference between these devices is the resistivity and thickness of the epitaxial layer. Tuning diodes and multiplier diodes need epitaxial layers where both the resistivity and the thickness are carefully controlled.

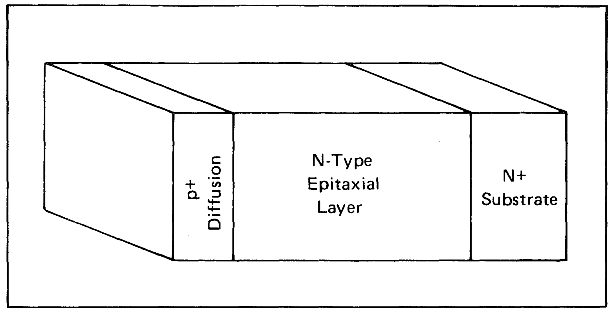


Figure 2-1.

ABRUPT JUNCTION

An abrupt junction diode is one in which the P^+, diffused, region of the diode is much more highly doped than the epitaxial layer. Also, the high doping drops to the doping level of the epitaxial layer in a distance that is short compared to the epitaxial layer thickness, and the doping level of the epitaxial layer is constant over its thickness. This is shown in Figure 2-2, with the corresponding C-V curve in Figure 2-3. When these requirements are satisfied, the diode capacity, diode area, epitaxial layer doping level and diode voltage are related by the following equation:

$$\frac{C(V)}{A} = K\left(\frac{N}{V+\varphi}\right)^n$$

where

C(V) = capacitance of the diode at voltage V
A = area of the diode
N = doping level of the epitaxial layer
V = voltage applied to the diode
φ = built in potential of the diode; (.6–.8 volts)
n = slope of diode C-V curve; n = ~0.5 for an abrupt junction diode
K = constant

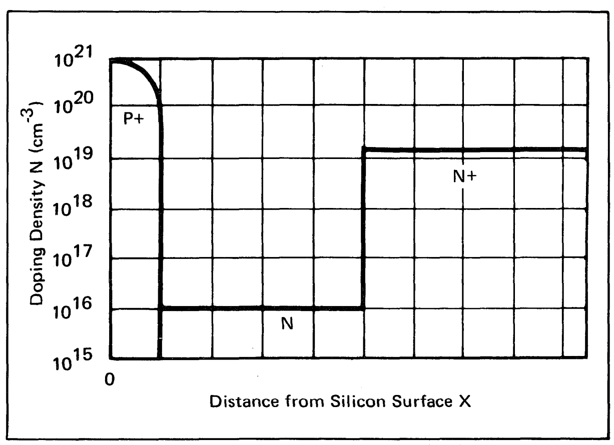


Figure 2-2. N-X Abrupt Junction Diode

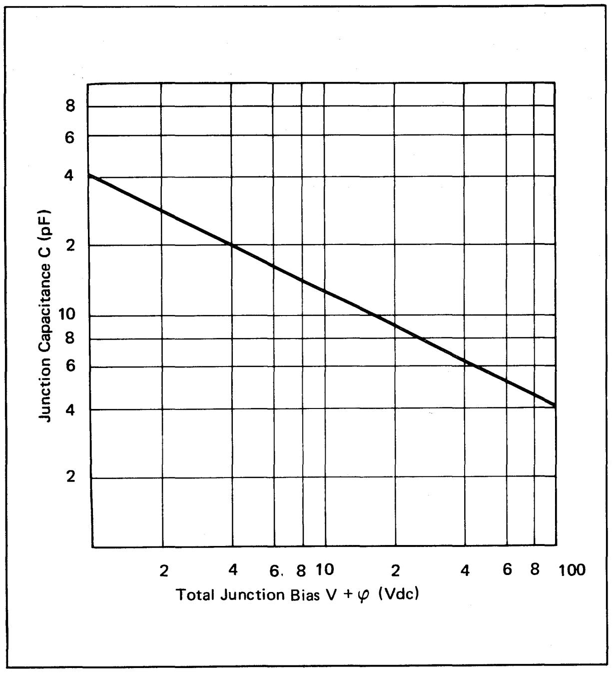


Figure 2-3. Capacitance vs. Total Junction Bias for Abrupt Diode

As a consequence of the physical properties of a PN junction a depletion layer is formed between the P and N regions whose width depends upon the voltage applied to the diode. The capacitance of the diode is inversely proportional to the width of the depletion layer, i.e. $C \sim \frac{1}{\ell_O}$. In addition, the series resistance of the diode is proportional to the width of the undepleted epitaxial layer. Thus, as diode reverse bias is increased, the depletion layer increases, causing a decrease in capacitance and a decrease in series resistance. As the diode reverse bias is increased further, a point is reached where the electric field caused by the reverse bias reaches a critical level, and current through the diode increases rapidly; this is the breakdown voltage of the diode. If, at the breakdown voltage, the epitaxial layer is not completely depleted, the diode will have excessive series resistance. Conversely, if the epitaxial layer is depleted before the breakdown voltage is reached, no further capacitance decrease occurs after the total depletion, and a condition called "punch through" occurs.

While, in the ideal case, voltage breakdown will occur just as the epitaxial layer is totally depleted, this seldom occurs in practice, and we generally have a condition of either punch through or excess series resistance.

LINEARLY GRADED JUNCTION

If, instead of the junction profile shown in Figure 2-2, we have a P^+ type region and an N type region whose doping levels increase linearly with distance from the PN junction as shown in Figure 2-4, with its corresponding C-V curve in Figure 2-5, we then have what is called a linearly graded junction diode. This diode follows Equation 2-1 with the exception that the exponent n is equal to 1/3. This means that, for a given voltage change, the linearly graded junction will have a smaller capacitance change than an abrupt junction diode. Since, in most cases, the designer is looking for the maximum capacitance change obtainable, the linearly graded junction is not used as a tuning diode. This structure found its greatest use several years ago as a "cube law" multiplier, but even this use has decreased as new structures have been developed.

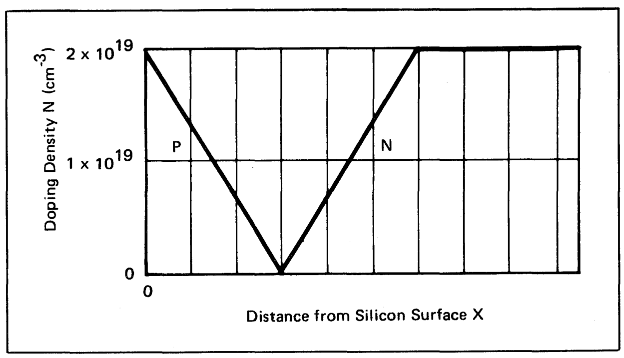


Figure 2-4. N-X Linearly Graded Junction

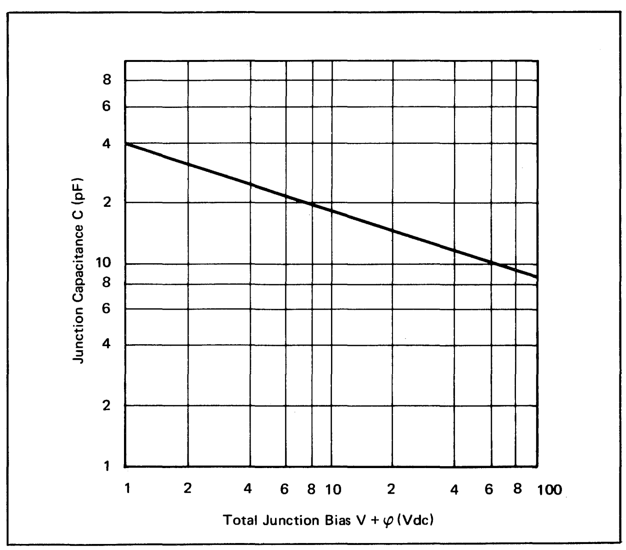


Figure 2-5. Capacitance vs. Total Junction Bias for Linearly Graded Junction

HYPERABRUPT JUNCTION

The hyperabrupt diode provides a greater capacitance change than the abrupt junction diode for a given voltage change, as well as a linear frequency vs. voltage characteristic over a limited voltage range. The structure of the hyperabrupt diode is shown in Figure 2-6 and can be seen to be an abrupt junction diode with an additional, increased, doping level at the PN junction. This diode also follows Equation 2-1 with the exception that n is now a function of voltage and is generally in the range of 0.5 to 2. A typical curve of n vs. voltage is shown in Figure 2-7.

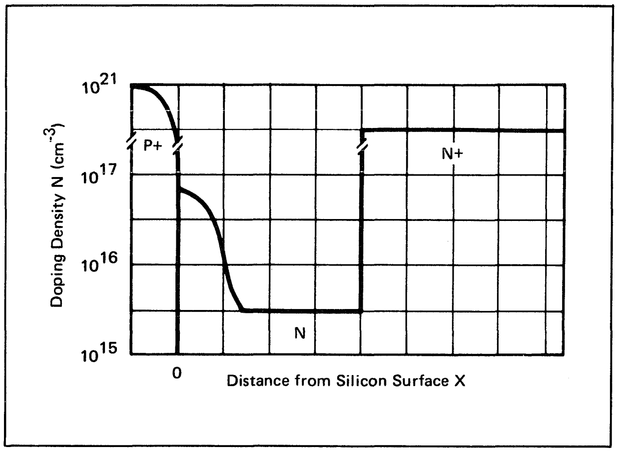


Figure 2-6. N-X Hyperabrupt Junction

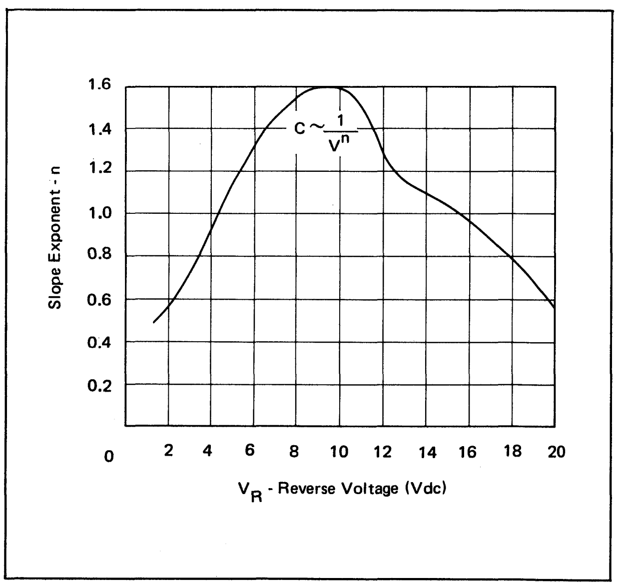


Figure 2-7 n vs. Reverse Voltage DKV6520 Series

The C-V curve in a hyperabrupt diode is shown in Figure 2-8 and is seen to start at a high value of capacitance per unit area at low bias (high epitaxial doping) and change to a lower value of capacitance per unit area (low epitaxial doping) at high bias. The details of the curve depend on details of the shape of the more highly doped region near the PN junction.

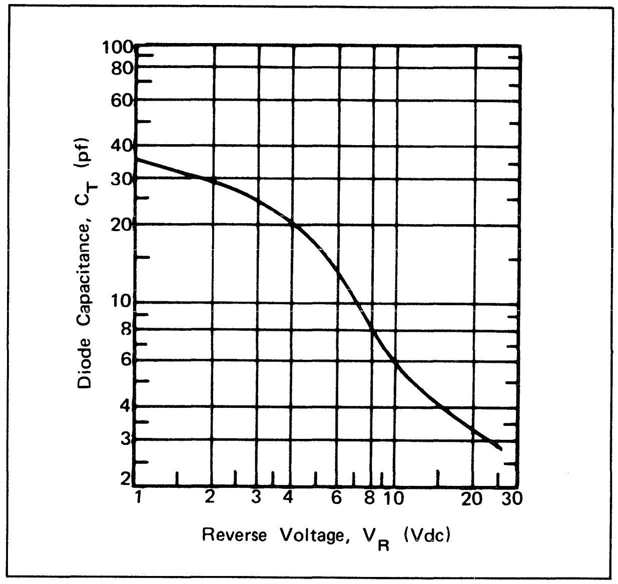


Figure 2-8. Capacitance vs. Junction Bias for Hyperabrupt Diode

Unfortunately, with a hyperabrupt diode, you must settle for a lower Q than an abrupt junction diode with the same breakdown voltage and same capacitance at four volts.

It should be noted that any diode which has an n value that exceeds 0.5 at any bias voltage is, by definition, a hyperabrupt diode. Thus, the hyperabrupt diode family can have an infinite number of different C-V curves. Since the abrupt junction diode has a well defined C-V curve, the capacitance value at one voltage is sufficient to define the capacitance at any other voltage. This is not the case for the hyperabrupt diode. In order to adequately define the C-V characteristics of a hyperabrupt diode, two and sometimes three points on the curve must be specified.

SILICON vs. GALLIUM ARSENIDE

Everything mentioned so far applies to both silicon and gallium arsenide (GaAs) diodes. The main difference between silicon and GaAs from a user's point of view is that higher Q can be obtained from GaAs devices. This is due to the lower resistivity of GaAs for a given doping level N. The resistivity of the epitaxial layer, or substrate, of a diode is given by the following equation:

$$\varrho = \frac{1}{Ne\mu}$$

where

ϱ is the resistivity
N is the doping level of the layer
e is the charge on an electron
μ is the mobility of the charge carriers in the layer.

Gallium arsenide has a mobility about four times that of silicon and, thus, a lower resistivity and higher Q for a given doping level N. Since diode capacitance is proportional to $\sqrt{N}$, independent of resistivity, a silicon diode and a GaAs diode of equal area and doping will have a capacitance difference proportional to the square root of the dielectric constant ratio. This gives the GaAs diode a five percent higher capacitance and is thus of little practical significance. The penalty paid for using GaAs is an unpassivated diode and a more expensive diode due to higher material and processing costs. If the higher Q of the GaAs device is not really needed, a substantial price saving will be obtained by using a silicon device.

PLANAR vs. MESA CONSTRUCTION

The two basic construction techniques used to manufacture tuning diodes are planar and mesa; a cross section of each of these devices is shown in Figure 2-9. The planar process, which is the backbone of the integrated circuit industry, lends itself to large volume production techniques and is the one used for the "1N" series of tuning diodes. Mesa processing, on the other hand, requires more processing steps and is generally done on a wafer-by-wafer basis. This results in a more costly process and thus a more expensive diode. All microwave tuning diodes are of mesa design because of greatly higher Q. Due to the relatively small radius of curvature at the junction edge of a planar diode the electric field in this area is greater than the electric field in the center, flat, portions of the junction. As a result the breakdown voltage of the diode is determined by both the epitaxial resistivity and the radius of curvature of the junction edge. Thus, for a given breakdown voltage a planar diode must use higher resistivity epitaxial material than a mesa diode which has a completely flat junction. The end result is that the planar diode has a greater series resistance than a mesa diode for the same capacitance and breakdown voltage, and thus lower Q.

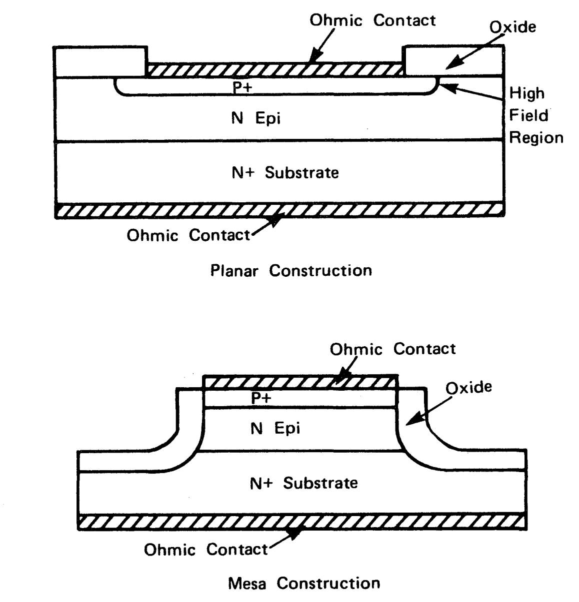


Figure 2-9. Cross Sections of Planar and Mesa Devices

III. Capacitance

CAPACITANCE MEASUREMENTS

In the section on device physics we described the various tuning "laws" obtained from varactors. In this section we will indicate how capacitance is measured and define a few new terms and problems pertinent to the subject.

Capacitance is measured at 1 MHz, and numerous experiments have shown that the junction capacitance is constant with frequency. A 1 MHz capacitance bridge or meter must operate with a low signal voltage to avoid errors due to the non-linear properties of the varactor; typically, about 15 millivolts rms is recommended. A balanced measuring circuit must be used in order that capacitance to ground of the associated cables, holders, etc. will be irrelevant. This introduces the first problem.

In any real, physical, environment the electric fields across any capacitor "fringe" away from the active or dielectric material into the surrounding space and are terminated on nearby or remote conductors. This contributes to something called "fringe" capacitance and is inherent to any capacitor. Some of this fringe is properly associated with the dielectric chip, as Figure 3-1 indicates. Clearly, the fringing fields shown here, because they exist (and cannot be reduced in any practical way) for all environments, are properly considered as part of the junction capacitance.

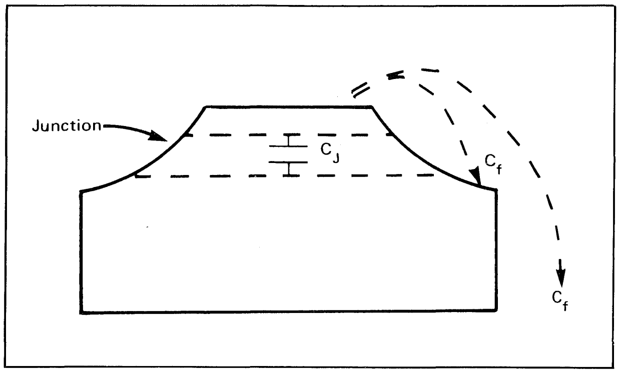


Figure 3-1. Inherent Chip Fringe Capacitance

Now, consider an erroneous measurement of chip capacitance, as shown in Figure 3-2. Here the probes used to contact the chip cause extra capacitance C_X. In this exaggerated example it is possible for C_X to exceed C_J. As a consequence it is necessary to minimize or eliminate capacitance introduced by the measuring probes. In chip measurements one obvious technique is to use a whisker as the top probe.

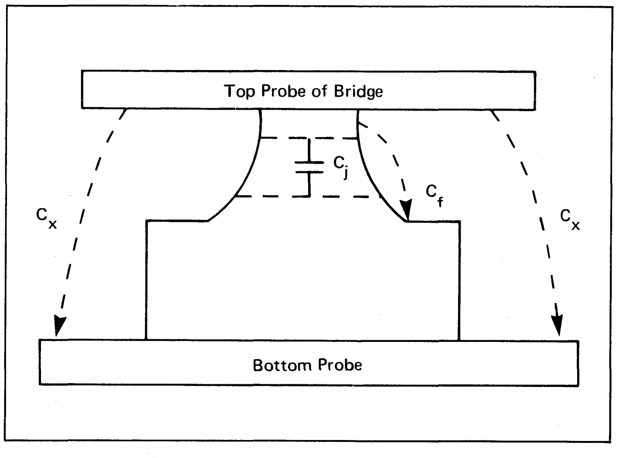


Figure 3-2. Stray Capacitance from Improper Measurement

Let's now take the chip and mount it in one of the many metal-ceramic packages available (see Figure 3-3).

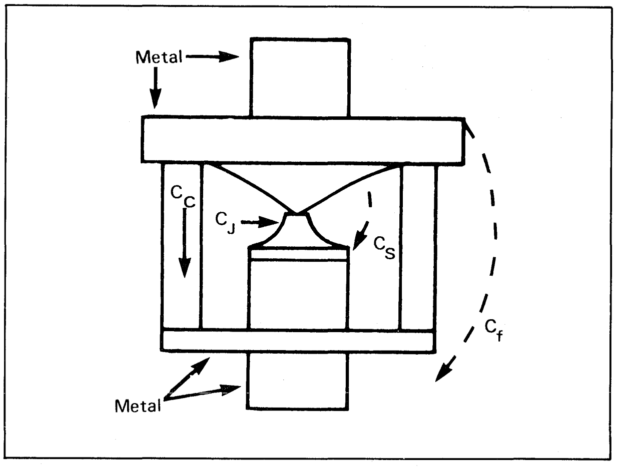


Figure 3-3. Stray Capacitance for Packaged Diode

We have added the following items:

1) A metal pedestal upon which the chip rests.
2) Bonding wires, or straps, to contact the top of the chip.
3) A ceramic envelope (almost always Alumina, $\varepsilon_r = 10$).
4) Various pieces of metal, copper or Kovar, to hermetically seal the package and provide mounting prongs.

We have also added capacitance:

1) C_S, from the straps to the pedestal and the base.
2) C_C, the ceramic capacitance.
3) More fringing C_F from the top of the package to the bottom and to the surrounding environment.

The strap and ceramic contributions are inherent to the package and are generally lumped together as C_P. The fringe capacitance, because it is dependent upon the exact method of mounting the package and the mechanical (conductive or dielectric) environment, is not inherent to the package and accordingly cannot be included in the diode specification. This capacitance is subject to control by the user, not the manufacturer.

Therefore, when the capacitance of the packaged, tuning varactors is measured, a so-called "fringe free" holder is used. See Figure 3-4.

The fringing fields are on ground and, since a balanced system is used, are neglected.

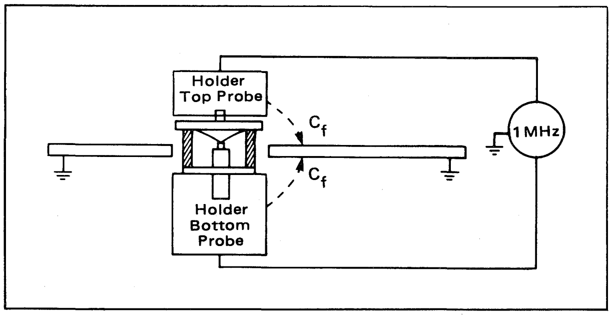


Figure 3-4. Fringe Free Capacitance Measurement

We belabor this point, because it is quite often a serious point of contention between customer and manufacturer, especially for low C_J varactors where theoretical capacitance ratios are often hard to obtain.

CAPACITANCE RATIO

From the user's point of view ratio is simply the capacitance change available in his circuit. Thus, if he is tuning from −4 to −45 volts, say, he defines ratio as

$$R = \frac{C_T(-4)}{C_T(-45)}$$ where C_T includes C_J plus C_P plus C_F.

The manufacturer, however, defines C_T as $C_J + C_P$.

To explore the significance of this difference let's take two examples, a large C_J and a small C_J, in chip, package and "typical" fringe situations. Both are 45 volt tuning varactors.

Device	C_{J0}	C_{J45}	Ratio
CVH-2045-01	0.6 pF	0.1	6.0
CVH-2045-17	15.0 pF	2.5	6.0

Put both devices into our standard 023 package with C_P (strap and ceramic) of .18 pF:

Device	C_{T0}	C_{T45}	Ratio
DVH-6741-02	0.78	0.28	2.75
DVH-6741-17	15.18	2.68	5.67

Notice the drop in ratio, especially for the low C_J diode. If we now add a typical 0.04 pF for external fringe capacitance, we get

Device	C_{T0}	C_{T45}	Ratio
DVH-6741-02	0.82	0.32	2.56
DVH-6741-17	15.22	2.72	5.60

The reduction in ratio, and thus circuit tuning capability, by the fringing fields is quite obvious and amounts to 7% in this example.

Because of the often stringent specifications on tuning ratio it is mandatory that the manufacturer and customer clearly agree on the exact design of the holder used to measure the varactors in question.

Having described how to measure capacitance, it is relatively easy to describe the results. The section on diode physics described the various types of "laws," or C-V curves, and we won't repeat. Nonetheless, several important points must be covered.

The first is "available capacitance swing": The laws indicate a steadily decreasing capacitance with voltage, which indicate that the epi region is widening and the electric field is increasing. (For an abrupt junction, since $C \propto \frac{1}{\sqrt{V}}$, the depletion zone width "W" is increasing as $\sqrt{V}$, and the electric field V/W increases as $\sqrt{V}$).

Two things can happen:

a) The junction width widens so that the entire intrinsic region is depleted. The capacitance bottoms out, resulting in voltage punch-through.

b) The electric field exceeds the dielectric strength of silicon, (or GaAs) and "solid state discharge" or "avalanche" current is drawn.

The diode impedance drops, the varactor no longer "varacts," and circuit operation ceases. Moreover, if more than a few milliamperes of current are drawn, localized overheating may destroy the diode resulting in breakdown voltage. All varactors are characterized for breakdown voltage, e.g., 45 volts minimum.

The theoretical tuning varactor is designed so that the punch-through occurs at a voltage equal to the voltage breakdown of the diode. Logically, then, this means that in order to obtain greater tuning ratios, it is necessary to be able to increase the depletion layer width without reaching punch-through or breakdown. You must have a thicker epi region to make this possible.

Figure 3-5 shows catalog ratio values, from zero bias to breakdown, as a function of breakdown voltage for abrupt junction chips.

If you know your required frequency range and capacitance ratio necessary to accomplish it, you have fixed the minimum breakdown voltage necessary. In the next section, on Q, we will discuss other elements in your choice of V_B.

To complete this section, we should mention that semiconductor processing control has been refined so well that capacitance track to within ±1% over the full range from zero to breakdown is now readily obtainable in production quantities.

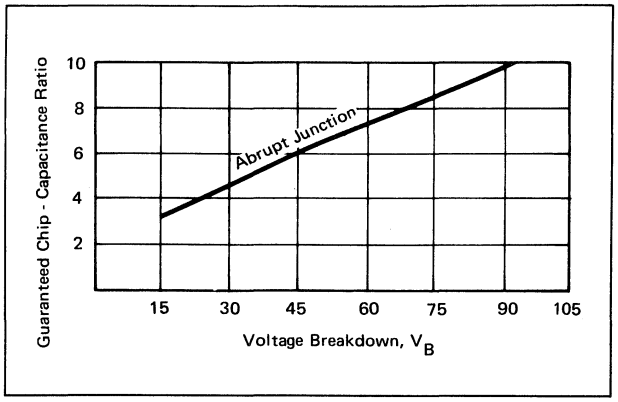


Figure 3-5. Capacitance Ratio vs. Breakdown Voltage

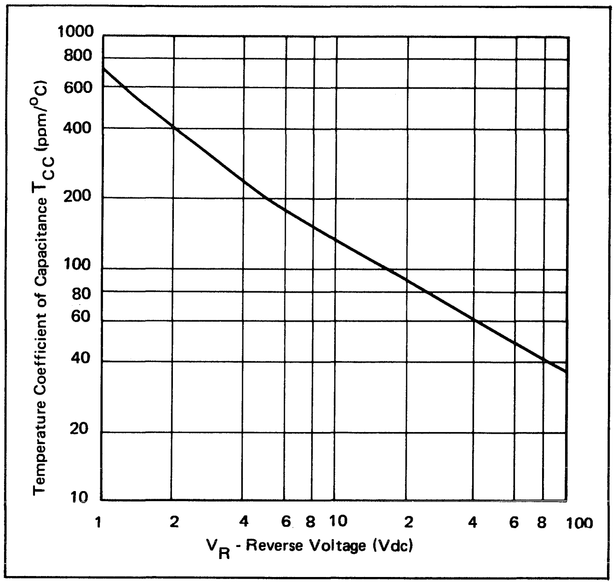


Figure 3-6. Temperature Coefficient of Capacitance vs. Tuning Voltage — Abrupt Junction Diode

TEMPERATURE COEFFICIENT OF CAPACITANCE (Tcc)

A parameter of interest to the circuit designer who is concerned with temperature stability is the diodes temperature coefficient of capacitance (Tcc). Unfortunately, since most data sheets give the value of Tcc at 4V, it is sometimes assumed that this value applies at all bias voltages. This is not the case. Consider Equation 3-1, a rewritten form of Equation 2-1:

$$C(V) = \frac{C(O)}{(V+\varphi)^n} \quad (3\text{-}1)$$

Taking the derivative of this with respect to temperature T we have

$$\frac{dC(V)}{dT} = \frac{+n\,C(O)}{(v+\varphi)(v+\varphi)^n}\frac{d\varphi}{dT} \quad (3\text{-}2)$$

or, after substituting Equation 3-1

$$Tcc = \frac{1}{C(V)}\frac{dC(V)}{dT} = \frac{-n}{(V+\varphi)}\frac{d\varphi}{dT} \quad (3\text{-}3)$$

As a first approximation we can say that $\frac{d\varphi}{dT} = -2.3$ mV/°C over the temperature range of interest.

From Equation 3-3 we can draw the following conclusions:

1) the temperature coefficient is inversely proportional to the applied voltage, and

2) the temperature coefficient is directly proportional to the diode slope, n.

For an abrupt junction diode which has a constant value of n, (0.5), the temperature coefficient is a smooth curve of the form $\frac{K}{V+\varphi}$. However, in the case of hyperabrupt diodes n is a function of voltage, and the shape of the Tcc curve depends on the details of the n(V) curve. A typical Tcc curve for an abrupt junction diode is shown in Figure 3-6 and for an Alpha DKV6520

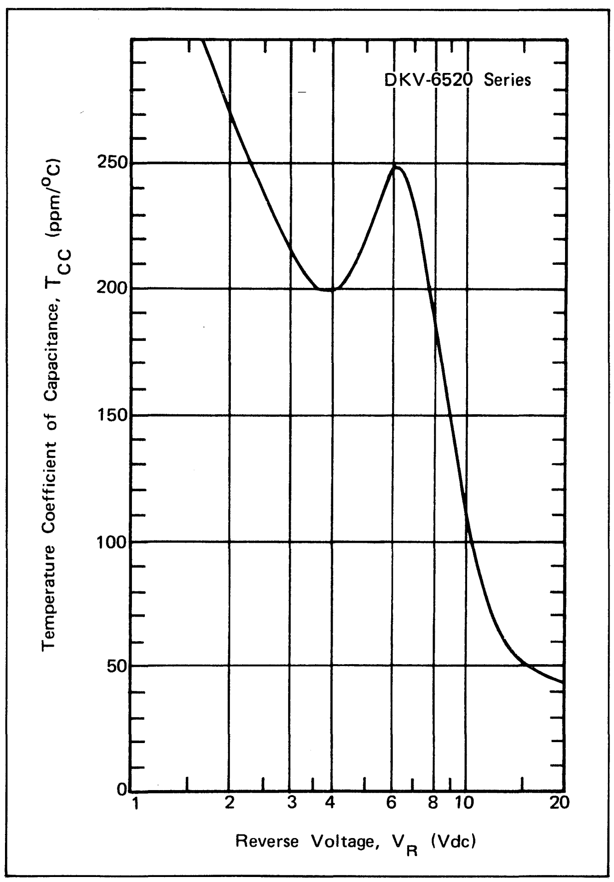


Figure 3-7. Temperature Coefficient of Capacitance vs. Tuning Voltage (T_A = 25°C) Hyperabrupt Junction Diode

series hyperabrupt diode in Figure 3-7. The inflection in the hyperabrupt Tcc is due to the fact that in this voltage range n(V) is increasing faster than 1/V, giving an increase in Tcc. It should be also noted, however, that over the range of the Tcc minimum the temperature coefficient is relatively constant, and operation in this area may be advantageous in some applications where a restricted tuning range can be used.

IV. Q Factor or Diode Loss

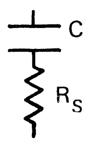
DEFINITIONS

The classical definition of the Q of any device or circuit is

$$Q = \frac{2\pi \text{ Energy Stored}}{\text{Energy Dissipated per cycle}}$$

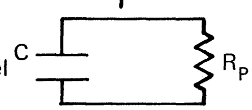
For a capacitor two formulations are possible.

a) Series



$$Q = \frac{1}{2\pi f R_s C}$$

b) Parallel



$$Q = 2\pi f R_p C$$

Clearly, the two definitions must be equal at any frequency, which establishes

$$R_P = \frac{1}{(2\pi f)^2 C^2 R_S}$$

In the case of a high Q tuning diode the proper physical model is the series configuration, for the depleted region is an almost perfectly pure capacitance, and the undepleted region, due to its relatively low resistivity, is almost a pure resistor in series with the capacitance. Furthermore, the contact resistances are also clearly in series.

Q, then, for a tuning varactor is given by

$$Q_{(-V)} = \frac{1}{2\pi fo R_{(-V)} C_{(-V)}}$$

where fo is the operating frequency, $C_{(-V)}$ is the junction capacitance, and $R_{(-V)} = R(epi) + R_C'$ the sum of the resistance of the undepleted epi and the fixed contact resistance.

Cutoff frequency, fc, is defined as that frequency at which Q equals unity.

Thus, $fc_{(-V)} = \frac{1}{2\pi R_{(-V)} C_{(-V)}}$

Historically, the tuning varactor business developed the habit of specifying Q at 50 MHz, in spite of the fact that Q values of microwave diodes are so high that it is almost impossible to measure them at 50 MHz. Instead, as discussed below, Q is measured at microwave frequencies (e.g., 1–3 GHz) and related to 50 MHz by the relationship $Q_{(f_1)} = Q_{(f_2)} \frac{f_2}{f_1}$, which derives quickly from the assumption that fc is independent of the measuring frequency.

Since both junction capacitance and epi resistance are functions of the applied bias, it is not possible to calculate Q as a function of bias from a measurement of capacitance alone. Catalog specifications typically show Q at −4 Volts, together with the capacitance at two or more voltages.

Relative to Q(−4), Q increases faster than the reduction in capacitance for bias greater than 4 volts and, conversely, decreases faster for bias less than 4 volts.

In the following section we will discuss the diode design parameters that determine Q. Following this, we will describe some elementary Q measurement techniques.

CAUSES

In the discussion on device physics the resistivity of the epi region was discussed, together with its impact on punch-through and breakdown.

For example, Table 1 below supplies typical resistivity and related parameters of 0.6 pF (C_{J-4}) diodes of different breakdowns.

Table 1. Parameters for 0.6 pF Diode

Breakdown Voltage V_B	Resistivity Ohm-cm	Junction Diameter Mil.	Epi Region Micron	Depleted Epi V = −4V Micron	Undepleted Epi V = −4V Micron	R Undepleted Ohm	Rsp Ohm	Q_4
30	.31	2.4	1.37	.54	.83	.81	.18	5200
45	.52	2.8	2.25	.73	1.52	1.86	.15	2600
60	.74	3.2	3.20	.90	2.30	3.24	.13	1500
90	1.25	3.7	5.27	1.21	4.06	7.17	.10	700

Application Note 80500: Tuning Diodes

If we remember that if at any bias lower than breakdown the epi region is not completely depleted, it follows that the undepleted portion presents a resistance in series with the pure capacitance of the depleted zone. The magnitude of this "undepleted" resistance is also shown in the table.

The entry "R spreading" (Rsp) is the series resistance between the epi region and the low resistivity substrate. The calculations are for idealized cylindrical epi regions of uniform resistivity, low resistivity contact on the anode (top) and low resistivity substrate on the cathode. This resistance is constant, independent of bias; also shown are epi thickness and width of the depletion zone at – 4 volt bias.

Note the substantial reduction in Q for higher voltage diodes caused by the increased epi resistance; this is true for any value of capacitance or type of junction. For greater voltage breakdown the epi thickness must be increased, which requires an increase in epi layer resistivity; the higher resistivity of the undepleted zone, multiplied by the fact that it is much wider for high voltage diodes, means the resistance increases substantially.

Consequently, a rule of thumb emerges: for maximum Q never choose a varactor with a voltage breakdown in excess of what is needed for the necessary tuning range.

Table 2 lists capacitance and Q for each of these chips as a function of bias. Please remember that Q is calculated at 50 MHz.

Table 3 rewrites the Data of Table 2 to show available capacitance ratios between zero bias and breakdown. The first column is the theoretical optimum, as tabulated. The second column is the typical catalog specification.

If the required tuning range is an octave, requiring a 4 to 1 ratio, the selection of a 30-volt varactor will result in diode losses half those of a 60-volt diode.

The reduction in tuning ratio below theoretical optima is caused by non-ideal junction fabrication. The junctions are never perfectly abrupt.

Although the tables and numbers above refer to abrupt junction silicon varactors, the principle applies without exception to all types of varactors. For comparison, Table 4 lists available ratios and Q values for a number of different varactors. The high Q values for GaAs and the low values for hyperabrupts are apparent.

One last point — the Q values and series resistance refer to chips only. The effects of package parasitics will be discussed later, but it is important to consider circuit contact losses at this time.

For small capacitance diodes, e.g., $C_{J4} = 0.6$ pF, the epi region contributes a high value of resistance and dominates Q except at punch-through. Diode contact losses are less significant.

Table 2. Q vs. Bias for 0.6 pF Diode

Breakdown Voltage V_B	C_{JO}	Q(0)	$C_J(-4)$	Q(−4)	$C_J(-10)$	Q(−10)	$C_J(-30)$	Q(−30)	$C_J(-45)$	Q(−45)	$C_J(-60)$	Q(−60)	$C_J(-90)$	Q(−90)
30	1.43	1700	.6	5200	.4	10k	.23	64k						
45	1.43	850	.6	2600	.4	5k	.23	20k	.19	90k				
60	1.43	550	.6	1500	.4	3k	.23	9k	.19	23k	.17	170k		
90	1.43	270	.6	700	.4	1.3k	.23	3.5k	.19	6k	.17	10k	.14	220k

Table 3. Capacitance Ratios — C_{J0}/C_JV_B

Breakdown Voltage V_B	Optimum Ratio	Minimum Guaranteed Ratio	Q_{-4} Typical
30	6.2	4.5	3000
45	7.5	6.0	2500
60	8.4	7.5	1400
90	10.2	8.7	650

Table 4. Comparative Tuning Diodes

Type	C_{JO}	Breakdown Voltage V_B	Q_{-4}*	Ratio C_{JO}/C_JVB*
Silicon Abrupt	1.0	30	5000	4.5
Silicon Abrupt	2.5	30	4600	4.5
Silicon Abrupt	5.0	30	3800	4.5
Gallium Arsenide Abrupt	1.0	25	10000	3.6
Gallium Arsenide Abrupt	.5	10	17000	2.5
Silicon Hyperabrupt	50.0	22	300	17.0
Silicon Hyperabrupt	2.5	22	500	14

*Minimum guaranteed.

For large capacitance the picture changes — dramatically. Table 5 lists a few 90-volt varactors of varying capacitance, with epi resistance, spreading resistance and Q tabulated. A presumed 0.1 ohm contact (not manufacturer's responsibility) is then used to calculate the Q you will obtain:

Table 5. – 90 Volt Diodes

C_{JO}	Repi (–4V)	Rsp	Q – 4	Circuit R	Q(–4) in circuit
1.43	7.17	.11	270	.1	267
5.72	1.78	.06	267	.1	252
22.88	.45	.03	256	.1	210

In short, be especially mindful of mounting contacts when using large capacitance varactors.

MEASUREMENTS

The measurement of Q of any product involves the measurement of a finite amount of loss, usually quite small, in the presence of measuring circuit losses. As tuning varactor technology has progressed, cut-off frequency has increased to the extent that the measurement frequency must be in the microwave range, where diode losses begin to exceed test equipment losses, and accurate measurements become possible.

The two common methods used in the industry are:

1. Resonant Cavity — A half wavelength partial coaxial cavity with the diode terminating the re-entrant center conductor, as shown in Figure 4-1.
2. Slotted Line — The diode is mounted at the end of a low loss silver plated line, as in Figure 4-2.

In the resonant cavity method, the resonant frequency and unloaded Q of the empty cavity are measured using power transmission to the 3 dB points and allowing for external coupling via the input and output probes. The diode is installed, proper bias applied, and the new resonant frequency and loaded Q observed.

Manipulation of a few equations extracts diode Q from these two measurements. Q at 50 MHz is then calculated, as is fc.

Typically, the cavity is silver plated invar, half wavelength near 2 GHz, with an I.D. of 1 inch and a 75-ohm center conductor. The coupling probes are adjusted for about – 20 to – 30 dB transmission.

There are several possible problems with this technique:

a. Losses in the bias choke can be large and, especially if the choke is disassembled for diode installation, can be variable. This can lead to serious error.

b. Voltage build-up at resonance can cause diode nonlinearities, especially at low bias. A non-symmetric power transmission curve is an indicator of this situation.

In the slotted line method, VSWR is measured, using the 3 dB width at the minimum, and corrected for diode holder and slotted line losses. Together with the position of minimum, the data are reduced to chip and/or total package reactance and loss parameters, and Q or fc calculated.

The RF signal is injected into the probe, to reduce signal strength at the diode, for a given level at the detector. This technique, plus the fact that this measurement is nonresonant, eliminates diode non-linearity problems experienced in the cavity technique.

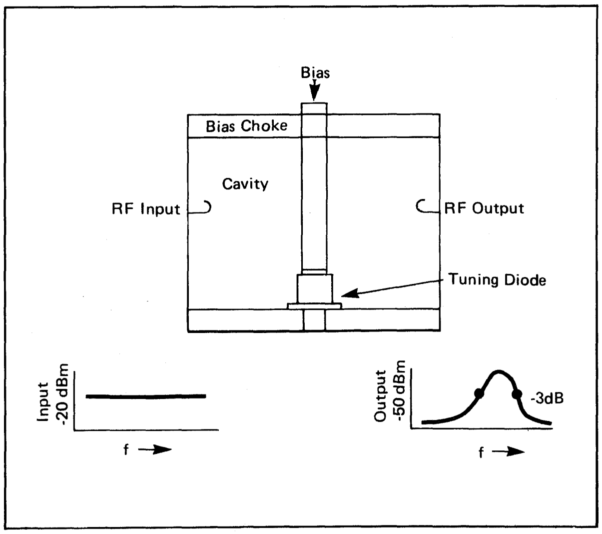


Figure 4-1. Resonant Cavity Q Measurement

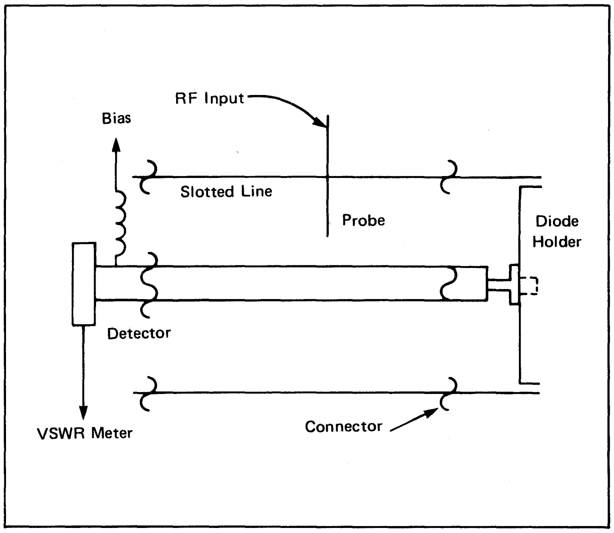


Figure 4-2. Slotted Line Q Measurement

Nonetheless, the slotted line approach has drawbacks — even at a measurement frequency of 3 GHz, the diode Q can approach that of the line, making measurements inaccurate. Typical limitation is an fc of about 500 GHz for both slotted line and cavity approaches.

Alpha prefers the cavity technique, as measurements can be reduced to a scope presentation of resonant frequency and 3 dB bandwidth, which makes reading quite simple.

The two methods can be shown to be equivalent, and the results correlate well. In both cases the effects of package parasitics can be considered and diode chip parameters extracted. This is difficult, but essential, if an analytical understanding of diode behavior over a wide range of frequency is required. Package parasitics are discussed in Section VII of this note.

Once fc is determined, the Q at 50 MHz is calculated, in keeping with tradition. The tabulated values are always for the packaged diode, not the chip.

For large capacitance diodes, with fc sufficiently low, Q measurements are taken directly at 50 MHz, using RF admittance bridges.

V. Other Device Parameters

REVERSE BIAS LEAKAGE CURRENT

The DC current which flows through the tuning diode under reverse bias is an indication of the quality of processing used in the manufacture of the device. In general, leakage currents should be less than 20 nanoamperes (2×10^{-8} Amp.) at 90% of the breakdown voltage. Large capacitance and therefore large junction area devices will have higher leakage current than small capacitance diodes.

As the junction temperature of the diode increases, the leakage current will also increase; a good design rule of thumb is that the leakage current will double for every 10°C rise in junction temperature. In general, this change in current will have a small effect on circuit performance unless the bias circuit is of very high DC impedance. The change in capacitance of the diode due to temperature coefficient effects will almost always over-shadow capacitance changes due to a change in bias voltage resulting from the change in leakage current. For decreasing temperature the leakage current decreases and will have no effect on device performance.

THERMAL RESISTANCE

In order to obtain maximum stability of tuning diode as the power dissipated in the diode is changed, temperature changes must be minimized. Thermal resistance and thermal time constants depend on several factors. Among these are geometry, thermal capacity of the materials used, thermal conductivity of the materials used and the thermal resistance of the various interfaces in the package and between the package and the heat sink.

The normal construction of a packaged tuning diode is shown in Figure 5-1. From this figure it can be seen that energy generated in the chip, which occurs in the junction — epitaxial layer, must travel through the thickness of the chip before it reaches the copper pedestal on which it is mounted. It is this thermal resistance path through the chip that accounts for the majority of the thermal resistance of the packaged device. This resistance depends upon the junction area of the device; the larger the junction area, the smaller the thermal resistance.

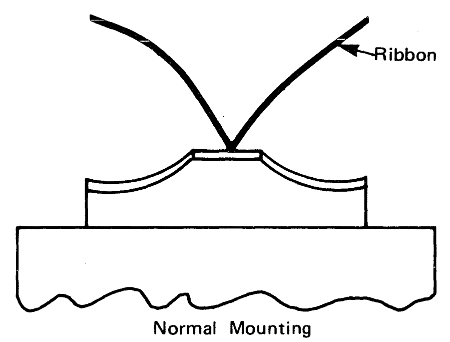


Figure 5-1. Normal Mounting

An alternate construction technique which is used to lower the thermal resistance of a packaged device is shown in Figure 5-2. This "flip chip" construction bonds the junction side of the chip to the copper pedestal, thus substantially reducing the thermal path through the chip and therefore the thermal resistance. A reduction in thermal resistance by a factor of two to four can be obtained in this manner. The disadvantage of flip chip mounting is that it is more difficult to fabricate than normal mounting and therefore imposes a price penalty on the user. In general, flip chip mounting should only be used where its improved thermal properties are really needed. This rarely occurs in tuning diode applications. Typical thermal resistance values of tuning diodes in ceramic packages are from 20 to 80°C/watt. Glass axial lead packages may have thermal resistance values of several hundred °C/watt and should not be used where more than a few tenths of a watt are to be dissipated.

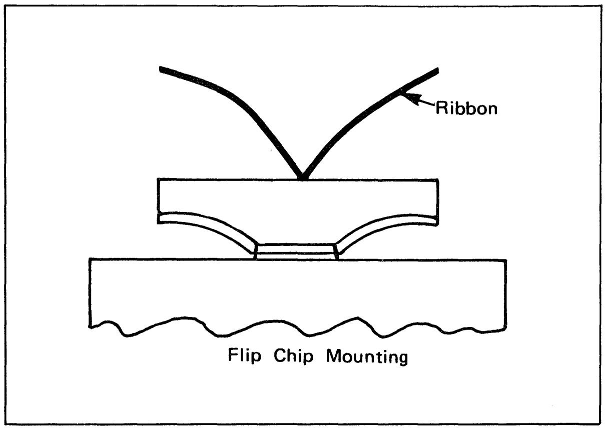


Figure 5-2. Flip Chip Mounting

POST TUNING DRIFT

Post tuning drift (PTD) is the change in oscillator frequency with time after the tuning voltage has stabilized. The minimization of PTD has assumed greater importance with the design of more sophisticated electronic countermeasure systems where rapid, accurate frequency changes are required.

Post tuning drift can be divided into two categories, short and long term. Short term PTD is in the time range of tens of nanoseconds to a few seconds, while long term PTD is in the time range of seconds to minutes, hours, or days.

Short term PTD is mainly dependent on the thermal properties of the diode and is improved by high Q (low power loss) and flip chip construction. Long term PTD depends on oxide stability and freedom of mobile charge in the oxide. It should be noted that actual oscillation frequency change may occur even with a perfect tuning diode due to changes in power dissipated in the diode as frequency is changed, changes in the diode heat sink temperature and frequency changes due to other circuit elements. As an example of what can be obtained, Alpha diodes have exhibited less than 0.01% frequency change for both short and long term PTD.

VI. Distortion Products

Inasmuch as nonlinear components generate harmonics and other distortion products, an understanding of this mechanism is of prime interest to the circuit designer. In some instances the distortion products are the desired end result of the circuit design, as in frequency multipliers where the harmonics of the input signal frequency are the required output signal. For other applications, such as in tuning diode circuits, distortion products are extremely undesirable, and in some instances the end product specification may set a maximum limit to the distortion products allowed.

CROSS MODULATION

Cross modulation is the transfer of the modulation on one signal to another signal and is caused by third and higher odd order nonlinearities in the transfer functions of the device.

Rewriting Equation 2-1 we have:

$$C(V) = \frac{C_O}{(1 + \frac{V}{\varphi})^n} \qquad (6\text{-}1)$$

where C_O = capacitance
V = applied voltage = $V_O + v$
V_O = DC applied voltage
v = AC applied voltage

then for a desired signal of

$$S_1 = \nu_1 \sin \omega_1 t \qquad (6\text{-}2)$$

and a second amplitude modulated signal of

$$S_2 = \nu_2(1 + m \cos \omega_m t) \sin \omega_2 t \qquad (6\text{-}3)$$

it can be shown that the cross modulation, γ, defined by:

$$\text{Output signal} \sim v_1 \sin \omega_1 t + \gamma \sin (\omega_1 \pm \omega_m)t$$

is found to be:

$$\gamma = \frac{n(n+1)m\nu_2^2}{4(V_o + \varphi)^2} \qquad (6\text{-}4)$$

From this equation it can be seen that cross modulation is:

1. Proportional to the square of the interfering signal
2. Directly proportional to the modulating index, m
3. Independent of the desired signal strength
4. Independent of the frequencies of the desired and interfering signals, and
5. No value of n gives zero cross modulation.

Solving Equation 6-4 for the signal level v_2 required to produce cross modulation of value γ we have:

$$\nu_2 = \frac{2(V_O + \phi)\gamma}{n(n+1)^m} \qquad (6\text{-}5)$$

The interfering signal levels required to produce 1% cross modulation from a 30% modulated interfering signal applied to an abrupt junction diode and a hyperabrupt junction diode are shown in Figure 6-1.

From this figure it can be seen that the hyperabrupt diode is more susceptible to cross modulation than the abrupt junction diode in the region of maximum slope of the hyperabrupt diode. For many applications, however, distortion products will be generated in other devices, such as a transistor, at signal levels considerably below those given in Figure 6-1.

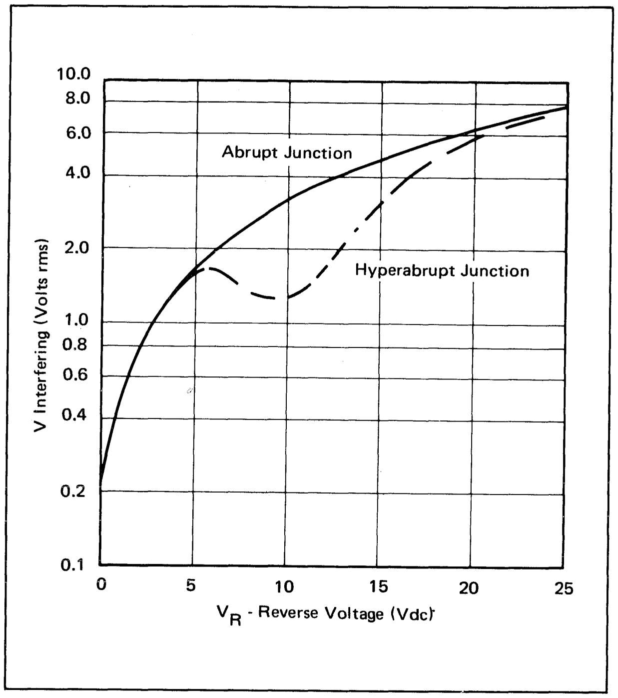


Figure 6-1. Interfering Signal Level vs. Bias for 1% Cross Modulation-Abrupt and Hyperabrupt (30% AM Modulation)

INTERMODULATION

Intermodulation is the production of undesired frequencies of the form

$$\sin(2\omega_1 t - \omega_2 t) \text{ and } \sin(\omega_1 t - 2\omega_2 t) \qquad (6\text{-}6)$$

from an input signal of the form

$$\nu(\cos \omega_1 t + \cos \omega_2 t) \qquad (6\text{-}7)$$

From an analysis similar to that done for cross modulation it can be shown that:

$$\text{Intermodulation} = \frac{n(n+1)\nu^2}{8(V_O + \varphi)^2} \qquad (6\text{-}8)$$

or

$$\text{Cross modulation} = (2m) \times \text{Intermodulation} \qquad (6\text{-}9)$$

HARMONIC DISTORTION

Harmonic distortion products are integral multiples of the signal frequencies and decrease in amplitude as the harmonic number increases. Due to pass band considerations and amplitude decrease with harmonic number, the second harmonic is the one of prime concern. Again, it can be shown that the second harmonic, v_2, of a signal of amplitude v_1 is:

$$\nu_2 = \frac{n}{3(V_O + \phi)} \nu_1^2 \qquad (6\text{-}10)$$

Figure 6-2 shows the signal level required to produce 10% second harmonic distortion in an abrupt junction and a hyperabrupt junction diode.

Again, as in the case of cross modulation, the hyperabrupt diode is slightly worse than the abrupt junction diode in the region of maximum slope of the hyperabrupt diode.

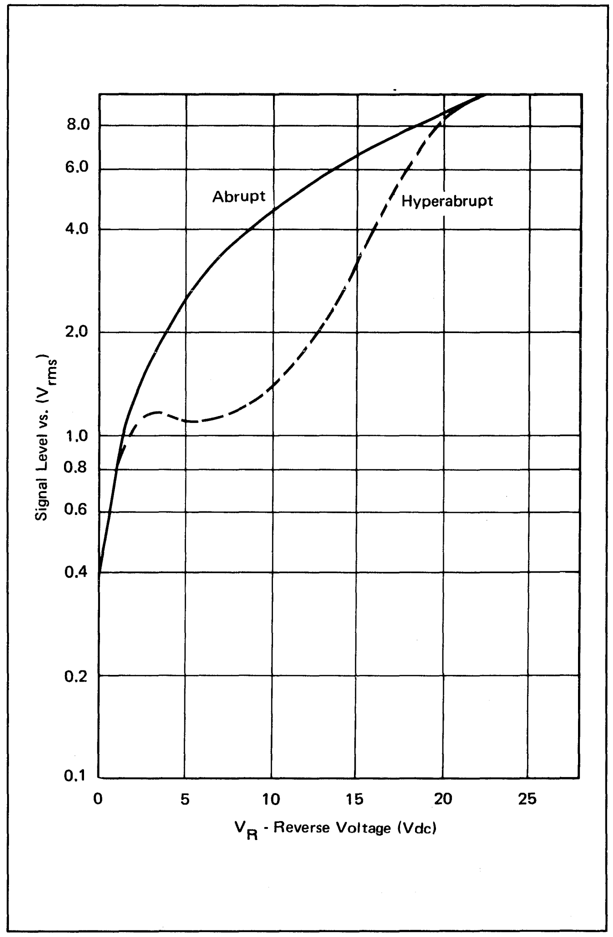


Figure 6-2. Signal Level vs. Reverse Voltage for 10% Harmonic Distortion

REDUCTION OF DISTORTION PRODUCTS

In some cases the signal levels applied to the diode generate distortion products larger than desirable for the circuit application. In this case significant reduction in the distortion products can be achieved by using two diodes in a back-to-back configuration, as shown in Figure 6-3. Analysis shows that the fundamental signal components through the diodes are in phase and add, while some distortion products are out of phase and cancel, thus improving distortion performance.

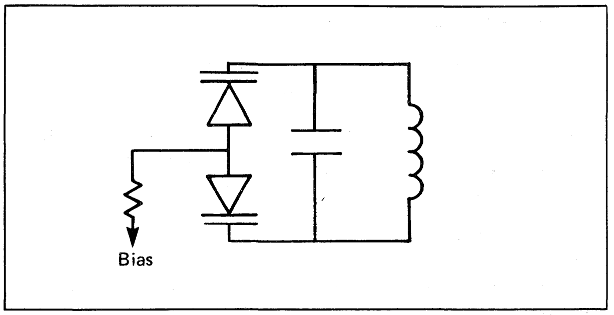


Figure 6-3. Back to Back Diodes

VII. Package Configurations and Characteristics

The discussion thus far has dealt with the properties of the tuning varactor chip, with only token mention of packaged diodes. Since most applications involve packaged chips, we shall discuss the effects of packaging.

First of all, the chief advantage of a packaged diode over a chip is the considerable ease of handling and installation in the circuit. Whether the package is ceramic or glass with prong or wire leads, the package offers a "handle" by which you can pick up the diode and large area metallic contacts on which you can connect the diode to the circuit.

Second, a package is hermetically sealed, which provides maximum protection of the chip from hostile environments. Also, the relatively delicate "lead-bonding" connection to the small anode contact of the chip has been performed and guaranteed by the manufacturer, relieving the user of this potential unreliable operation. However, packaging also has its disadvantages.

Let us examine the RF influence of the package on chip behavior, by referring to Figure 3-3. This happens to show a metal-ceramic package, but functionally it corresponds to a glass-leaded device also.

The external dimensions of the package create inductance, whose magnitude depends upon the physical circuit environment (e.g., effective return path for RF current). This inductance is effectively in series with the parallel circuit of ceramic and chip.

The ceramic (or glass) adds capacitance. The bonding wires create a new lumped inductance, directly in series with the chip, which itself consists of a series resistance and junction capacitance. There is a fringing capacitance from bond wire to the chip-pedestal as well as to the package cover. The whole package-chip circuit is broken down as follows:

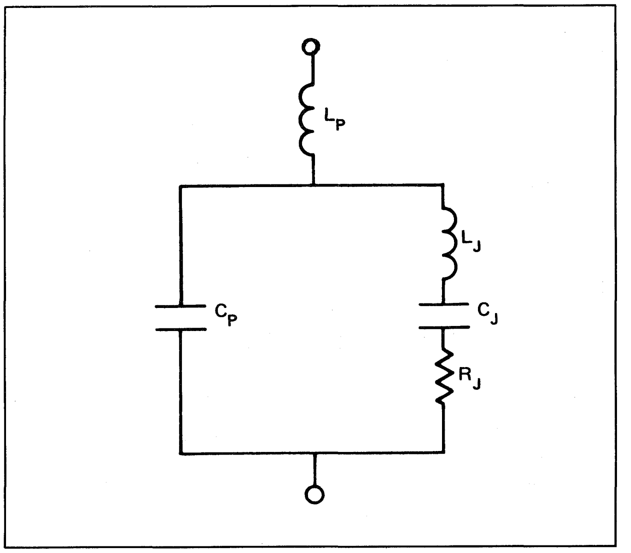


Figure 7-1. Equivalent Network of Packaged Diode

L_P is the package inductance, partially under user control. C_P is package capacitance, plus fringe as may occur, plus half of the bonding wire capacitance. L_J is strap inductance. C_J, R_J represent the chip, plus the other half of the bonding wire capacitance. Strap inductance L_J is often referred to as "excess inductance", relative to the inductance of a solid metal slug of the same external dimensions as the package. (The inductance of the solid metal "diode" is L_P.)

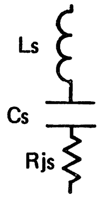
The behavior with frequency of this network can get quite complicated.

Briefly:

1. Well below series resonance (L_J and C_J) C_P adds directly to C_J; the Q of the diode (not the chip) is increased, but tuning ratio is reduced accordingly.
2. Near series resonance the effective resistance increases considerably, and the diode Q drops drastically. Most users avoid operation here.
3. Above series resonance there is a parallel resonance of the C_P and the chip-L_J branch. Q rises, but the diode acts as a variable inductance, not variable capacitance.
4. Higher still in frequency there is a second resonance, between L_P and C_P. The diode is capacitive.

For the mathematically inclined it is possible to reduce the complex actual network to a simpler equivalent network, with elements almost independent of frequency over a narrow band (5–10%).

Thus, Figure 7-1 reduces to 7-2.



where: $L_s = L_p + L_j/D$

$R_s = R_j/D$

$$C_s = \frac{C_j + C_p}{1 + \omega^2 \frac{C_j C_p (R_j^2 + \omega^2 L_J^2)}{D}}$$

$$D = \left(1 + \frac{C_P}{C_J} - \omega^2 L_j C_P\right)^2 + \omega^2 C_P^2 R_J^2$$

Figure 7-2. Diode Equivalent Circuit

In deriving this equivalent network, we have equated both $Z(\omega)$ and $\frac{dX(\omega)}{d\omega}$ of the actual network.

Dimensions and values of the parasitic elements for a variety of packages are contained in our package data sheet. You may consider Table 6 below which lists a few packages.

Table 6

Package Style	L_P(1) nH	C_P pF	L_J(2) nH	Typical First Series Resonance $C_J = 1.0$ pF GHz
023-001	.4	.18	.5	7
048-001	.24	.27	.3	9
082-001	.12	.20	.17	12
290-001	.10	.12	.10	16
075-001 (Glass)	.75	.06	1.0	5

Notes:
1. L_P varies with mounting environment. The values listed correspond to the diode mounted in a 50-ohm coaxial line with inner conductor of the same diameter as the ceramic or glass envelope. Thus, $L_P = 4.2$ h, where h is height of envelope in inches, and L_P is in nanohenries. [In a General Radio slotted line, GR900LB, with a center conductor of 0.244″, the 0.023 package L_P becomes 0.75 nH, indicating the substantial effects of mounting environment.] The package end prongs are "buried" in the circuit.
2. L_J varies with strap bonding technique & wire dimension and internal package construction. The values given are typical.

VIII. Applications

How to specify a tuning diode:

- Assuming that your application is sufficiently specified and can be analyzed mathematically, you must determine the capacitance, the tuning ratio and minimum Q of the required diode.
- Be sure to consider distortion, which may help you define the minimum bias voltage you will use.
- Knowing the lowest bias voltage and tuning ratio, you have effectively fixed V_B (for abrupt junctions). You have then approximately fixed Q.
- Review the various catalogs of available diodes to find if you can satisfy your requirements.
- Review the mechanical configuration of your circuit, and find a package that will be compatible.
- Calculate the effects of package parasitics, and see if the diode (chip) still satisfies you.
- Assuming you can't quite get a diode that works, either in ratio or Q, consider a variation from catalog specs.

Catalog specifications reflect both manufacturing guard bands and conservatism. In order to maintain a reasonable price structure, it is necessary to offer diodes with both Q and capacitance ratio below the theoretical optima, in order that the values quoted can be guaranteed. Tighter specifications can often be accepted by the manufacturer.

Furthermore, design deviations from "ideal" can provide higher Q or higher ratio.

The mathematically ideal tuning varactor is designed so that punch-through occurs at a voltage exactly equal to voltage breakdown, with both being just greater than the catalog rating of the diode. In real life, however, since in many applications theoretical tuning performance is not required out to breakdown, an improvement in Q is obtained by allowing punch-through to occur before breakdown. Consequently, if in your application you need higher Q and can sacrifice tuning ratio, this is generally possible. Similarly, if you need greater ratio and can accept lower Q, such diodes are also available within, of course, the constraints of the square law and V_B.

Please consult Alpha.

Finally, we present two circuits:

- In the section on distortion we discussed back-to-back diodes, to reduce distortion products. Figure 8-1 sketches such a circuit and the corresponding diode package.

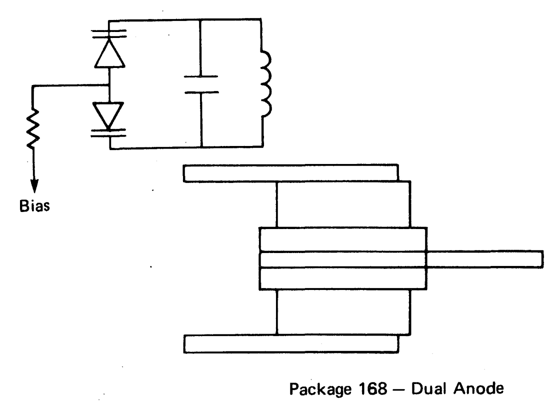


Figure 8-1. Back to Back Diode Package

- We mentioned linear tuning for hyperabrupts. Figure 8-2 shows curves for a simple tank circuit, using a DKV6550B hyperabrupt and an abrupt junction, DVH6791, a 90 volt diode.

Both are $C_{J(-4)}$ 1.24 pF, mounted in a package 023-001 (C_P = .18), and 0.1 pF stray capacitance is assumed.

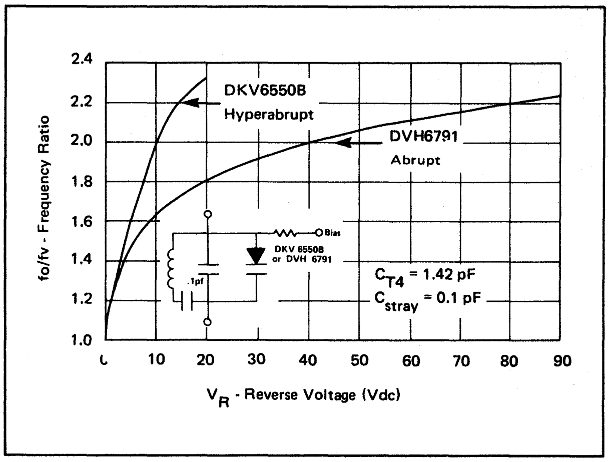


Figure 8-2. Frequency Ratio vs. Voltage for Hyperabrupt and Abrupt Diodes

Section 4
Power Generation Devices

Gunn Diodes and Modules

GaAs and Silicon Paramp Diodes

Quick Reference List: Gunn Diodes, Gunn Oscillators and Motion Detectors

Frequency Band / Category or Application	C Band 4–8.2 GHz		X Band 8.2–12.4 GHz		Ku Band 12.4–18 GHz		K Band 18–26.5 GHz		Ka Band 26.5–40 GHz		U Band 40–60 GHz		V & W Bands 60–100 GHz	
	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page
Lowest Cost Gunn Diodes			DGB8081	4-7	DGB8131	4-8	DGB8091	4-9						
			DGB8181	4-7	DGB8231	4-8	DGB8191	4-9						
			DGB8281	4-7			DGB8141	4-9						
			DGB8381	4-7										
			DGB8121	4-7										
			DGB8221	4-7										
Low Cost Gunn Diodes			DGB8122	4-7	DGB8132	4-8	DGB8094	4-9	DGB8054	4-10	DGB8064	4-11		
			DGB8123	4-7	DGB8133	4-8	DGB8095	4-9	DGB8055	4-10	DGB8065	4-11		
			DGB8124	4-7	DGB8134	4-8	DGB8194	4-9	DGB8056	4-10	DGB8066	4-11		
			DGB8125	4-7	DGB8135	4-8	DGB8195	4-9	DGB8154	4-10	DGB8164	4-11		
			DGB8222	4-7	DGB8232	4-8	DGB8291	4-9	DGB8155	4-10	DGB8165	4-11		
			DGB8223	4-7	DGB8233	4-8	DGB8294	4-9	DGB8156	4-10	DGB8166	4-11		
			DGB8224	4-7	DGB8234	4-8	DGB8295	4-9						
			DGB8225	4-7	DGB8235	4-8	DGB8144	4-9						
							DGB8145	4-9						
							DGB8244	4-9						
							DGB8245	4-9						
Lowest Cost C.W. Oscillators			GOS2572	4-27										
			GOS2573	4-27										
Low Cost C.W. Oscillator			GOS2573	4-27										
Lowest Cost C.W. Motion Detector			GOS2580	4-15										
Low Cost Motion Detectors			GOS2583	4-17										
			GOS2581	4-19										
Low Cost Pulsed Oscillators			GOS2569	4-29										
			GOS2570	4-29										

Frequency Band / Category or Application	C Band 4–8.2 GHz		X Band 8.2–12.4 GHz		Ku Band 12.4–18 GHz		K Band 18–26.5 GHz		Ka Band 26.5–40 GHz		U Band 40–60 GHz		V & W Bands 60–100 GHz	
	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page
Motion Detector Gunn Diodes for Intrusion Alarms and Door Openers			DGB8081	4-7			DGB8091	4-9						
			DGB8181	4-7			DGB8191	4-9						
			DGB8281	4-7			DGB8291	4-9						
			DGB8381	4-7										
Motion Detector Modules for Intrusion Alarms and Door Openers			GOS2580	4-15										
			GOS2581	4-19										
			GOS2583	4-17										
			GOS2579	4-19										
			GOS2578	4-19										
Self Detect Gunn Oscillators for Door Opener Applications			GOS2572	4-27										
			GOS2573	4-27										
			GOS2569	4-29										
			GOS2570	4-29										
Very Low Current C.W. Motion Detector Module			GOS2583	4-17										
Low Current C.W. Motion Detector Module			GOS2580	4-15										
Pulsed Motion Detector Module			GOS2581	4-19										
Pulsed Motion Detector Modules with Electronic Circuitry			GOS2578	4-19										
			GOS2579	4-19										
C.W. Gunn Oscillators			GOS2572	4-27										
			GOS2573	4-27										
			GOS2574	4-27										
			GOS2575	4-27										
			GOS2576	4-27										
			GOS2577	4-27										

Quick Reference List: Gunn Diodes, Gunn Oscillators and Motion Detectors

Frequency Band	C Band 4–8.2 GHz		X Band 8.2–12.4 GHz		Ku Band 12.4–18 GHz		K Band 18–26.5 GHz		Ka Band 26.5–40 GHz		U Band 40–60 GHz		V & W Bands 60–100 GHz	
Category or Application	**Type Number**	**Page**	**Type Number**	**Page**	**Type Number**	**Page**	**Type Number**	**Page**	**Type Number**	**Page**	**Type Number**	**Page**	**Type Number**	**Page**
Pulsed Gunn Oscillators			GOS2569 GOS2570 GOS2571 GOS2584 GOS2585	4-29 4-29 4-29 4-29 4-29										
Pulsed Gunn Oscillators with Integral Pulse Modulator			GOS2566 GOS2567 GOS2568 GOS2586 GOS2587	4-29 4-29 4-29 4-29 4-29										
Very Low Current C.W. Gunn Diodes			DGB8081	4-7			DGB8091	4-9						
Pulsed Gunn Diodes Low Power	Inquire		Inquire		Inquire		Inquire		Inquire					
Pulsed Gunn Diodes High Power	Inquire		Inquire		Inquire		Inquire		Inquire					
Radar Detector Local Oscillator			DGB8121 DGB8221 DGB8381 DGB8081 DGB8181 DGB8281	4-7 4-7 4-7 4-7 4-7 4-7			DGB8091 DGB8191	4-9 4-9						
Radar Detector Receiver Head			Inquire				Inquire							

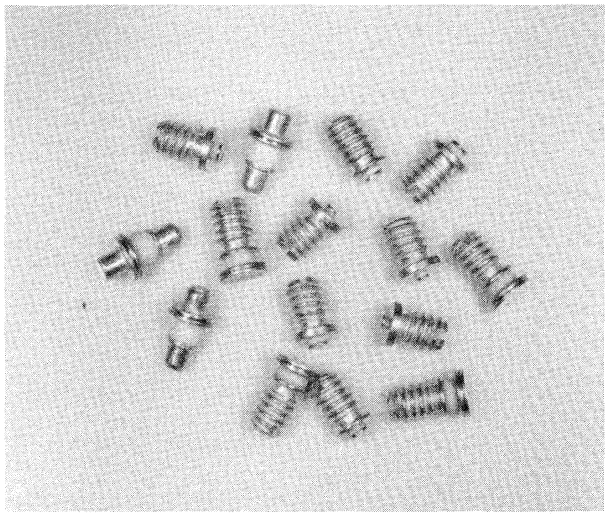
Frequency Band	C Band 4–8.2 GHz		X Band 8.2–12.4 GHz		Ku Band 12.4–18 GHz		K Band 18–26.5 GHz		Ka Band 26.5–40 GHz		U Band 40–60 GHz		V & W Bands 60–100 GHz	
Category or Application	**Type Number**	**Page**	**Type Number**	**Page**	**Type Number**	**Page**	**Type Number**	**Page**	**Type Number**	**Page**	**Type Number**	**Page**	**Type Number**	**Page**
Wideband YIG Tuned Oscillator Gunn Diodes	DGB9214 DGB9215 DGB9314 DGB9315 DGB9414 DGB9415 DGB9514 DGB9515	4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6	DGB9224 DGB9225 DGB9324 DGB9325 DGB9424 DGB9425 DGB9524 DGB9525 DGB9624 DGB9625	4-7 4-7 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8	DGB9234 DGB9235 DGB9236 DGB9334 DGB9335 DGB9336 DGB9434 DGB9435 DGB9436 DGB9534 DGB9535	4-9 4-9 4-9 4-9 4-9 4-9 4-9 4-9 4-9 4-9 4-9	DGB9244 DGB9245 DGB9246 DGB9344 DGB9345 DGB9346 DGB9444 DGB9445 DGB9446 DGB9544 DGB9545 DGB9546	4-10 4-10 4-10 4-10 4-10 4-10 4-10 4-10 4-10 4-10 4-10 4-10	DGB9254 DGB9255 DGB9256 DGB9354 DGB9355 DGB9356	4-11 4-11 4-11 4-11 4-11 4-11				
Wideband V.C.O. Gunn Diodes	DGB9211 DGB9212 DGB9213 DGB9214 DGB9215 DGB9311 DGB9312 DGB9313 DGB9314 DGB9315 DGB9411 DGB9412 DGB9413 DGB9414 DGB9415 DGB9512 DGB9513 DGB9514 DGB9515 DGB9612 DGB9613	4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6 4-6	DGB9221 DGB9222 DGB9223 DGB9224 DGB9225 DGB9321 DGB9322 DGB9323 DGB9324 DGB9325 DGB9421 DGB9422 DGB9423 DGB9424 DGB9425 DGB9522 DGB9523 DGB9524 DGB9525 DGB9622 DGB9623 DGB9624 DGB9625	4-7 4-7 4-7 4-7 4-7 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8 4-8	DGB9234 DGB9235 DGB9236 DGB9334 DGB9335 DGB9336 DGB9434 DGB9435 DGB9436 DGB9534 DGB9535	4-9 4-9 4-9 4-9 4-9 4-9 4-9 4-9 4-9 4-9 4-9	DGB9244 DGB9245 DGB9246 DGB9344 DGB9345 DGB9346 DGB9444 DGB9445 DGB9446 DGB9544 DGB9545 DGB9546	4-10 4-10 4-10 4-10 4-10 4-10 4-10 4-10 4-10 4-10 4-10 4-10	DGB9254 DGB9255 DGB9256 DGB9354 DGB9355 DGB9356	4-11 4-11 4-11 4-11 4-11 4-11				

Quick Reference List: Gunn Diodes, Gunn Oscillators and Motion Detectors

Frequency Band	C Band 4–8.2 GHz		X Band 8.2–12.4 GHz		Ku Band 12.4–18 GHz		K Band 18–26.5 GHz		Ka Band 26.5–40 GHz		U Band 40–60 GHz		V & W Bands 60–100 GHz	
Category or Application	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page
Parametric Amplifier Pump Gunn Diodes									DGB8454	4-10	DGB8466	4-11		
									DGB8455	4-10	DGB8566	4-11		
									DGB8456	4-10	DGB8666	4-11		
									DGB8554	4-10	DGB8766	4-11		
									DGB8555	4-10				
									DGB8556	4-10				
									DGB8654	4-11				
									DGB8655	4-11				
									DGB8656	4-11				
									DGB8754	4-11				
									DGB8755	4-11				
									DGB8756	4-11				
Local Oscillator Gunn Diodes	DGB8211	4-5	DGB8081	4-7	DGB8131	4-8	DGB8091	4-9	DGB8054	4-10			DGB8076	4-11
	DGB8212	4-5	DGB8181	4-7	DGB8132	4-8	DGB8094	4-9	DGB8055	4-10			DGB8176	4-11
	DGB8213	4-5	DGB8281	4-7	DGB8133	4-8	DGB8095	4-9	DGB8056	4-10			DGB8276	4-11
	DGB8214	4-5	DGB8381	4-7	DGB8134	4-8	DGB8191	4-9	DGB8154	4-10			DGB8376	4-11
	DGB8215	4-5	DGB8121	4-7	DGB8135	4-8	DGB8194	4-9	DGB8155	4-10				
	DGB8311	4-5	DGB8122	4-7	DGB8231	4-8	DGB8195	4-9	DGB8156	4-10				
	DGB8312	4-5	DGB8123	4-7	DGB8232	4-8	DGB8291	4-9	DGB8254	4-10				
	DGB8313	4-5	DGB8124	4-7	DGB8233	4-8	DGB8294	4-9	DGB8255	4-10				
	DGB8314	4-5	DGB8125	4-7	DGB8234	4-8	DGB8295	4-9	DGB8256	4-10				
	DGB8315	4-5	DGB8221	4-7	DGB8235	4-8	DGB8141	4-9	DGB8354	4-10				
			DGB8222	4-7	DGB8331	4-8	DGB8144	4-9	DGB8355	4-10				
			DGB8223	4-7	DGB8332	4-8	DGB8145	4-9	DGB8356	4-10				
			DGB8224	4-7	DGB8334	4-8	DGB8241	4-9						
			DGB8225	4-7	DGB8335	4-8	DGB8244	4-9						
			DGB8321	4-7			DGB8245	4-9						
			DGB8322	4-7			DGB8344	4-10						
			DGB8323	4-7			DGB8345	4-10						
			DGB8324	4-7			DGB8346	4-10						
			DGB8325	4-7										

Frequency Band	C Band 4–8.2 GHz		X Band 8.2–12.4 GHz		Ku Band 12.4–18 GHz		K Band 18–26.5 GHz		Ka Band 26.5–40 GHz		U Band 40–60 GHz		V & W Bands 60–100 GHz	
Category or Application	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page	Type Number	Page
Communication Transmitter C.W. Gunn Diodes	DGB8612	4-6	DGB8622	4-7	DGB8531	4-8	DGB8544	4-10						
	DGB8613	4-6	DGB8623	4-7	DGB8532	4-8	DGB8545	4-10						
	DGB8614	4-6	DGB8624	4-7	DGB8533	4-8	DGB8546	4-10						
	DGB8615	4-6	DGB8625	4-7	DGB8534	4-8	DGB8644	4-10						
	DGB8712	4-6	DGB8722	4-7	DGB8535	4-8	DGB8645	4-10						
	DGB8713	4-6	DGB8723	4-7	DGB8632	4-9	DGB8646	4-10						
	DGB8714	4-6	DGB8724	4-7	DGB8633	4-9	DGB8744	4-10						
	DGB8715	4-6	DGB8725	4-7	DGB8634	4-9	DGB8745	4-10						
	DGB8812	4-6	DGB8822	4-7	DGB8635	4-9								
	DGB8813	4-6	DGB8823	4-7	DGB8732	4-9								
	DGB8912	4-6	DGB8922	4-7	DGB8733	4-9								
	DGB8913	4-6	DGB8923	4-7	DGB8734	4-9								
	DGB8012	4-6	DGB8082	4-7	DGB8735	4-9								
	DGB8013	4-6	DGB8083	4-7	DGB8832	4-9								
	DGB8112	4-6	DGB8982	4-7	DGB8833	4-9								
	DGB8113	4-6	DGB8983	4-7	DGB8834	4-9								
					DGB8835	4-9								
					DGB8932	4-9								
					DGB8933	4-9								
					DGB8934	4-9								
					DGB8935	4-9								
Millimeter Wave Communications Transmitter Gunn Diodes									DGB8454	4-10	DGB8366	4-11		
									DGB8455	4-10	DGB8466	4-11		
									DGB8456	4-10	DGB8566	4-11		
									DGB8554	4-10	DGB8666	4-11		
									DGB8555	4-10	DGB8766	4-11		
									DGB8556	4-10				
									DGB8654	4-11				
									DGB8655	4-11				
									DGB8656	4-11				
									DGB8754	4-11				
									DGB8755	4-11				
									DGB8756	4-11				
Pulsed Transmitter Gunn Diodes	Inquire		Inquire		Inquire		Inquire		Inquire		Inquire		Inquire	

Features



- Spot Frequency or Wideband Operation
- Choice of Package Styles
- Range of Microwave Power Outputs
- Specific Types for Low Cost Commercial Applications
- High Reliability
- Special Screening to Customer Requirements Available

Description

Gunn devices are solid state components which are used to generate energy at microwave frequencies from a DC power input.

Alpha Gunn diodes are produced from epitaxial gallium arsenide grown in Alpha's own in-house epitaxy facility. This sheet describes both the performance of low power, low cost devices suitable for high volume commercial applications as well as high power diodes. Devices for the lowest power applications are produced in a nonflip configuration; that is with the active layer uppermost in the package, requiring the heat sink to be biased as the anode. A flip device construction is used for the higher power diodes in which the active layer is bonded close to the package heat sink for optimum thermal performance. Such devices require the heat sink to be biased as the cathode.

The tables below list standard device types with performance data applicable to their operation in Alpha critically coupled test cavities. To accommodate alternative requirements, special devices may also be manufactured and tested against other specifications in customer supplied cavities. Please inquire.

C.W. GUNN DEVICES FOR C-BAND (5-8.2 GHz)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB8211	5–8.2	20	150	12	Cathode	023-001
DGB8212	5–8.2	20	150	12	Cathode	158-001
DGB8213	5–8.2	20	150	12	Cathode	188-001
DGB8214	5–8.2	20	150	12	Cathode	315-001
DGB8215	5–8.2	20	150	12	Cathode	305-001
DGB8311	5–8.2	50	200	12	Cathode	023-001
DGB8312	5–8.2	50	200	12	Cathode	158-001
DGB8313	5–8.2	50	200	12	Cathode	188-001
DGB8314	5–8.2	50	200	12	Cathode	315-001
DGB8315	5–8.2	50	200	12	Cathode	305-001
DGB8411	5–8.2	100	300	12	Cathode	023-001
DGB8412	5–8.2	100	300	12	Cathode	158-001
DGB8413	5–8.2	100	300	12	Cathode	188-001
DGB8414	5–8.2	100	300	12	Cathode	315-001
DGB8415	5–8.2	100	300	12	Cathode	305-001
DGB8511	5–8.2	200	500	12	Cathode	023-001
DGB8512	5–8.2	200	500	12	Cathode	158-001
DGB8513	5–8.2	200	500	12	Cathode	188-001
DGB8514	5–8.2	200	500	12	Cathode	315-001
DGB8515	5–8.2	200	500	12	Cathode	305-001

C.W. GUNN DEVICES FOR C-BAND (5-8.2 GHz) (cont.)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB8612	5–8.2	300	700	12	Cathode	158-001
DGB8613	5–8.2	300	700	12	Cathode	188-001
DGB8614	5–8.2	300	700	12	Cathode	315-001
DGB8615	5–8.2	300	700	12	Cathode	305-001
DGB8712	5–8.2	400	900	12	Cathode	158-001
DGB8713	5–8.2	400	900	12	Cathode	188-001
DGB8714	5–8.2	400	900	12	Cathode	315-001
DGB8715	5–8.2	400	900	12	Cathode	305-001
DGB8812	5–8.2	500	1100	12	Cathode	158-001
DGB8813	5–8.2	500	1100	12	Cathode	188-001
DGB8912	5–8.2	600	1250	12	Cathode	158-001
DGB8913	5–8.2	600	1250	12	Cathode	188-001
DGB8012	5–8.2	700	1450	12	Cathode	158-001
DGB8013	5–8.2	700	1450	12	Cathode	188-001
DGB8112	5–8.2	800	1650	12	Cathode	158-001
DGB8113	5–8.2	800	1650	12	Cathode	188-001
DGB9211	FULLBAND 5–8.2	20	250	9–17	Cathode	023-001
DGB9212	FULLBAND 5–8.2	20	250	9–17	Cathode	158-001
DGB9213	FULLBAND 5–8.2	20	250	9–17	Cathode	188-001
DGB9214	FULLBAND 5–8.2	20	250	9–17	Cathode	315-001
DGB9215	FULLBAND 5–8.2	20	250	9–17	Cathode	305-001
DGB9311	FULLBAND 5–8.2	50	350	9–17	Cathode	023-001
DGB9312	FULLBAND 5–8.2	50	350	9–17	Cathode	158-001
DGB9313	FULLBAND 5–8.2	50	350	9–17	Cathode	188-001
DGB9314	FULLBAND 5–8.2	50	350	9–17	Cathode	315-001
DGB9315	FULLBAND 5–8.2	50	350	9–17	Cathode	305-001
DGB9411	FULLBAND 5–8.2	100	500	9–17	Cathode	023-001
DGB9412	FULLBAND 5–8.2	100	500	9–17	Cathode	158-001
DGB9413	FULLBAND 5–8.2	100	500	9–17	Cathode	188-001
DGB9414	FULLBAND 5–8.2	100	500	9–17	Cathode	315-001
DGB9415	FULLBAND 5–8.2	100	500	9–17	Cathode	305-001
DGB9512	FULLBAND 5–8.2	200	900	9–17	Cathode	158-001
DGB9513	FULLBAND 5–8.2	200	900	9–17	Cathode	188-001
DGB9514	FULLBAND 5–8.2	200	900	9–17	Cathode	315-001
DGB9515	FULLBAND 5–8.2	200	900	9–17	Cathode	305-001
DGB9612	FULLBAND 5–8.2	300	1200	9–17	Cathode	158-001
DGB9613	FULLBAND 5–8.2	300	1200	9–17	Cathode	188-001

C.W. GUNN DEVICES FOR X-BAND (8.2-12.4 GHz)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB8081	9.3–10.9	5	40	8	Anode	023-001
DGB8181	9.3–10.9	10	80	8	Anode	023-001
DGB8281	9.3–10.9	20	110	8	Anode	023-001
DGB8381	8.2–12.4	30	140	8	Anode	023-001
DGB8121	8.2–9.3 & 10.9–12.4	10	80	8	Anode	023-001
DGB8122	8.2–12.4	10	80	8	Anode	158-001
DGB8123	8.2–12.4	10	80	8	Anode	188-001
DGB8124	8.2–12.4	10	80	8	Anode	315-001
DGB8125	8.2–12.4	10	80	8	Anode	305-001
DGB8221	8.2–9.3 & 10.9–12.4	20	110	8	Anode	023-001
DGB8222	8.2–12.4	20	110	8	Anode	158-001
DGB8223	8.2–12.4	20	110	8	Anode	188-001
DGB8224	8.2–12.4	20	110	8	Anode	315-001
DGB8225	8.2–12.4	20	110	8	Anode	305-001
DGB8321	8.2–12.4	50	200	10	Cathode	023-001
DGB8322	8.2–12.4	50	200	10	Cathode	158-001
DGB8323	8.2–12.4	50	200	10	Cathode	188-001
DGB8324	8.2–12.4	50	200	10	Cathode	315-001
DGB8325	8.2–12.4	50	200	10	Cathode	305-001
DGB8421	8.2–12.4	100	300	10	Cathode	023-001
DGB8422	8.2–12.4	100	300	10	Cathode	158-001
DGB8423	8.2–12.4	100	300	10	Cathode	188-001
DGB8424	8.2–12.4	100	300	10	Cathode	315-001
DGB8425	8.2–12.4	100	300	10	Cathode	305-001
DGB8521	8.2–12.4	200	600	10	Cathode	023-001
DGB8522	8.2–12.4	200	600	10	Cathode	158-001
DGB8523	8.2–12.4	200	600	10	Cathode	188-001
DGB8524	8.2–12.4	200	600	10	Cathode	315-001
DGB8525	8.2–12.4	200	600	10	Cathode	305-001
DGB8622	8.2–12.4	300	800	10	Cathode	158-001
DGB8623	8.2–12.4	300	800	10	Cathode	188-001
DGB8624	8.2–12.4	300	800	10	Cathode	315-001
DGB8625	8.2–12.4	300	800	10	Cathode	305-001
DGB8722	8.2–12.4	400	1050	10	Cathode	158-001
DGB8723	8.2–12.4	400	1050	10	Cathode	188-001
DGB8724	8.2–12.4	400	1050	10	Cathode	315-001
DGB8725	8.2–12.4	400	1050	10	Cathode	305-001
DGB8822	8.2–12.4	500	1300	10	Cathode	158-001
DGB8823	8.2–12.4	500	1300	10	Cathode	188-001
DGB8922	8.2–12.4	600	1550	10	Cathode	158-001
DGB8923	8.2–12.4	600	1550	10	Cathode	188-001
DGB8082	8.2–12.4	700	1750	10	Cathode	158-001
DGB8083	8.2–12.4	700	1750	10	Cathode	188-001
DGB8982	8.2–11.0	800	1850	10	Cathode	158-001
DGB8983	8.2–11.0	800	1850	10	Cathode	188-001
DGB9221	FULLBAND 8.2–12.4	20	300	7–14	Cathode	023-001
DGB9222	FULLBAND 8.2–12.4	20	300	7–14	Cathode	158-001
DGB9223	FULLBAND 8.2–12.4	20	300	7–14	Cathode	188-001
DGB9224	FULLBAND 8.2–12.4	20	300	7–14	Cathode	315-001
DGB9225	FULLBAND 8.2–12.4	20	300	7–14	Cathode	305-001

C.W. GUNN DEVICES FOR X-BAND (8.2-12.4 GHz) (cont.)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB9321	FULLBAND 8.2–12.4	50	450	7–14	Cathode	023-001
DGB9322	FULLBAND 8.2–12.4	50	450	7–14	Cathode	158-001
DGB9323	FULLBAND 8.2–12.4	50	450	7–14	Cathode	188-001
DGB9324	FULLBAND 8.2–12.4	50	450	7–14	Cathode	315-001
DGB9325	FULLBAND 8.2–12.4	50	450	7–14	Cathode	305-001
DGB9421	FULLBAND 8.2–12.4	100	600	7–14	Cathode	023-001
DGB9422	FULLBAND 8.2–12.4	100	600	7–14	Cathode	158-001
DGB9423	FULLBAND 8.2–12.4	100	600	7–14	Cathode	188-001
DGB9424	FULLBAND 8.2–12.4	100	600	7–14	Cathode	315-001
DGB9425	FULLBAND 8.2–12.4	100	600	7–14	Cathode	305-001
DGB9522	FULLBAND 8.2–12.4	200	1050	7–14	Cathode	158-001
DGB9523	FULLBAND 8.2–12.4	200	1050	7–14	Cathode	188-001
DGB9524	FULLBAND 8.2–12.4	200	1050	7–14	Cathode	315-001
DGB9525	FULLBAND 8.2–12.4	200	1050	7–14	Cathode	305-001
DGB9622	FULLBAND 8.2–12.4	300	1250	7–14	Cathode	158-001
DGB9623	FULLBAND 8.2–12.4	300	1250	7–14	Cathode	188-001
DGB9624	FULLBAND 8.2–12.4	300	1250	7–14	Cathode	315-001
DGB9625	FULLBAND 8.2–12.4	300	1250	7–14	Cathode	305-001

C.W. GUNN DEVICES FOR Ku-BAND (12.4-18 GHz)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB8131	12.4–18	10	95	7	Anode	023-001
DGB8132	12.4–16	10	95	7	Anode	158-001
DGB8133	12.4–16	10	95	7	Anode	188-001
DGB8134	12.4–18	10	95	7	Anode	315-001
DGB8135	12.4–18	10	95	7	Anode	305-001
DGB8231	12.4–18	20	125	7	Anode	023-001
DGB8232	12.4–16	20	125	7	Anode	158-001
DGB8233	12.4–16	20	125	7	Anode	188-001
DGB8234	12.4–18	20	125	7	Anode	315-001
DGB8235	12.4–18	20	125	7	Anode	305-001
DGB8331	12.4–18	50	260	8	Cathode	023-001
DGB8332	12.4–16	50	260	8	Cathode	158-001
DGB8333	12.4–16	50	260	8	Cathode	188-001
DGB8334	12.4–18	50	260	8	Cathode	315-001
DGB8335	12.4–18	50	260	8	Cathode	305-001
DGB8431	12.4–18	100	400	8	Cathode	023-001
DGB8432	12.4–16	100	400	8	Cathode	158-001
DGB8433	12.4–16	100	400	8	Cathode	188-001
DGB8434	12.4–18	100	400	8	Cathode	315-001
DGB8435	12.4–18	100	400	8	Cathode	305-001
DGB8531	12.4–18	200	700	8	Cathode	023-001
DGB8532	12.4–16	200	700	8	Cathode	158-001
DGB8533	12.4–16	200	700	8	Cathode	188-001
DGB8534	12.4–18	200	700	8	Cathode	315-001
DGB8535	12.4–18	200	700	8	Cathode	305-001

C.W. GUNN DEVICES FOR Ku-BAND (12.4-18 GHz) (cont.)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB8632	12.4–16	300	1000	8	Cathode	158-001
DGB8633	12.4–16	300	1000	8	Cathode	188-001
DGB8634	12.4–18	300	1000	8	Cathode	315-001
DGB8635	12.4–18	300	1000	8	Cathode	305-001
DGB8732	12.4–16	400	1300	8	Cathode	158-001
DGB8733	12.4–16	400	1300	8	Cathode	188-001
DGB8734	12.4–18	400	1300	8	Cathode	315-001
DGB8735	12.4–18	400	1300	8	Cathode	305-001
DGB8832	12.4–16	500	1550	8	Cathode	158-001
DGB8833	12.4–16	500	1550	8	Cathode	188-001
DGB8834	12.4–18	500	1550	8	Cathode	315-001
DGB8835	12.4–18	500	1550	8	Cathode	305-001
DGB8932	12.4–15	600	1750	8	Cathode	158-001
DGB8933	12.4–15	600	1750	8	Cathode	188-001
DGB8934	12.4–15	600	1750	8	Cathode	315-001
DGB8935	12.4–15	600	1750	8	Cathode	305-001
DGB9234	FULLBAND 12.4–18	20	360	6–12	Cathode	315-001
DGB9235	FULLBAND 12.4–18	20	360	6–12	Cathode	305-001
DGB9236	FULLBAND 12.4–18	20	360	6–12	Cathode	296-001
DGB9334	FULLBAND 12.4–18	50	520	6–12	Cathode	315-001
DGB9335	FULLBAND 12.4–18	50	520	6–12	Cathode	305-001
DGB9336	FULLBAND 12.4–18	50	520	6–12	Cathode	296-001
DGB9434	FULLBAND 12.4–18	100	720	6–12	Cathode	315-001
DGB9435	FULLBAND 12.4–18	100	720	6–12	Cathode	305-001
DGB9436	FULLBAND 12.4–18	100	720	6–12	Cathode	296-001
DGB9534	FULLBAND 12.4–18	200	1050	6–12	Cathode	315-001
DGB9535	FULLBAND 12.4–18	200	1050	6–12	Cathode	305-001

C.W. GUNN DEVICES FOR K-BAND (18-26.5 GHz)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB8091	23.5–24.5	5	70	5	Anode	023-001
DGB8094	23.5–24.5	5	70	5	Anode	315-001
DGB8095	23.5–24.5	5	70	5	Anode	305-001
DGB8191	23.5–24.5	10	110	5	Anode	023-001
DGB8194	23.5–24.5	10	110	5	Anode	315-001
DGB8195	23.5–24.5	10	110	5	Anode	305-001
DGB8291	23.5–24.5	20	175	5	Anode	023-001
DGB8294	23.5–24.5	20	175	5	Anode	315-001
DGB8295	23.5–24.5	20	175	5	Anode	305-001
DGB8141	18–23.5 & 24.5-26.5	10	120	5	Anode	023-001
DGB8144	18–23.5 & 24.5-26.5	10	120	5	Anode	315-001
DGB8145	18–23.5 & 24.5-26.5	10	120	5	Anode	305-001
DGB8241	18–23.5 & 24.5-26.5	20	185	5	Anode	023-001
DGB8244	18–23.5 & 24.5-26.5	20	185	5	Anode	315-001
DGB8245	18–23.5 & 24.5-26.5	20	185	5	Anode	305-001

Gunn Diodes

C.W. GUNN DEVICES FOR K-BAND (18-26.5 GHz) (cont.)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB8344	18–26.5	50	300	6	Cathode	315-001
DGB8345	18–26.5	50	300	6	Cathode	305-001
DGB8346	18–26.5	50	300	6	Cathode	296-001
DGB8444	18–26.5	100	550	6	Cathode	315-001
DGB8445	18–26.5	100	550	6	Cathode	305-001
DGB8446	18–26.5	100	550	6	Cathode	296-001
DGB8544	18–26.5	200	900	6	Cathode	315-001
DGB8545	18–26.5	200	900	6	Cathode	305-001
DGB8546	18–26.5	200	900	6	Cathode	296-001
DGB8644	18–26.5	300	1250	6	Cathode	315-001
DGB8645	18–26.5	300	1250	6	Cathode	305-001
DGB8646	18–26.5	300	1250	6	Cathode	296-001
DGB8744	18–26.5	400	1600	6	Cathode	315-001
DGB8745	18–26.5	400	1600	6	Cathode	305-001
DGB9244	FULLBAND 18–26.5	20	400	4–8	Cathode	315-001
DGB9245	FULLBAND 18–26.5	20	400	4–8	Cathode	305-001
DGB9246	FULLBAND 18–26.5	20	400	4–8	Cathode	296-001
DGB9344	FULLBAND 18–26.5	50	600	4–8	Cathode	315-001
DGB9345	FULLBAND 18–26.5	50	600	4–8	Cathode	305-001
DGB9346	FULLBAND 18–26.5	50	600	4–8	Cathode	296-001
DGB9444	FULLBAND 18–26.5	100	950	4–8	Cathode	315-001
DGB9445	FULLBAND 18–26.5	100	950	4–8	Cathode	305-001
DGB9446	FULLBAND 18–26.5	100	950	4–8	Cathode	296-001
DGB9544	FULLBAND 18–26.5	200	1250	4–8	Cathode	315-001
DGB9545	FULLBAND 18–26.5	200	1250	4–8	Cathode	305-001
DGB9546	FULLBAND 18–26.5	200	1250	4–8	Cathode	296-001

C.W. GUNN DEVICES FOR Ka-BAND (26.5-40 GHz)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB8054	26.5–40	5	100	4	Anode	315-001
DGB8055	26.5–40	5	100	4	Anode	305-001
DGB8056	26.5–40	5	100	4	Anode	296-001
DGB8154	26.5–40	10	175	4	Anode	315-001
DGB8155	26.5–40	10	175	4	Anode	305-001
DGB8156	26.5–40	10	175	4	Anode	296-001
DGB8254	26.5–40	20	280	5	Cathode	315-001
DGB8255	26.5–40	20	280	5	Cathode	305-001
DGB8256	26.5–40	20	280	5	Cathode	296-001
DGB8354	26.5–35	50	380	5	Cathode	315-001
DGB8355	26.5–35	50	380	5	Cathode	305-001
DGB8356	26.5–40	50	380	5	Cathode	296-001
DGB8454	26.5–35	100	650	5	Cathode	315-001
DGB8455	26.5–35	100	650	5	Cathode	305-001
DGB8456	26.5–40	100	650	5	Cathode	296-001
DGB8554	26.5–35	150	950	5	Cathode	315-001
DGB8555	26.5–35	150	950	5	Cathode	305-001
DGB8556	26.5–40	150	950	5	Cathode	296-001

C.W. GUNN DEVICES FOR Ka-BAND (26.5-40 GHz) (cont.)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB8654	26.5–35	200	1300	5	Cathode	315-001
DGB8655	26.5–35	200	1300	5	Cathode	305-001
DGB8656	26.5–40	200	1300	5	Cathode	296-001
DGB8754	26.5–35	225	1400	5	Cathode	315-001
DGB8755	26.5–35	225	1400	5	Cathode	305-001
DGB8756	26.5–40	225	1400	5	Cathode	296-001
DGB9254	FULLBAND 26.5–35	20	500	4–7	Cathode	315-001
DGB9255	FULLBAND 26.5–35	20	500	4–7	Cathode	305-001
DGB9256	FULLBAND 26.5–40	20	500	4–7	Cathode	296-001
DGB9354	FULLBAND 26.5–35	50	800	4–7	Cathode	315-001
DGB9355	FULLBAND 26.5–35	50	800	4–7	Cathode	305-001
DGB9356	FULLBAND 26.5–40	50	800	4–7	Cathode	296-001

C.W. GUNN DEVICES FOR U-BAND (40-60 GHz)

Type	Specified Frequency[1] (GHz)	Min. C.W. Output[2 3] (mW)	Operating Current Typical (mA)	Operating Voltage Typical (V)	Heat Sink Polarity[5]	Package Style[4]
DGB8064	40–50	5	140	3	Anode	315-001
DGB8065	40–50	5	140	3	Anode	305-001
DGB8066	40–60	5	140	3	Anode	296-001
DGB8164	40–50	10	250	3	Anode	315-001
DGB8165	40–50	10	250	3	Anode	305-001
DGB8166	40–60	10	250	3	Anode	296-001
DGB8266	40–60	20	400	4	Cathode	296-001
DGB8366	40–60	50	600	4	Cathode	296-001
DGB8466	40–50	75	750	4	Cathode	296-001
DGB8566	40–50	100	950	4	Cathode	296-001
DGB8666	40–50	125	1100	4	Cathode	296-001
DGB8766	40–50	150	1300	4	Cathode	296-001

C.W. devices for 60–100 GHz are available. Consult the factory for your specific requirement. For example:

DGB8076	94GHz	5	600	4	Cathode	296-001
DGB8176	94GHz	10	750	4	Cathode	296-001
DGB8276	94GHz	15	900	4	Cathode	296-001
DGB8376	94GHz	20	950	4	Cathode	296-001

Notes:
1. The required operating frequency (or in the case of wide band types, the frequency range) must be specified when ordering. The specification of any unnecessarily wide frequency range will result in unnecessary expenditure.
2. The power output is measured at a single frequency (except for wide band units) in a critically coupled Alpha test cavity at 25°C. Alpha may agree to undertake special testing in a customer cavity if required.
3. The standard catalog range of Alpha Gunn devices are tested under C.W. conditions. For certain pulse applications, alternative device types are available. Consult the factory.
4. Alternative package styles are available and should be requested as specials at the time of ordering.
5. Devices with cathode heat sink are burned in for 24 hours as standard.

Absolute Maximum Ratings

Operating Temperature
−40°C to +85°C for standard types
Storage Temperature
−55°C to +100°C
Operating Voltage
Each diode is individually rated by Alpha with respect to operating voltage. Application of bias voltage in excess of this value may lead to a degradation in performance.

Gunn Device Packages

Several different package types are offered to suit different requirements.

Thermal Resistance. In general, unless the package heat sink is to be soldered into position, the lowest thermal resistance is offered by the package styles which incorporate threaded heat sink. However, for lower power applications and particularly where product assembly time must be minimized, a package with a plain pin heat sink such as the 023-001 will be preferred.

Frequency Band. Each package style necessarily incorporates certain parasitic reactances (see Figure 1). In general, the magnitude of these reactances is reduced with the choice of a smaller package type. Hence the more robust, larger, package styles are normally specified for operation in the lower frequency bands. The smaller, lower parasitic reactance types are used for the higher frequency bands.

Magnetically Tuned Circuits. For applications involving YIG tuned oscillators the user should bear in mind that the package types 023-001, 158-001, and 188-001 have Kovar in their construction. These are therefore not suitable for YIG tuned oscillator applications.

Application Notes

Gunn devices act as converters of DC to microwave energy using the negative resistance characteristics of bulk gallium arsenide. The cavities in which these devices are operated often appear deceptively simple. It should be the aim of the cavity designer not merely to design a cavity which enables the Gunn device to operate to the designer's specifications, but the designer should also aim to produce a cavity which will operate just as successfully with other devices from the same manufacturing batch and indeed other batches of devices. Generally, most oscillators are best designed with some sort of adjustable matching element to facilitate this. Successful Gunn oscillator designs require the understanding of device operation and microwave circuit theory, together with experience and a willingness to experiment. For example, the negative resistance of a Gunn device is not restricted to a single frequency, but exists over a band of frequencies when a suitable bias voltage is applied. These devices are therefore capable of producing oscillations in the bias circuit in the VHF range which are normally suppressed by a suitable choice of bias line impedance. Normally a relatively low impedance quasi constant voltage source is used together with a capacitor (typically 0.047 µF) connected directly across the terminal of the microwave cavity from the bias line to cavity ground. The design of the microwave circuit can significantly affect the susceptibility of a unit to bias circuit oscillations and also significantly influence the diode turn on voltage. (The turn on voltage $V_{t.o.}$ is the voltage at which the device produces single frequency microwave power free from bias circuit oscillations and at a frequency which can be pushed without discontinuity to the operating frequency at the operating voltage V_{op} merely by increasing the bias from $V_{t.o.}$ to V_{op}.)

As shown in Figure 2, at the threshold voltage the current drain is at a maximum. Typically, the threshold current I_{th} may be expected to be 30% more than the operating current I_{op}. In addition, both I_{th} and I_{op} increase as the temperature is decreased and therefore power supplies should be designed with this in mind. It is also desirable that the Gunn oscillator power supply should have a low ripple content, particularly if the application requires the oscillator to have good noise performance. Power supply ripple will, in general, degrade the inherent AM and FM noise performance of the Gunn oscillator.

Care must be taken to ensure that the packaged diodes are provided with an adequate heat sink so that the temperature rise of the package above the heat sink is limited to only a few °C.

The equivalent circuit of the packaged diode is shown in Figure 1. The Gunn device chip may be represented as a negative resistance in parallel with a capacitance and a small positive resistance in series with these. Additionally, when incorporated into a package structure of whatever type, a series inductance and a parallel capacitative reactance are introduced. In general, the magnitude of these parasitic reactances is reduced with the choice of a smaller package. Hence, although the larger package types are offered in the lower frequency bands, higher frequency diodes are only available in the smaller lower parasitic reactance packages.

Typical curves showing the general characteristics of Gunn devices operated in various cavities and at various frequencies are shown in Figures 2 to 8.

Gunn Oscillators

Alpha's Semiconductor Division also designs and manufactures a range of oscillator products incorporating Alpha Gunn devices.

Standard products include fixed frequency and tuneable oscillators and modules designed for use in microwave motion detection systems.

Inquiries are also invited for oscillator products not in our standard range.

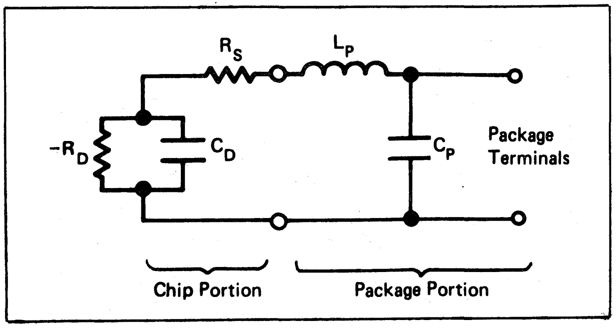


Figure 1. Equivalent Circuit of Packaged Gunn Diode

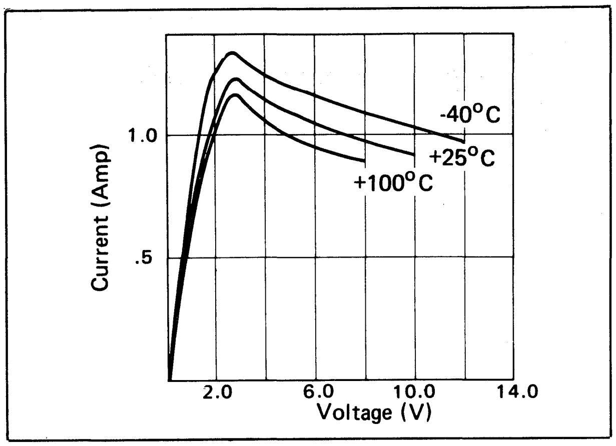


Figure 2. DC I-V Characteristic at Different Temperatures (Ambient)

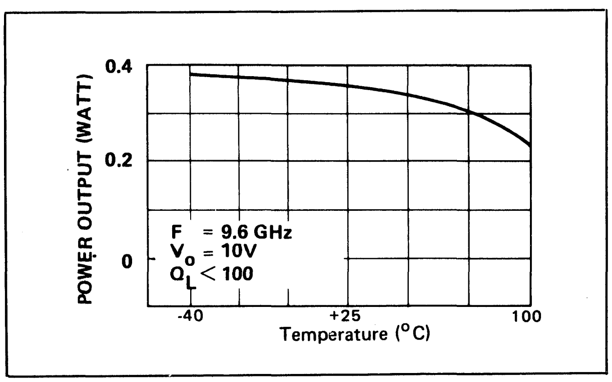


Figure 3. Power Output vs. Temperature (Ambient) at a Fixed Bias

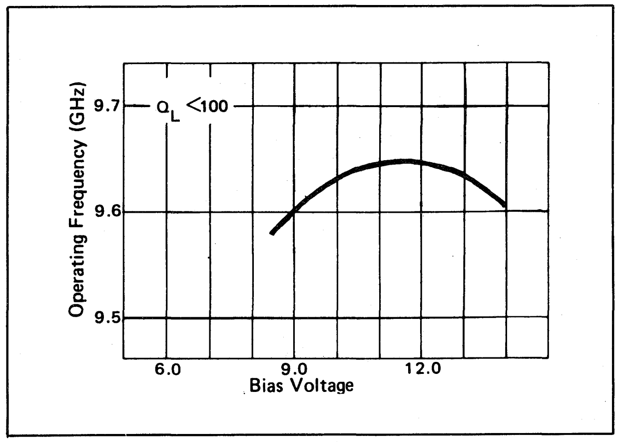


Figure 4. Frequency Pushing vs. Bias Voltage

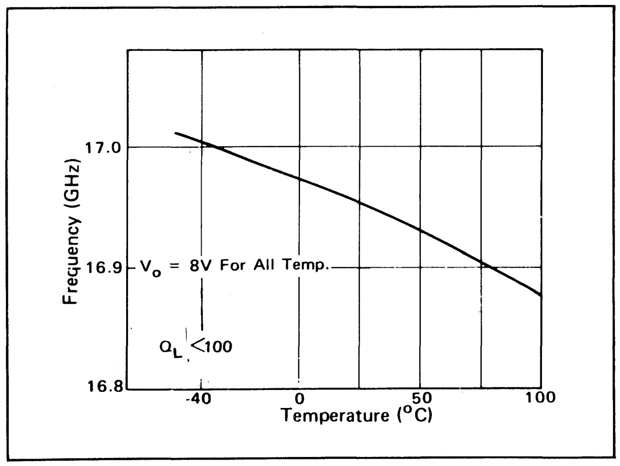


Figure 5. Frequency Drift vs. Temperature (Ambient)

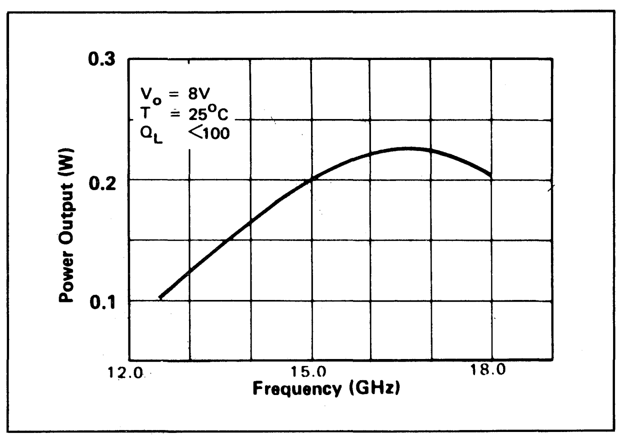


Figure 6. Power Output vs. Frequency

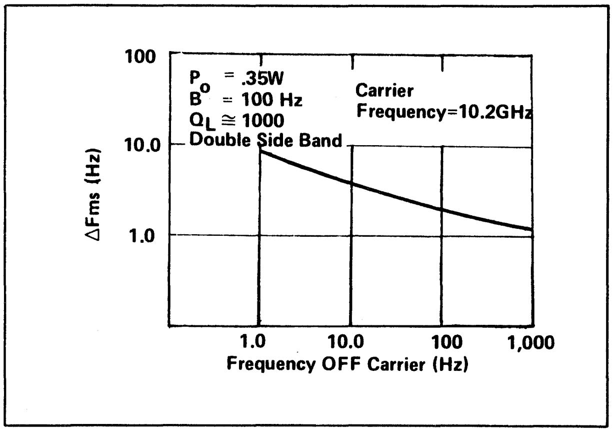


Figure 7. FM Noise vs. Frequency

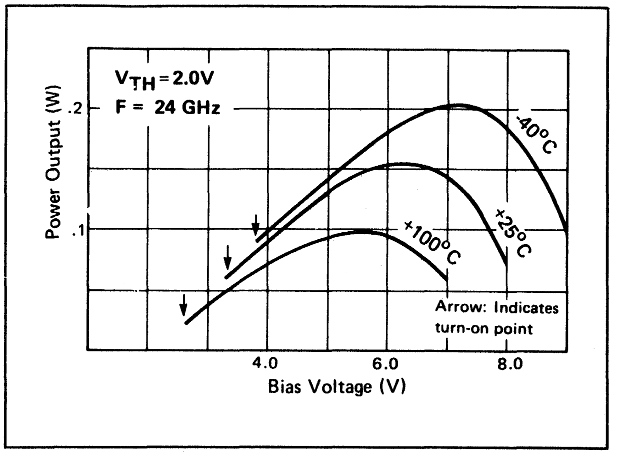
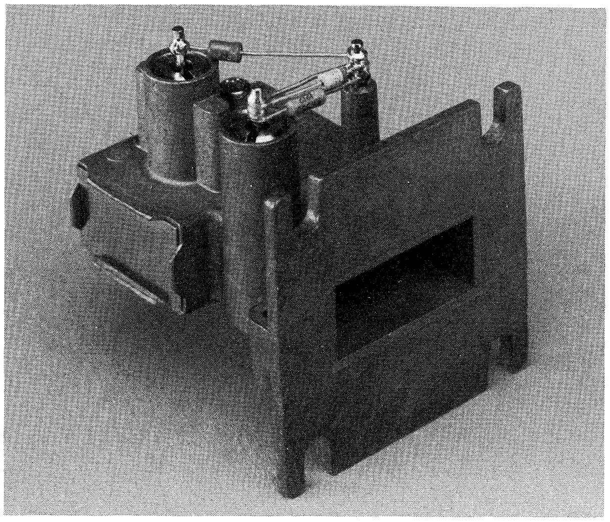


Figure 8. Output Power vs. Bias Voltage at Different Temperatures (Ambient)

C. W. Motion Detector Module

Features

- Low Cost
- High Reliability
- High Sensitivity
- Designed to Meet FCC Regulations
- Low Voltage Operation
- Low Current



Type

- GOS2580

Description

The Alpha Industries Type GOS2580 Motion Detector Module is a microwave transmit and receive unit which is designed for motion sensing and speed measurement applications. Through the use of the Doppler shift principle, an audio output is obtained whose frequency is proportional to the velocity of the target towards or away from the module.

The module features both low cost and high reliability construction.

The Type GOS2580 Motion Detector Module incorporates an Alpha Industries Gunn diode mounted in a waveguide cavity which acts as the transmitter and local oscillator, together with an Alpha Schottky barrier mixer diode for the receiver.

This module is designed to meet FCC requirements.

Applications

The Alpha Industries Type GOS2580 Motion Detector Module is designed for application in the fields of motion detection and speed sensing including:

- Intrusion Alarms
- Automatic Door Openers
- Speed and Rotation Measurement Systems
- Obstruction Warning Systems
- Contactless Vibration Measurement
- Counting/Process Control
- Traffic Signal Actuators
- Automatic Illumination Systems

Electrical Characteristics at 25°C

TRANSMITTER

Frequency .... fixed, in range 9.47–10.7 GHz
Power Output .... 5mW Min. 10.4–10.7 GHz
4mW Min. 9.47–10.4 GHz
Operating Voltage .... +8V (Cavity ground negative)
Operating Current .... 80mA Typical

U.S.A. operation 10.525 GHz — The module is designed to meet FCC regulations in respect of frequency, power output, frequency stability, harmonic and spurious emissions.

Other countries — Special versions exist for operation at frequencies in the range 9.47 – 10.7 GHz to meet alternative frequency allocation requirements.

RECEIVER

The receiver sensitivity will depend upon the IF bandwidth chosen.

Sensitivity in an IF Bandwidth 1 Hz to 10 KHz .... – 100 dBc Typical
Noise for an IF Bandwidth 1 Hz to 10 KHz .... 10 µV Max.

ENVIRONMENTAL CHARACTERISTICS

Operating Temperature Range .... – 40 to + 70°C

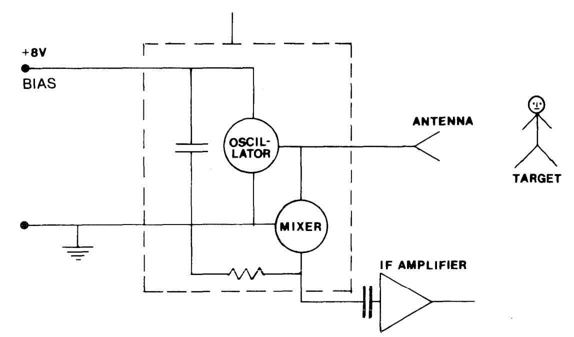
The module is unaffected by the presence of magnetic fields.

C. W. Motion Detector Module

MECHANICAL CHARACTERISTICS

Transmitter Bias Input Connector .... Solder pin
Receiver IF Output Connector .... Solder pin
Microwave Output .... Mates with standard UG39/U style flanges.

GOS 2580 Operational Schematic

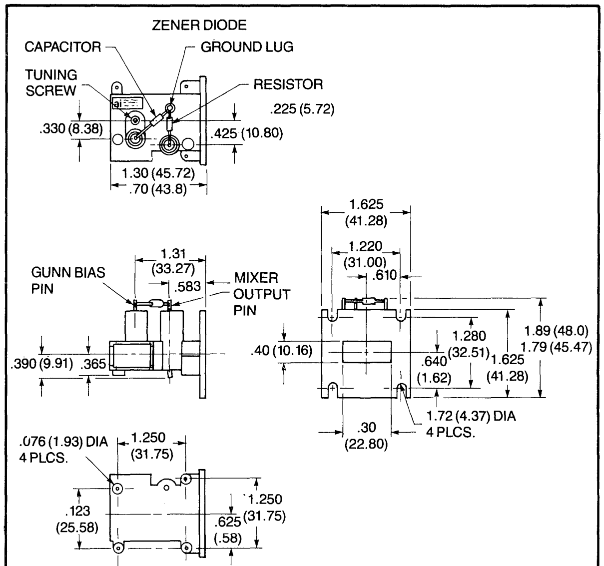


Microwave Motion Detector Module

Notes:

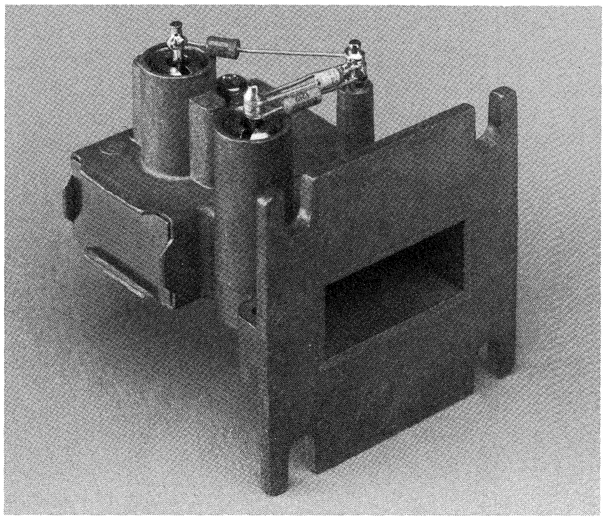
1. The module is supplied with a capacitor fitted between the Gunn bias terminal and ground to suppress bias circuit oscillations.
2. The mixer output terminal is fitted with a 12KΩ load resistor. This module has been designed to feed an IF amplifier system incorporating a D.C. blocking capacitor.
3. The module is supplied with a shorting link across the mixer to protect it from the effects of static charge. This shorting link should be left in position until after all wiring assembly work is complete.
4. For a transmitter frequency of 10.525 GHz the Doppler frequency obtained is 31.39 Hz for each mile per hour of radial velocity (i.e., velocity towards or away from the transmitting antenna).
5. The detection range obtained will depend on the size and reflectivity of the target, the signal to noise ratio required and the antenna gain.
6. The motion detector module mates with standard UG39/U flange fittings. Thus, many antenna types may be used with this module. For long range applications, a high gain antenna will be preferred, while for volume protection where a large angular coverage is needed, a low gain antenna will be fitted as required.
   Note that for some applications it may not be necessary to fit a separate antenna.
7. The transmitter frequency is factory preset. The required operating frequency must be specified when ordering.

Outline Drawing



967-001

Low Current Drain C. W. Motion Detector Module



Features

- Very Low Current Drain
- Low Cost
- High Reliability
- High Sensitivity
- Designed to Meet FCC Regulations
- Low Voltage Operation

Type

- GOS2583

Description

The Alpha Industries Type GOS2583 Motion Detector Module is a microwave transmit and receive unit which is designed for motion sensing and speed measurement applications. Through the use of the Doppler shift principle, an audio output is obtained whose frequency is proportional to the velocity of the target towards or away from the module.

The module features both low cost and high reliability construction.

The Type GOS2583 Motion Detector Module incorporates an Alpha Industries Gunn diode mounted in a waveguide cavity which acts as the transmitter and local oscillator, together with an Alpha Schottky barrier mixer diode for the receiver.

This module is designed to meet FCC requirements.

Applications

The Alpha Industries Type GOS2583 Motion Detector Module is designed for application in the fields of motion detection and speed sensing including:

- Intrusion Alarms
- Automatic Door Openers
- Speed and Rotation Measurement Systems
- Obstruction Warning Systems
- Contactless Vibration Measurement
- Counting/Process Control
- Traffic Signal Actuators
- Automatic Illumination Systems

Electrical Characteristics at 25°C

TRANSMITTER

Frequency ....fixed, in range 10.4–10.7 GHz
Power Output .... 2.5mW Min. 10.4–10.7 GHz
Operating Voltage .... + 8V (Cavity ground negative)
Operating Current .... 40mA Typical

U.S.A. operation 10.525 GHz — The module is designed to meet FCC regulations in respect of frequency, power output, frequency stability, harmonic and spurious emissions.

Other countries — Special versions exist for operation at frequencies in the range 10.4 – 10.7 GHz to meet alternative frequency allocation requirements.

RECEIVER

The receiver sensitivity will depend upon the IF bandwidth chosen.

Sensitivity in an IF Bandwidth 1 Hz to 10 KHz .... – 97 dBc Typical
Noise for an IF Bandwidth 1 Hz to 10 KHz .... 10 μV Max.

ENVIRONMENTAL CHARACTERISTICS

Operating Temperature Range .... – 40 to + 70°C

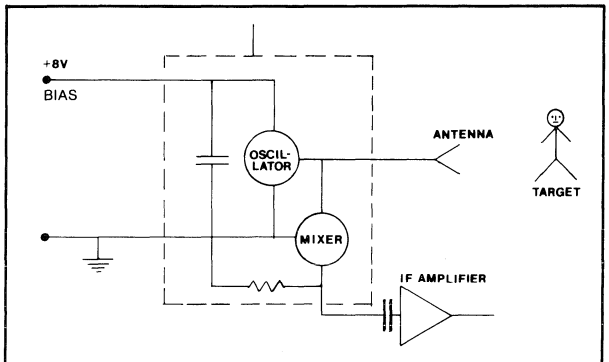
The module is unaffected by the presence of magnetic fields.

Low Current Drain
C.W. Motion Detector Module

MECHANICAL CHARACTERISTICS

Transmitter Bias Input Connector .... Solder pin
Receiver IF Output Connector .... Solder pin
Microwave Output .... Mates with standard UG39/U style flanges.

GOS2583 Operational Schematic

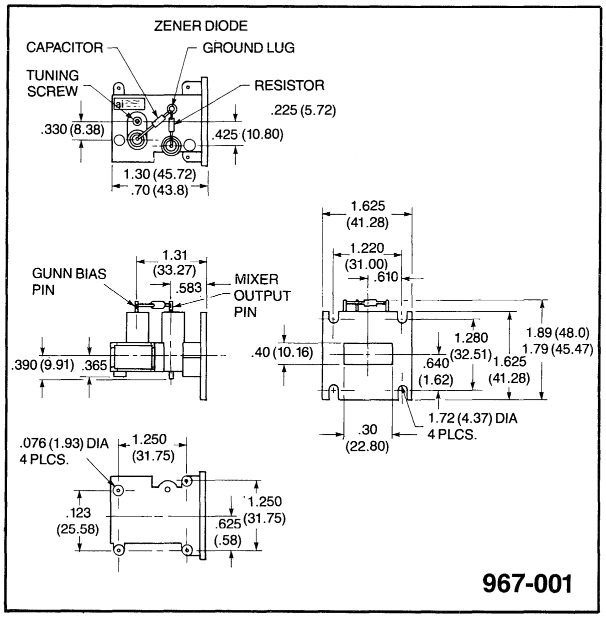


Microwave Motion Detector Module

Notes:

1. The module is supplied with a capacitor fitted between the Gunn bias terminal and ground to suppress bias circuit oscillations.
2. The mixer output terminal is fitted with a 12KΩ load resistor. This module has been designed to feed an IF amplifier system incorporating a D.C. blocking capacitor.
3. The module is supplied with a shorting link across the mixer to protect it from the effects of static charge. This shorting link should be left in position until after all wiring assembly work is complete.
4. For a transmitter frequency of 10.525 GHz the Doppler frequency obtained is 31.39 Hz for each mile per hour of radial velocity (i.e., velocity towards or away from the transmitting antenna).
5. The detection range obtained will depend on the size and reflectivity of the target, the signal to noise ratio required and the antenna gain.
6. The motion detector module mates with standard UG39/U flange fittings. Thus, many antenna types may be used with this module. For long range applications, a high gain antenna will be preferred, while for volume protection where a large angular coverage is needed, a low gain antenna will be fitted as required.
   Note that for some applications it may not be necessary to fit a separate antenna.
7. The transmitter frequency is factory preset. The required operating frequency must be specified when ordering.

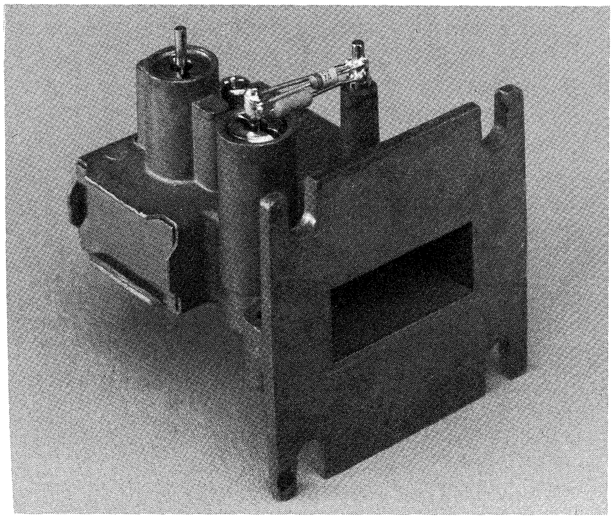
Outline Drawing



Pulsed Motion Detector Modules

Features

- Very Low Average Current Drain
- Low Cost
- High Reliability
- High Sensitivity
- Designed to Meet FCC Regulations
- Low Voltage Operation



Types

- GOS2581
- GOS2579 (with Integral Pulse Modulator)
- GOS2578 (with Integral Pulse Modulator and Signal Processing)

Description

The Alpha Industries Type GOS2581 Pulsed Motion Detector Module is a microwave transmit and receive unit which is designed for motion sensing and speed measurement applications. Through the use of the Doppler shift principle, an audio output is obtained whose frequency is proportional to the velocity of the target towards or away from the module.

The module features both low cost and high reliability construction.

The Type GOS2581 Motion Detector Module incorporates an Alpha Industries Gunn diode mounted in a waveguide cavity which acts as the transmitter and local oscillator, together with an Alpha Schottky barrier mixer diode for the receiver.

The Type GOS2579 module combines a GOS2581 pulsed motion detector module with an integral pulse modulator for driving the transmitter.

The Type GOS2578 module combines a GOS2581 pulsed motion detector together with an integral pulse modulator and signal processing circuits with both sample and hold and amplification functions.

These modules are designed to meet FCC requirements.

Applications

The Alpha Industries GOS2581, GOS2578, GOS2579 Pulsed Motion Detector Modules are designed for application in the fields of motion detection and speed sensing including:

- Intrusion Alarms
- Automatic Door Openers
- Speed and Rotation Measurement Systems
- Obstruction Warning Systems
- Contactless Vibration Measurement
- Counting/Process Control
- Traffic Signal Actuators
- Automatic Illumination Systems

GOS2581 Electrical Characteristics at 25° C

TRANSMITTER (for 1% duty cycle)

Frequency .... Fixed, in Range 9.47–10.7 GHz
Power Output Peak ....9 mW Min. 10.4–10.7 GHz
6 mW Min. 9.47–10.4 GHz
Operating Voltage (pulsed) . + 9 V (8 V Also Available)
Polarity .... Cavity Ground Negative
Pulse Width ....20μs Typical
Duty Cycle ....1% Typical

(A wide range of pulse widths and duty cycles may be used.)

Operating Current
(average for 1% duty cycle) .... 1.3 mA Typical

Pulsed Motion Detector Modules

U.S.A. operation 10.525 GHz — The module is designed to meet FCC regulations in respect of frequency, power output, frequency stability, harmonic and spurious emissions.

Other countries — Special versions exist for operation at frequencies in the range 9.47 – 10.7 GHz to meet alternative frequency allocation requirements.

RECEIVER

The receiver sensitivity will depend upon the IF bandwidth chosen.

Sensitivity in an IF
Bandwidth 1 Hz to 10 KHz .... – 95 dBc Typical
Noise for an IF bandwidth
1 Hz to 10 KHz .... 10 μV Max.

ENVIRONMENTAL CHARACTERISTICS

Operating Temperature Range .... – 30 to + 70°C

The module is unaffected by the presence of magnetic fields.

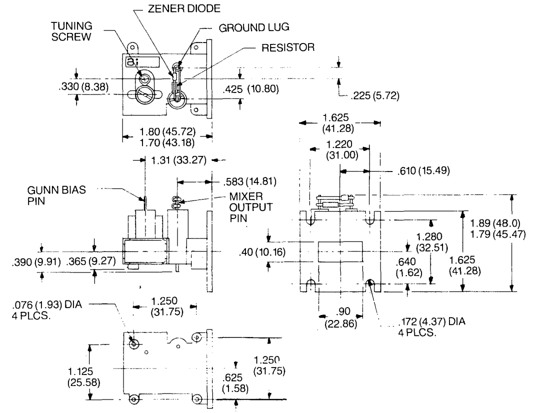
MECHANICAL CHARACTERISTICS

Transmitter Bias Input Connector .... Solder pin
Receiver IF Output Connector .... Solder pin
Microwave Output .... Mates with standard UG39/U Style Flanges.

Notes:

1. The mixer output terminal is fitted with a 12KΩ load resistor. This module has been designed to feed an IF amplifier system incorporating a D.C. block.
2. The module is supplied with a shorting link across the mixer to protect it from the effects of static charge. This shorting link should be left in position until after all wiring assembly work is complete.
3. For a transmitter frequency of 10.525 GHz the Doppler frequency obtained is 31.39 Hz for each mile per hour of radial velocity (i.e., velocity towards or away from the transmitting antenna).
4. The detection range obtained will depend on the size and reflectivity of the target, the signal to noise ratio required and the antenna gain.
5. The motion detector module mates with standard UG39/U flange fittings. Thus, many antenna types may be used with this module. For long range applications, a high gain antenna will be preferred, while for volume protection where a large angular coverage is needed, a low gain antenna will be fitted as required.
   Note that for some applications it may not be necessary to fit a separate antenna.
6. The transmitter frequency is factory preset. The required operating frequency must be specified when ordering.

Outline Drawing



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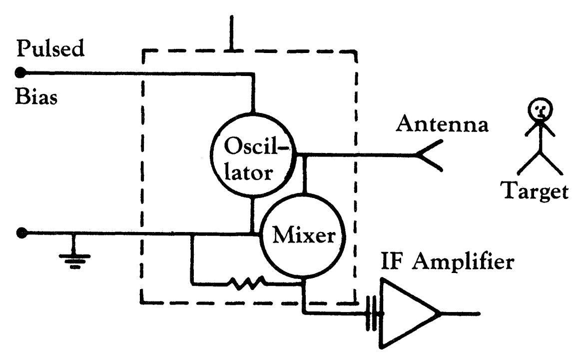
GOS 2581 Operational Schematic

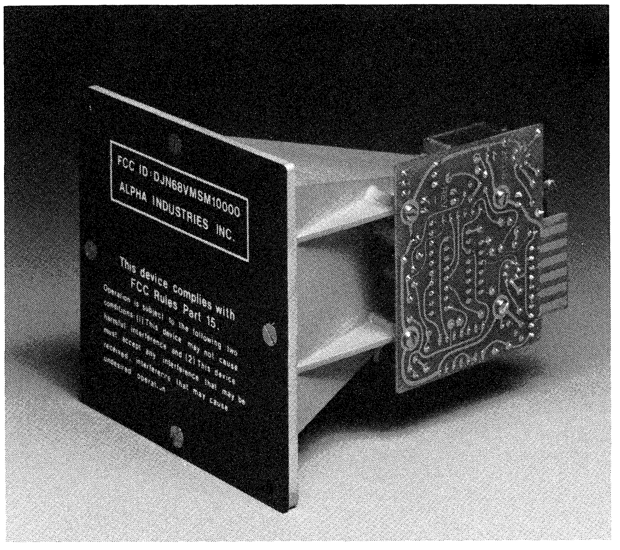


Microwave Motion Detector Module

Microwave Sensor Module Type MSM10000

Features

- FCC Certified
- Detects Both Metallic and Non-Metallic Objects
- High Sensitivity — Range Up To 8 Feet
- Can Be Adjusted To "See Through" Some Materials
- Narrow Detection Beam
- Unaffected By Ambient Contaminants
- Complete Signal Conditioning Circuitry
- All Solid State For Maximum Reliability
- Wide Input Voltage Range
- High Electrical Noise Rejection
- Extremely Low Power Consumption
- Wide Operating Temperature Range
- Rugged Construction
- Plug-In Module



Description

The MSM10000 module contains a microwave transmitter/receiver and signal conditioning electronics for non-contact motion sensing.

The microwave portion of the unit incorporates a Gunn diode mounted in waveguide cavity which acts as both a transmitter and receiver. The output of this oscillator is focused by an integral horn antenna into a narrow beam and any object moving through this beam can be detected. The microwave energy is virtually unaffected by dirt, grease, or other contaminants, making the unit suitable for use in industrial environments with a minimum of maintenance.

The signal conditioning circuitry contains the power supply, amplifiers, comparator, hold-off and output switch to drive the oscillator and convert the detected output into a useful control signal. The power supply allows the module to operate with a wide range of input voltages and provides the high electrical noise rejection required by the industrial environment. The amplifier and comparator sections convert the detected low level output to a useable signal. The sensitivity of this section is controlled by a single external potentiometer so that objects of various sizes, densities and ranges from the transmitter can be selectively detected. It is possible to detect, for example, whether a metallic object is in a cardboard box or not. The hold-off circuitry allows adjustment of the length of the output pulse with one external potentiometer. This regulates the time between output signals and is used to eliminate multiple signals from one object. The output driver is a solid state switch to ground which is short circuit protected.

The input voltage range and extremely low current requirements allow great flexibility of use. Simple power supplies, connection to existing supplies, or two-wire supply/output connections are possible.

Rugged construction, wide supply range, high electrical noise immunity, wide operating temperature range and contaminant rejection make this module ideal for use in industrial environments.

The MSM10000 module is designed for ease of incorporation in standard industrial enclosures. The horn antenna is protected by a window to seal out contaminants. The unit plugs into a standard printed circuit board connector and is secured by four mounting screws on the antenna flange. In addition, mounting ears are provided on the rear of the module for guide pins.

Typical Applications

- Parts Counting
- Process Control
- Container Fill Monitoring
- Die Ejection Monitoring
- Obstruction Warning Systems
- Automatic Door Openers
- Intrusion Alarms
- Limit Switch

Microwave Sensor Module Type MSM10000

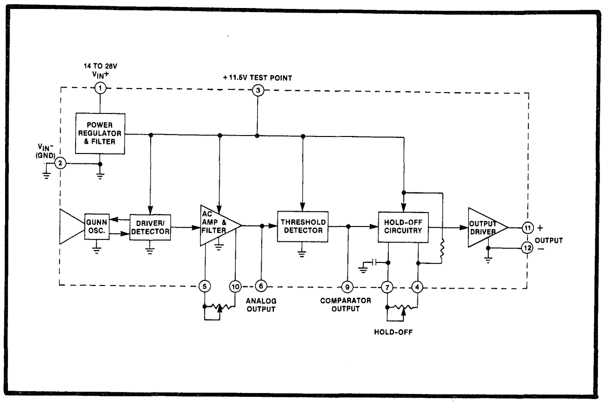
ELECTRICAL SPECIFICATIONS

Input Voltage	+ 14 to + 26 Volts
Operating Current	500 Microamperes Max. 350 Microamperes Typ.
Frequency	10.525 GHz + / − 25 MHz
Control Output	OFF + 60Vdc Max. @ 10μA ON 2.5V Max. @ 500 mA
Comparator Output	OFF + 10V Min. @ 100 μA ON + .5V Max. @ 100 μA
Analog Output	Nom. + 7V
Bandwidth	1–15 Hz
Sensitivity	*Depends on density, size, and distance to detected object
Hold-Off	50ms to 1 sec.
Warm-Up Time	15 Sec. Max. after application of power.
Beamwidth	11 × 18 Degrees (− 3dB)
FCC Regulations	This module meets FCC regulations with respect to frequency, power output, stability, harmonic and spurious emissions.
Mating Connector	Amphenol 225-20621-4-01(117) or equivalent. (See Figure 1 for PIN designations)

MECHANICAL SPECIFICATIONS

Operating Temperature Range	− 40 to + 85 Degrees Celcius
Weight	1 lb.
Dimensions	3.25″ × 3.25″ × 4.25″ (See Outline — Drawing Figure 2)
Humidity	0 to 95% Relative
Construction	Body — Cast Aluminum PC BD — FR4 Epoxy Glass Window — Lexan (TM)
Mounting	4 − .150″ Holes In Corners Of Flange 2 − .125″ Holes In Brackets On Rear (See Figure 12 and Figure 13)

*Please contact the plant for further information



Block Diagram
MSM 10000

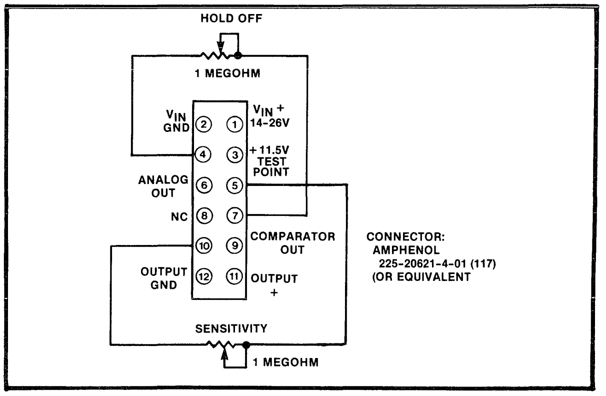


Figure 1 PIN Connections

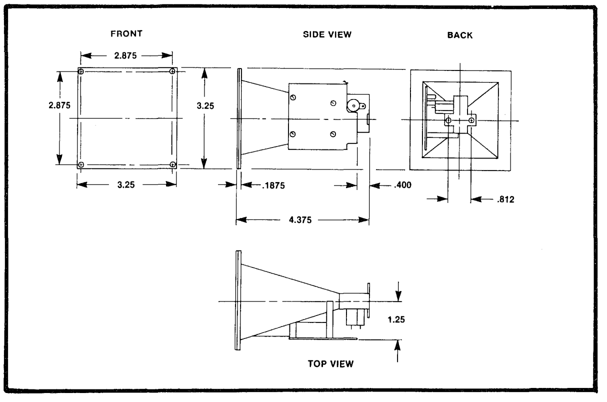


Figure 2. Mechanical Outline

Application Notes

EXTERNAL COMPONENTS

Control Potentiometers

The MSM1000 module is easily incorporated in control systems with a minimum of external components. Only two potentiometers are necessary for basic operation. One of these controls the sensitivity of the unit and the other controls the hold-off time (length of output pulse). Both of these potentiometers can be 1 megohm, industrial quality devices and should be mounted as close as possible to the connector to minimize noise interference. If it is necessary to locate them more than 4 inches from the module, then the leads should be shielded.

Sensitivity Adjustment

The sensitivity adjustment allows a wide range of objects to be detected. This control can be easily adjusted to the minimum level necessary to see the object, so that spurious detections will not occur. In some cases, such as detecting objects inside containers, this adjustment may be critical. In these applications, a multiturn potentiometer or a fixed resistor in series with a lower value pot may be used to make the adjustment easier (see Figure 3). The value of this potentiometer can be between 10 kilohms and 5 megohms although values higher than 1 megohm will cause an increase in turn-on time.

Hold-off Adjustment

The hold-off circuitry effectively stretches the output pulse length to eliminate multiple signals from one object. This is a retriggerable delay which is variable between 100 milliseconds minimum and 1 second maximum by means of the hold-off potentiometer. If it is necessary to increase this time, an external capacitor can be added between pins 7 & 2 on the module connector (see figure 4). This capacitor should not exceed 100 microfarads. To decrease the minimum hold-off time an external resistor can be added between pins 3 & 4 on the module connector (see Figure 4). This resistor should not be less than 10 kilohms minimum.

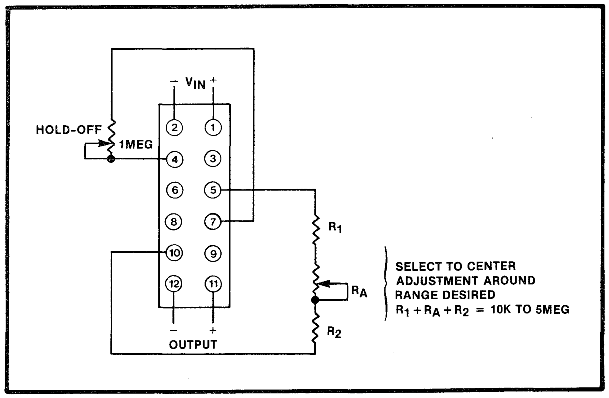


Figure 3. Reducing Sensitivity Adjustment Range

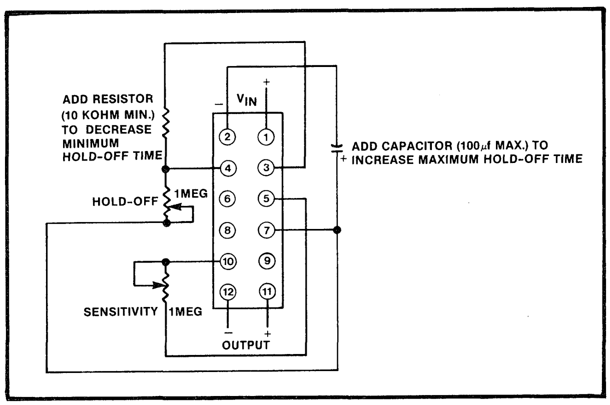


Figure 4. Varying Maximum — Minimum Hold-Off Times

POWER SUPPLY AND OUTPUT CONFIGURATIONS

Power Supply

The MSM10000 module is designed to operate with a wide range of input voltages (14 to 26 volts dc) and low current (500 microamperes). Filters and regulators in the module reduce the requirements on the external power source and allow simple power supplies to be used. The design of the circuitry maximizes the rejection of electrical noise found in the industrial environment. Therefore, any existing DC supply which meets the voltage range can be used with minimal loading by the module. If it is not feasible to use such a source, a simple supply such as is shown in Figure 5 is sufficient to power the module. Here, only a transformer supplying 12.6 to 15 VAC and a single rectifier are necessary since the module itself provides the filtering required.

Turn-on Time

The unit requires up to 15 seconds to stabilize after the application of power. Objects passing through the beam will not be detected during this time and all signals from the module should be ignored.

Output Configurations

Figure 5 shows the module driving a relay in an external device. Note, that in this case, a diode must be placed across the relay to eliminate inductive voltage spikes when the relay turns off. This relay may be of any size as long as the coil current does not exceed 0.5 ampere.

In some applications, it is desirable to electrically isolate the module from the control system. Figure 6 shows such a connection. Here an external filter capacitor must be added to the power supply to account for the increased current drawn by the optical isolator.

Figure 7 shows a two-wire system where the same wires are used to supply power to the unit and to transmit the output. When nothing is being detected, the current drawn by the module is insufficient to turn on the optical isolator. When an object is detected, however, the output turns on drawing more current through resistor R1. The value of this resistor should be chosen so that the extra current will turn on the optical isolator and trigger the control logic. This technique minimizes the wire runs necessary to install the modules in a control system.

Figure 8 shows the module being used as the detector head for a counter. The low current requirement of the module makes it feasible to operate from two 9 volt batteries. The counter/display driver is made by Intersil Inc. (part number ICM72241PL) and the display is a liquid crystal type made by AND Inc. (part number FE0206).

Comparator Output

The comparator output from pin 9 of the module connector is a high level (11V) if nothing is being detected, and a low level if the detection threshold is exceeded. This output precedes the hold-off circuitry, (see block diagram) and, therefore, can generate multiple triggers for each object detected. The output is driven from a CMOS gate and should be buffered if the designer intends to use this output.

Analog Output

The analog output is taken from the amplifier stages before the comparator (see block diagram). This output has a nominal value of + 7V and a maximum swing of 10V peak to peak, depending on the detected input. It will also exhibit some drift with temperature and operating conditions which are compensated by the comparator circuitry, so that if the designer intends to use this output, AC coupling is recommended. The amplifier is capable of driving a 10 kilohm load with no degradation in performance, but care should be taken to shield the leads to avoid noise coupling.

+ 11.5 Volt Test Point

The + 11.5 volt test point is used for test purposes and for decreasing the minimum hold-off time only. It should ***not*** be used as a power source for external circuitry in the system since this may seriously degrade the regulation and noise rejection of the module.

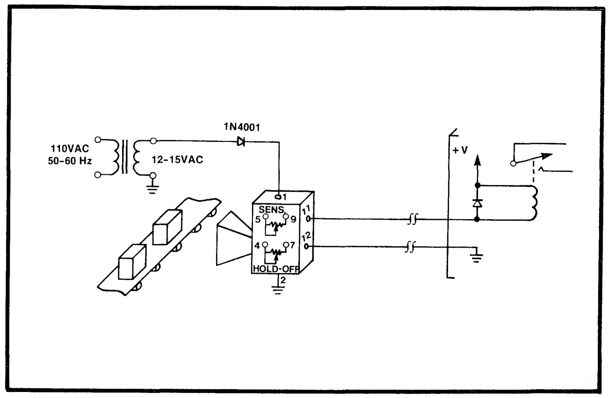


Figure 5. Simple Power Supply

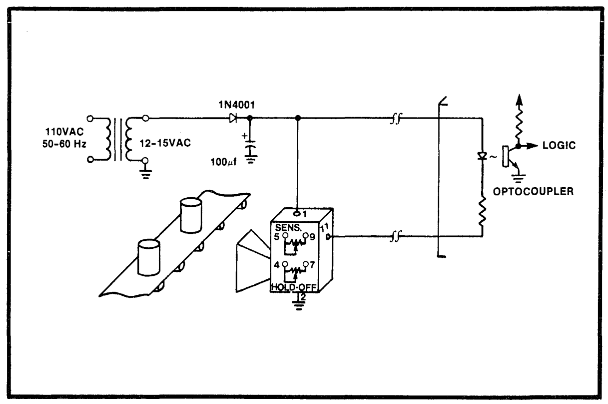


Figure 6. Isolated System

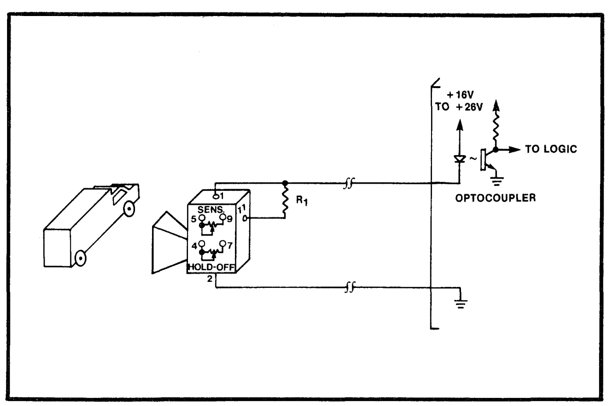


Figure 7. 2-Wire System

MICROWAVE RADIATION PATTERN & SENSITIVITY

Radiation Pattern

The radiation pattern from the MSM10000 module is shown in Figures 9 & 10. Note that the pattern has a narrower beam in the horizontal plane than in the vertical. This allows the designer some flexibility in the application of the unit. If it is necessary to detect small objects on a conveyer belt, the module should be mounted so that they pass horizontally through the beam. If wider coverage is necessary, for example in a door opener application, the module should be rotated 90 degrees so that the objects encounter the wider pattern.

To eliminate false triggering, an object which has been detected must have left the beam before the next object enters it. This limits the effective spacing between objects to 2 inches minimum.

The microwave energy will be reflected by most materials which have a density greater than air. As the density decreases, however, an object becomes more and more difficult to detect. Foam materials and paper, for example, may require the maximum gain setting, while metal objects will require much less sensitivity. An advantage of this is that some objects may be detected inside cardboard and foam shipping containers as a final check before shipment. In effect, the detector can "see-through" the box. This effect may be used to count parts traveling through a plastic shute or, depending on the density, liquid in a plastic pipe without any physical contact.

The sensor module depends on motion through the radiation pattern for operation and, therefore, is rate dependent. The maximum rate has been set by the amplifier bandwidth at 10 objects/second. In most cases, this will be sufficient since it is very difficult to move an object 2 inches (the beam width) in 1/10 of a second. The minimum rate is, normally, not a concern because some edge or irregularity of an object will cause a detected frequency component in the amplifier bandwidth. This minimum rate does, however, allow the module to reject stationary walls and frameworks.

Because the sensor is a motion detector, care must be exercised in the mounting of the module so that vibration of the unit does not cause false outputs. If the unit is allowed to vibrate and the beam is being reflected from a stationary object, the module will detect this as movement in its field. In many applications, this response can be corrected by reducing the sensitivity control, but in some situations vibration damping mountings may be necessary.

Although the unit has a limited range, in some crowded factory environments the unit may false trigger on objects beyond the intended target range. In this case, an absorptive shield should be used. Conductive foam, such as is made by the 3M company, is recommended for this application. Other absorbers made specifically for microwave applications are

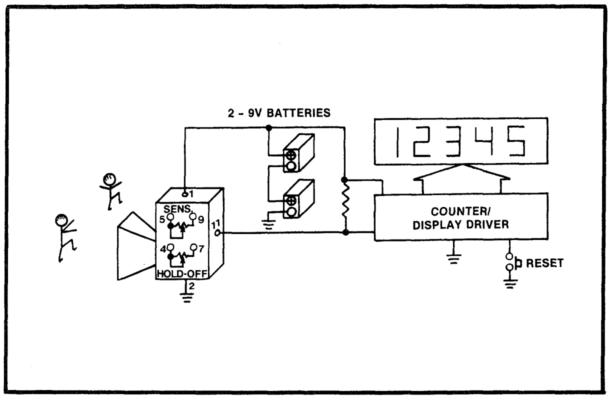


Figure 8. Battery Powered Counter

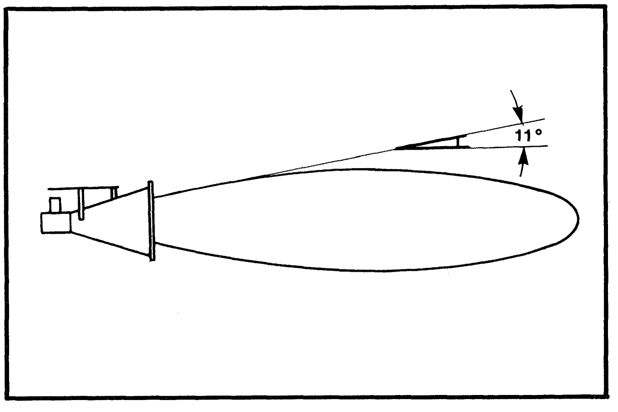


Figure 9. Beam Pattern — Horizontal

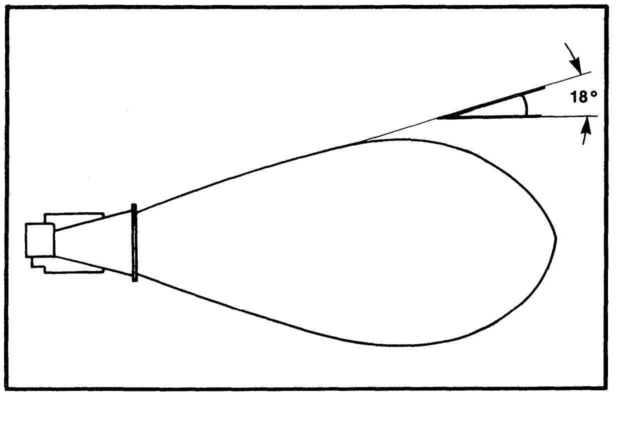


Figure 10. Beam Pattern — Vertical

available from companies such as Emerson and Cummings. Metal sheeting could be used also for this shield but will be much more susceptible to vibration since it will act as a reflector and not an absorber.

FCC REGULATIONS

Qualification

The Federal Communications Commission imposes strict requirements on radiating sources such as the MSM10000. This unit is tested to and meets these requirements, which include operating frequency and stability, harmonic and spurious generation and power output. Any external guides or windows placed in front of the antenna or any change in the antenna itself will require re-evaluation with respect to these requirements. The MSM10000 module has been designed, therefore, to be mounted with antenna output on the OUTSIDE of any enclosure which the OEM user may add, and the radiation pattern has been optimized for use in the majority of applications. Any customer-requested changes will require a lengthy requalification process.

MOUNTING CONFIGURATION

The MSM10000 module is designed to allow the maximum flexibility in mounting configurations. It can be easily removed for servicing if required from the outside of its protective box. An example is shown in Figure 11. Here the MSM 10000 is inserted from the outside of the box, the printed circuit board plugged into the mating connector on a mother board which contains the power supply and control potentiometers, and is bolted to the face of the box with 4 #6-32 UNC-2B screws through the antenna flange. Guide pins on the mother board support the rear of the module or #4-40 UNC-2B screws may be used. The box shown is a standard oil tight JIC box manufactured by HOFFMAN ENGINEERING Co. (part #A6044CH). Figure 12 shows the recommended panel opening and Figure 13 shows the location of the rear mounting holes.

WARRANTY

Alpha warrants that the products delivered hereunder will be in substantial conformity with the specifications and will be free of defects in material and workmanship. Alpha's obligation under this warranty shall be limited to (at its option) repairing, replacing, or granting a credit at the prices invoiced at the time of shipment for any modules which shall within 90 days after shipment be returned to the factory of origin, transportation charges prepaid, which are determined to Alpha's satisfaction to be defective. This warranty shall not apply to any modules which have been repaired or altered, except by Alpha, or which have been subjected to physical or electrical abuse or misuse. The warranties stated herein are in lieu of all other warranties expressed or implied, and Alpha neither assumes nor authorizes another person to assume for it any other liability. Alpha shall not be liable for special or consequential damages of any nature with respect to any products or services sold or rendered hereunder.

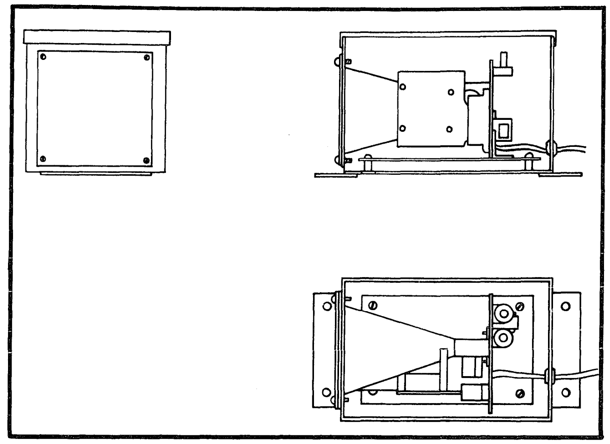


Figure 11. Mounting Example

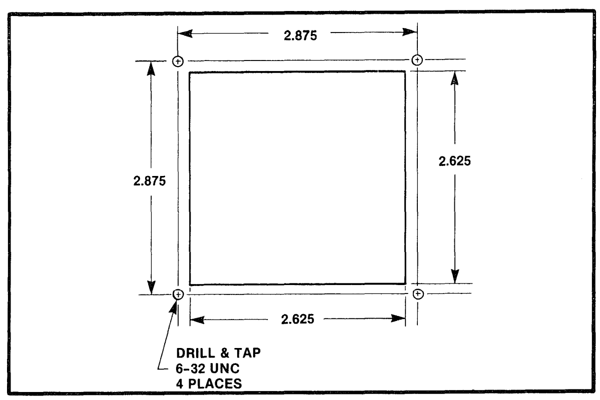


Figure 12. Panel Cut-Out

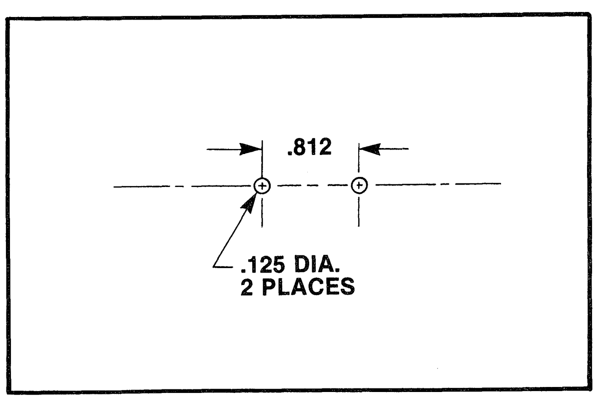
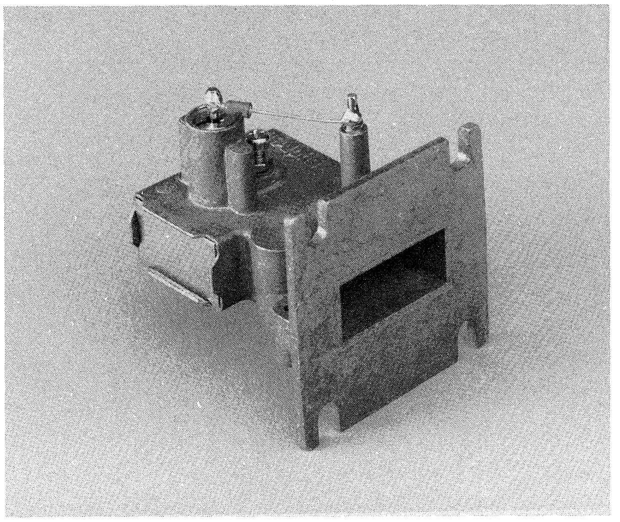


Figure 13. Rear Mounting Holes

Low Cost C.W. X-Band Gunn Oscillator

Features

- Low Cost
- High Reliability
- Low Voltage Operation
- Range of Power Levels Available



Types

- GOS2572, 2573, 2574
- GOS2575, 2576, 2577

Description

The Alpha Industries GOS2572, 2573 and 2574 are very low cost fixed frequency X-Band oscillators. These incorporate an Alpha Industries non-flip Gunn device mounted in a waveguide cavity. These oscillators are significantly decoupled for improved frequency stability and immunity to the effects of load mismatch. A harmonic suppression circuit is incorporated so that FCC requirements may be met with an appropriate antenna.

The GOS2575, 2576 and 2577 fixed frequency X-Band oscillators incorporate an Alpha Industries flip Gunn device mounted in a waveguide cavity. These should be used where the power output of the GOS2574 is insufficient. This series of oscillators is also decoupled for improved frequency stability and immunity to the effects of load mismatch.

Applications

- Automatic Door Opener
- Speed and Rotation Measurement
- Obstruction Warning
- Contactless Vibration Measurement
- Counting and Process Control
- Automatic Illumination
- Receiver Local Oscillator
- Transmitters

ENVIRONMENTAL CHARACTERISTICS

Operating Temperature Range .... − 40 to + 70°C

The cavity body finish is a chromate passivation.

MECHANICAL CHARACTERISTICS

Bias Input Connector .... Solder Pin
Microwave Output .... Mates with standard UG39/U style flange

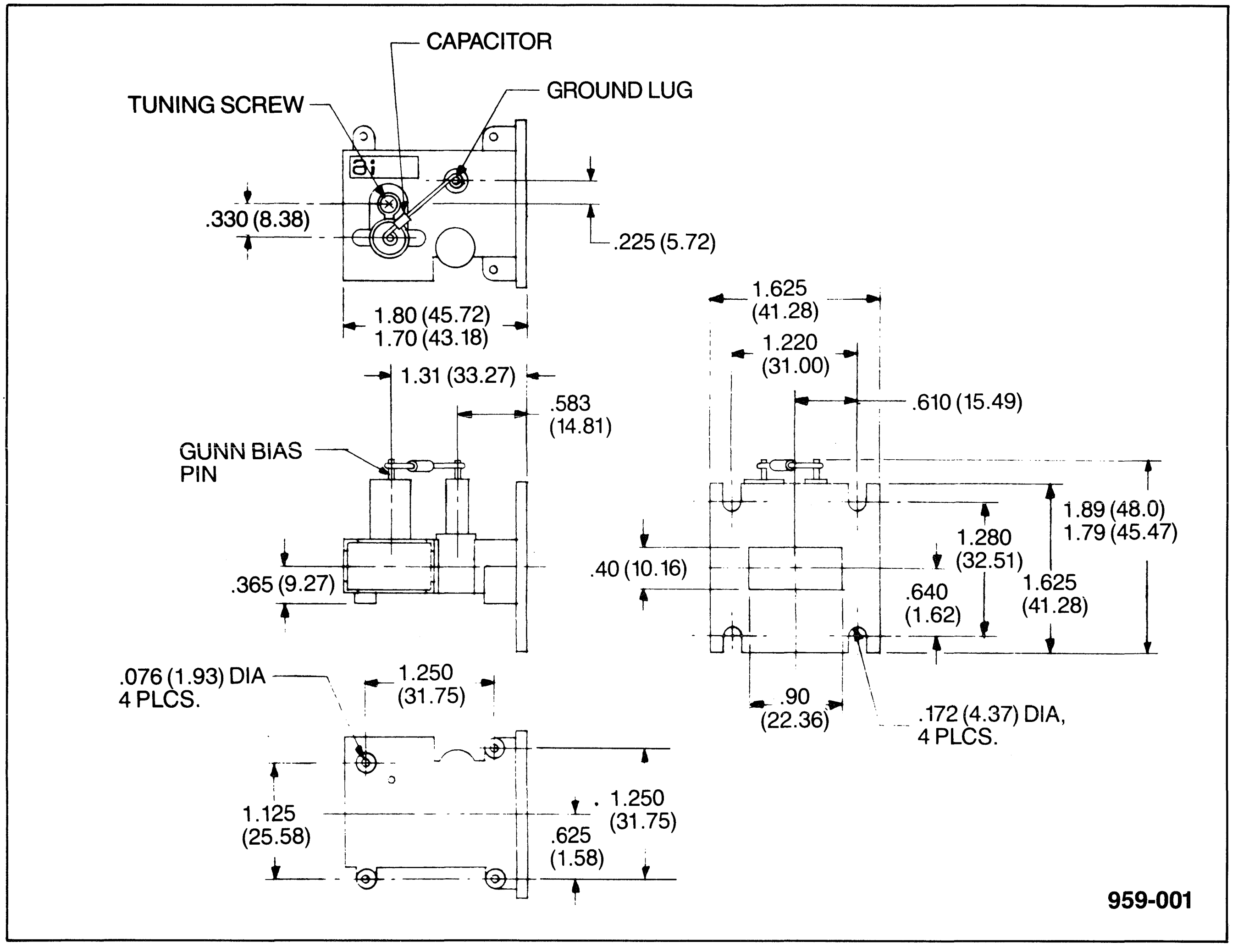
Electrical Characteristics

Type Number	GOS2572	GOS2573	GOS2574	GOS2575	GOS2576	GOS2577
Frequency GHz (see note 1)	10.525	10.525	10.525	10.525	10.525	10.525
Power Output (mW Min.)	5	10	20	50	75	100
Operating Current mA typical	60	100	170	300	400	500
Operating Voltage V typical	8	8	8	10	10	10
Bias Polarity	positive	positive	positive	positive	positive	positive

Note:
1. The frequency is preset at the factory. Other frequencies are available, please inquire.

Low Cost C.W. X-Band Gunn Oscillator

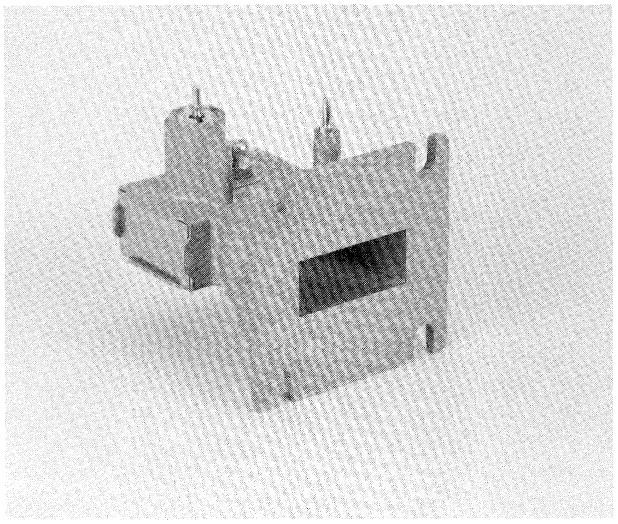
Outline Drawing



Low Cost Pulsed X-Band Gunn Oscillators

Features

- Very Low Average Current Drain
- High Reliability
- Low Voltage Operation
- Range of Power Levels Available
- Designed to Meet FCC Regulations



Types

- GOS2569, 2570, 2571, 2584, & 2585
- GOS2566, 2567, 2568, 2586, & 2587 (with Integral Pulse Modulator)

Description

The Alpha Industries GOS2569, and GOS2570 are very low cost pulsed X-Band oscillators. These incorporate an Alpha Industries non-flip Gunn device mounted in a waveguide cavity. These oscillators are significantly decoupled for improved frequency stability and immunity to the effects of load mismatch. A harmonic suppression circuit is incorporated so that FCC requirements may be met with an appropriate choice of pulse width, duty cycle, and antenna.

The GOS2571, 2584 and 2585 fixed frequency X-Band pulsed oscillators incorporate an Alpha Industries flip Gunn device mounted in a waveguide cavity. These should be used where the power output of the GOS 2570 is insufficient. This series of oscillators is also decoupled for improved frequency stability and immunity to the effects of load mismatch.

The GOS2566, 2567, 2568, 2586 and 2587 pulsed X-Band sources combine a pulsed Gunn oscillator (GOS 2569, 2570, 2571, 2584 and 2585, respectively) together with a pulse modulator for driving the Gunn device.

Applications

- Automatic Door Opener
- Obstruction Warning
- Counting and Process Control
- Automatic Illumination
- Transmitters
- Security System Fences
- Distance Measurement
- Radar

MECHANICAL CHARACTERISTICS

Bias Input Connector .... Solder Pin
Microwave Output .... Mates with Standard UG39/U style flange

ENVIRONMENTAL CHARACTERISTICS

Operating Temperature Range .... – 20 to + 70°C

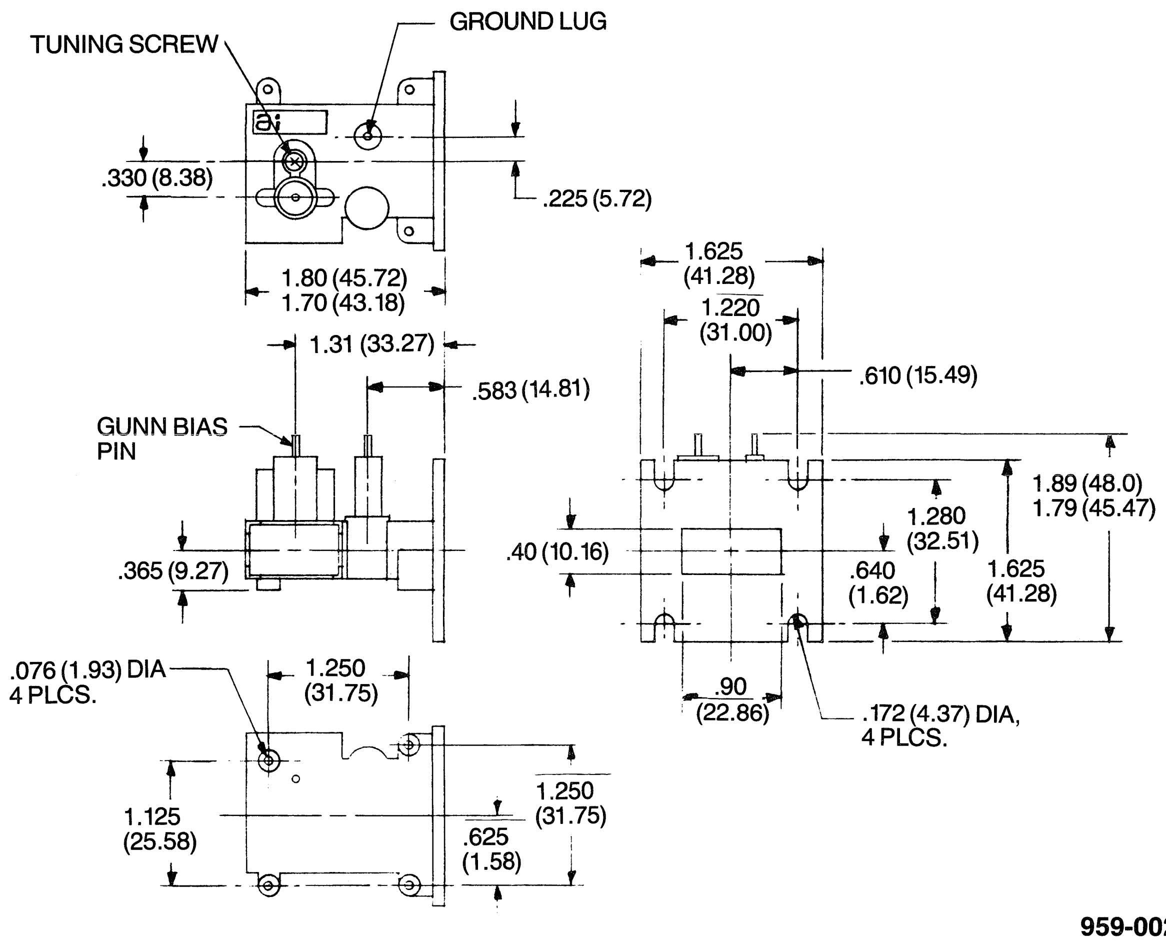
The cavity body finish is a chromate passivation.

Electrical Characteristics

Type Number	GOS2569	GOS2570	GOS2571	GOS2584	GOS2585
Frequency GHz (see note 1)	10.525	10.525	10.525	10.525	10.525
Power Output (mW Min.)	10	20	50	100	200
Pulse Width (typical) µS (see Note 2)	10	10	10	10	10
Duty Cycle (typical) (see Note 2)	1%	1%	1%	1%	1%
Operating Current (ave. for 1% duty cycle) typ.mA	1.0	1.4	2.2	4.0	8.0
Operating Voltage pulsed V	9 (8 also available)	9(8 also available)	10-14	10-14	10-14
Bias Polarity	positive	positive	positive	positive	positive

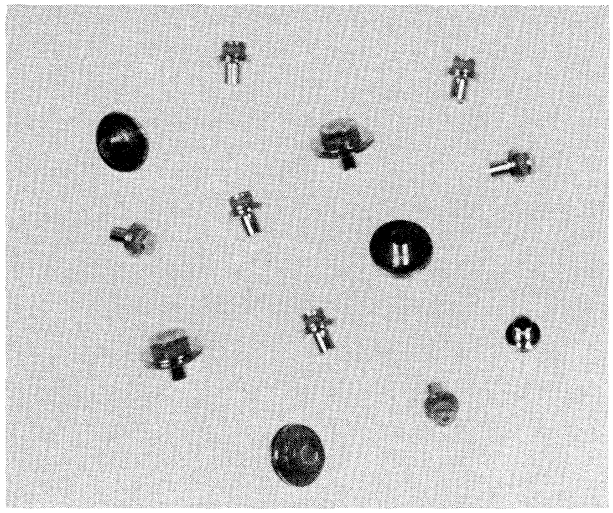
Note:
1. The frequency is preset at the factory. Other frequencies are available, please inquire
2. A wide range of pulse widths and duty cycles may be used.

Outline Drawing



Note: Millimeters in parentheses.

High Cutoff GaAs Parametric Amplifier Varactor Diodes



Features

- Highest Cutoff Frequencies Available, from 900 to 1300 GHz
- More Accurate and Reliable Characterization

Description

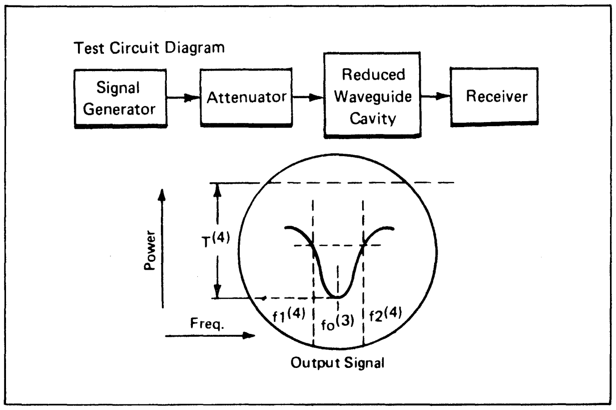
The Alpha DVE6722 and DVE6810 series gallium arsenide parametric amplifier varactor diodes offer the user the highest cutoff frequencies available in the microwave industry today. To obtain the high cutoff frequency and capacitance nonlinearity, a P^+ material is diffused into a very thin layer of N type material, with a flat doping profile, on an N^+ substrate.

Diode frequency cutoff is measured as a function of junction capacitance using the "Deloach" method.[1] The Deloach measurement technique eliminates holder losses that are present in the conventional "Houlding" method. With the Deloach method, a direct measurement of diode cutoff to low junction capacitance values can be obtained.

Burn-In

All GaAs varactors are subjected to burn-in screening prior to final measurements. Typical burn-in for: $C_{j0} = 0.3$ pF is: 60 Hz, $I_p = 30$ mA. $V_p = 2.5$V (50 ohm load) at 100°C, 16 hrs.

Measurement



Notes:

1. Deloach, "A New Microwave Measurement Technique to Characterize Diodes and an 800 Gc Cutoff Frequency Varactor at Zero Volts Bias." IEEE Transactions on Microwave Theory and Technique, January, 1964, pp. 15-20.
2. Signal is applied to diode at series resonance frequency of diode:

$$f_0 = \frac{1}{2\pi\sqrt{L\,C_{J0}}}$$

3. Power transmission loss ratio, T, is measured at frequencies f_1 and f_2 at which power transmitted to receiver is twice that at resonance.
4. Calculate $f_{c0} = \dfrac{f_1 f_2}{(f_1 - f_2)\left(1 - \frac{2}{T}\right)^{1/2}}$. This is the cutoff frequency for packaged diode in the Deloach holder.

High Cutoff GaAs Parametric Amplifier Varactor Diodes

General Characteristics (B_V min[1] = 10 volts)

Package 290-001

MODEL NUMBER	C_{j0}[2] pf Min.	C_{j0}[2] pf Max.	fco[3] Min. GHz	fc (−6 V)[3] Min. GHz	Δ n C_j (−6 V)[4,5] Min.
DVE6810A	0.35	0.40	360	820	0.555
DVE6810B	0.30	0.35	400	900	0.551
DVE6810C	0.25	0.30	440	1000	0.547
DVE6810D	0.20	0.25	490	1070	0.537
DVE6810E	0.15	0.20	570	1230	0.519
DVE6810F	0.10	0.15	620	1300	0.500

Package 082-001

MODEL NUMBER	C_{j0}[2] pf Min.	C_{j0}[2] pf Max.	fco[3] Min. GHz	fc (−6 V)[3] Min. GHz	Δ n C_j (−6 V)[4,5] Min.
DVE6722A	0.35	0.40	360	815	0.545
DVE6722B	0.30	0.35	400	890	0.541
DVE6722C	0.25	0.30	440	970	0.534
DVE6722D	0.20	0.25	490	1050	0.526
DVE6722E	0.15	0.20	570	1200	0.507
DVE6722F	0.10	0.15	620	1270	0.487

Notes to General Characteristics:

1. Breakdown voltage, (B_V) is measured at 10μA reverse current.
2. Total Capacitance is measured at 1 MHz and 0 bias. Junction Capacitance (C_j) is calculated by subtracting the typical package capacitance from the total capacitance. Capacitance selection to ± 0.025 pF is standard.
3. fco measured by Deloach method: $fc(-6V) = fco \times C_{j0}/C_j(-6V)$ This compares with the Houlding measurement in the Alpha test fixture for $C_{j0} = 0.4$ pF and fco Deloach = 360 GHz while fco Houlding = 270 GHz.
4. $\Delta n C_j(-6V) = \frac{C_{j0} - C_j(-6V)}{C_{j0}}$ Log C_j vs. log (V + ϕ) gives best fit to straight line for ϕ = 1.2V.
5. The method used for calculating junction capacitance includes ribbon stray capacitance as part of C_{j0}. This stray value is larger for the 082-001 and Δ n C_{j-6} is therefore less than for the 290-001 outline.

Parametric Amplifier Diode Design Choice

Parametric amplifier diodes can be chosen for application using the table below as a guide. The idler frequency is chosen according to the mode of resonance — series or parallel at idler frequency:

f idler = f pump − f signal

f pump = pump frequency

f signal = signal frequency to be amplified

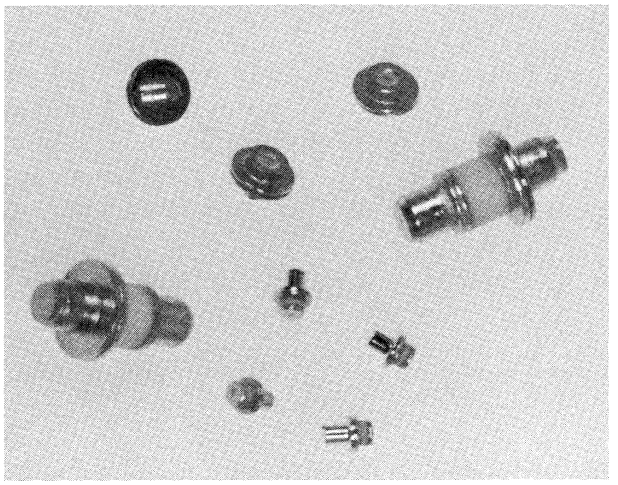
Package	C_{j0} pF	Series[1] Resonance Frequency GHz	Parallel[2] Resonance Frequency GHz	Product Numbers
082 C_p = .2pF	.4	15	31	6810A, 4557-01 - 08
L_p = .2nH	.3	21	33	6810B,C 4557-11 - 26
	.2	24	36	6810D,E
290 C_p = .11pF	.3	21	58	6722B,C 4558-01 - 08
L_p = .10nH	.2	24	62	6722D,E
	.1	32	70	6722F

[1]These values correspond to observed Deloach resonance frequencies

[2]Calculated using equation:

$$f_{parallel\ resonance} = \frac{1}{2\pi\sqrt{L_p \frac{C_p C_{J0}}{C_p + C_{J0}}}}$$

GaAs Parametric Amplifier Varactors



Features

- High Gain and Low Noise Temperature
- Deloach and Houlding Measurements Insure Reproducibility
- High Reliability and Space Qualified
- Low Temperature Performance

Description

By controlling the epitaxial material doping level and profile, Alpha diffused gallium arsenide parametric amplifier diodes provide low series resistance to low temperatures (20°K) and large capacitance swing with applied bias for optimum bandwidth.

Frequency cutoff in this data presentation is measured using the Houlding method.

Environmental Capability

Thermal Shock...................... – 195.8°C to + 100°C
Centrifuge.............................20,000 G
Gross Leak Test ....10^{-5} cc/sec
Fine Leak Test.......................10^{-8} cc/sec
High Temperature Storage.....200°C

Burn-In

All GaAs varactors are subjected to burn-in screening prior to final measurements: typical burn-in for C_{J0} = 0.3 pF is: 60 Hz, I_P = 30 mA. V_P = 2.5 V (50 ohm load) at 100°C, 16 hrs.

DVE 4556 Series

Voltage Breakdown **$V_B^{(1)}$ = 6 volts** **Package Outline: 023-001**

Minimum $F_{C-6}^{(4)}$ (GHz)	Junction Capacitance Range, $C_{J0}^{(2)}$ (pF)							
	.3-.35	.35-.4	.4-.45	.45-.55	.55-.65	.65-.8	.8-1.0	1.0-1.2
200	DVE4556-01	DVE4556-11	DVE4556-21	DVE4556-31	DVE4556-41	DVE4556-51	DVE4556-61	DVE4556-71
250	DVE4556-02	DVE4556-12	DVE4556-22	DVE4556-32	DVE4556-42	DVE4556-52	DVE4556-62	
300	DVE4556-03	DVE4556-13	DVE4556-23	DVE4556-33	DVE4556-43	DVE4556-53		
350	DVE4556-04	DVE4556-14	DVE4556-24	DVE4556-34	DVE4556-44			
400	DVE4556-05	DVE4556-15	DVE4556-25	DVE4556-35				
450	DVE4556-06	DVE4556-16	DVE4556-26					
500	DVE4556-07	DVE4556-17						
550	DVE4556-08							

Power Dissipation, P_T (at 25°C) ....200 mW
Operating Temperature .... + 175°C Max. (T_J)

Capacitance Ratio $\frac{Cj0}{Cj6} \geq 2.0$

DVE 4557 Series

Voltage Breakdown **$V_B^{(1)}$ = 6 volts** **Package Outline: 082-001**

Minimum $F_{C-6}^{(4)}$ (GHz)	Junction Capacitance Range, $C_{J0}^{(2)}$ (pF)							
	.3-.35	.35-.4	.4-.45	.45-.55	.55-.65	.65-.8	.8-1.0	1.0-1.2
200	DVE4557-01	DVE4557-11	DVE4557-21	DVE4557-31	DVE4557-41	DVE4557-51	DVE4557-61	DVE4557-71
250	DVE4557-02	DVE4557-12	DVE4557-22	DVE4557-32	DVE4557-42	DVE4557-52	DVE4557-62	
300	DVE4557-03	DVE4557-13	DVE4557-23	DVE4557-33	DVE4557-43	DVE4557-53		
350	DVE4557-04	DVE4557-14	DVE4557-24	DVE4557-34	DVE4557-44			
400	DVE4557-05	DVE4557-15	DVE4557-25	DVE4557-35				
450	DVE4557-06	DVE4557-16	DVE4557-26					
500	DVE4557-07	DVE4557-17						
550	DVE4557-08							

Power Dissipation, P_T (at 25°C) ....200 mW
Operating Temperature .... + 175°C Max. (T_J)

Capacitance Ratio $\frac{Cj0}{Cj6} \geq 2.0$

GaAs Parametric Amplifier Varactors

DVE 4558 Series

Voltage Breakdown $V_B^{(1)} = 6$ volts **Package Outline: 290-001**

Minimum $F_{C-6}^{(4)}$ (GHz)	Junction Capacitance Range, $C_{J0}^{(2)}$ (pF)							
	.3-.35	.35-.4	.4-.45	.45-.55	.55-.65	.65-.8	.8-1.0	1.0-1.2
200	DVE4558-01	DVE4558-11	DVE4558-21	DVE4558-31	DVE4558-41	DVE4558-51	DVE4558-61	DVE4558-71
250	DVE4558-02	DVE4558-12	DVE4558-22	DVE4558-32	DVE4558-42	DVE4558-52	DVE4558-62	
300	DVE4558-03	DVE4558-13	DVE4558-23	DVE4558-33	DVE4558-43	DVE4558-53		
350	DVE4558-04	DVE4558-14	DVE4558-24	DVE4558-34	DVE4558-44			
400	DVE4558-05	DVE4558-15	DVE4558-25	DVE4558-35				
450	DVE4558-06	DVE4558-16	DVE4558-26					
500	DVE4558-07	DVE4558-17						
550	DVE4558-08							

Power Dissipation, P_T (at 25°C) .... 200 mW
Operating Temperature .... +175°C Max. (T_J)

Capacitance Ratio $\frac{Cj0}{Cj6} \geq 2.0$

DVE 5337 Series

Low Temperature (4.2°K) Varactors
Voltage Breakdown $V_B^{(1)} = 6$ volts **Package Outline: 023-001**

Type	$F_{C-6}^{(4)}$ (GHz)	$F_{C0}^{(4)}$ (GHz)	$C_{J0}^{(2)}$ Range
D5337-00	150	65	0.3-1.0
D5337-06	150	85	0.3-0.7
D5337-12	150	110	0.3-0.5

Notes
1. Breakdown Voltage (V_B) is measured at 10µA reverse current.
2. Total Capacitance is measured at 1 MHz and 0 bias. Junction Capacitance (C_J) is calculated by subtracting the typical package capacitance from the total capacitance. Capacitance selection to ±0.025 is standard. Various other package styles are available upon request.
3. Frequency cutoff is quoted for measurement by Houlding method.

Technical Note on Frequency Cutoff Measurement — A Brief Description

Frequency cutoff measurements using the Deloach method of measurement as well as the Houlding method are available. The Deloach measurement technique eliminates holder losses present in the conventional Houlding method at capacitance below 0.3pF. Above 0.3pF, the Houlding method is accurate.

The Deloach method also gives the packaged diode resonance frequency, F_0, as a direct measurement. F_0 can be effectively used as an indication of diode series and parallel resonance comparing consistency within a production lot and for lot to lot performance.

A comparison of Deloach frequency cutoff-vs.-Houlding is shown in Figure 1. We find

$$\frac{\text{Fc Deloach}}{\text{Fc Houlding}} = 1.4 \text{ at } C_{j0} = 0.4\text{pF}$$

In Figure 2, Deloach resonance frequency vs. junction capacitance is shown.

Performance Curves

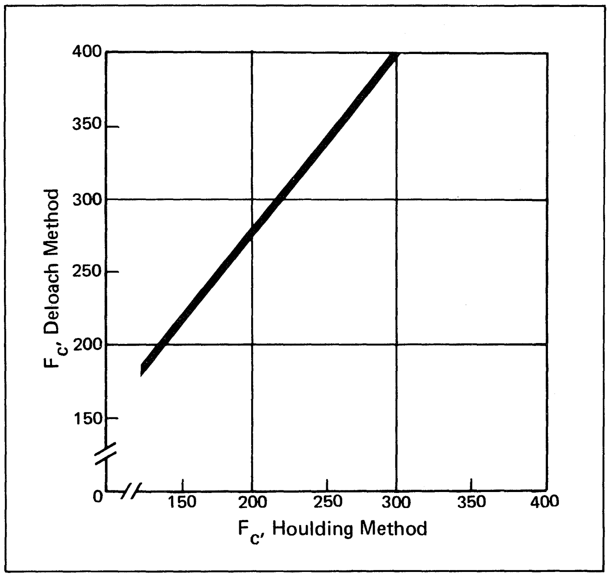


Figure 1. Frequency Cutoff — Deloach vs Houlding Method (C_{J0} = 0.4pF)

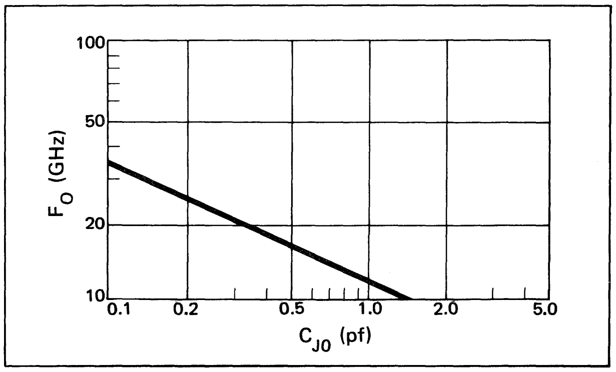
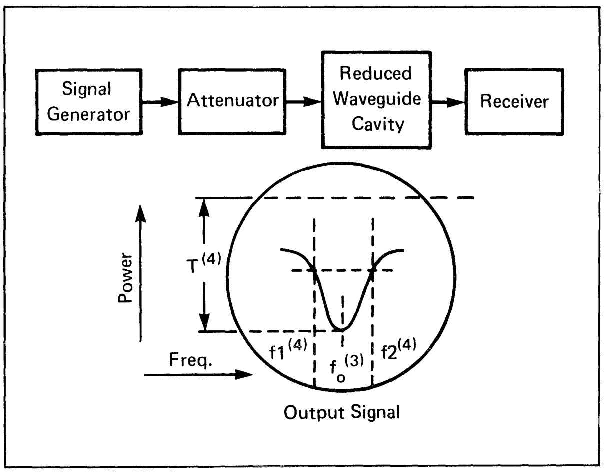
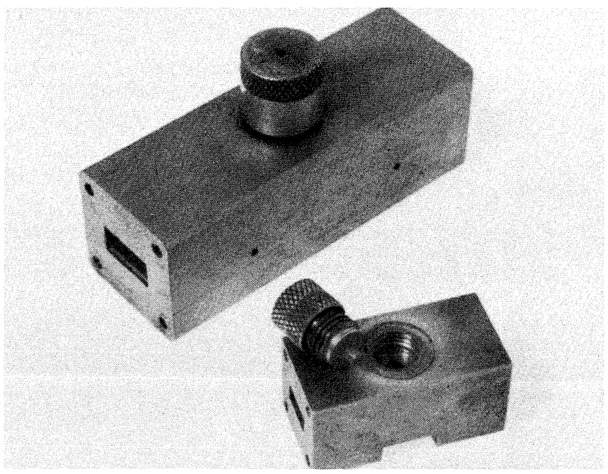


Figure 2. Deloach Resonant Frequency vs C_{J0} (082 Outline)

Deloach Method





Photograph of Deloach Cavities

Notes:

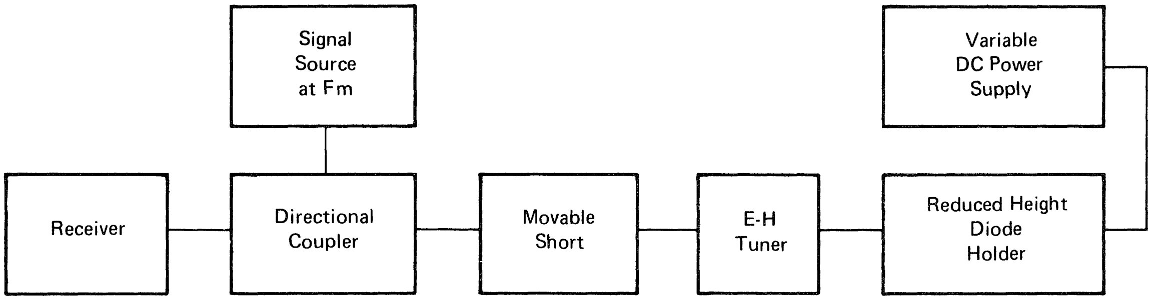
1. Deloach, "A New Microwave Measurement Technique to Characterize Diodes and an 800 Gc Cutoff Frequency Varactor at Zero Volts Bias." IEEE Transactions on Microwave Theory and Technique, January, 1964, pp. 15-20.
2. Signal is applied to diode at series resonance frequency of diode:

$$f_0 = \frac{1}{2\pi\sqrt{L\,C_{J0}}}$$

3. Power transmission loss ratio, T, is measured at frequencies f_1 and f_2 at which power transmitted to receiver is twice that at resonance.
4. Calculate $f_{C0} = \frac{f_1 f_2}{(f_1 - f_2)\sqrt{1 - \frac{2}{T}}}$. This is the cutoff frequency for packaged diode in the Deloach holder. F_{C-6} is calculated by: $f_{C-6} = f_{C0} \times \frac{C_{J0}}{C_{J6}}$.

GaAs Parametric Amplifier Varactors

Houlding Method



$$\frac{1}{\Gamma^2} = \frac{A^2}{A^2\Gamma^2}$$

A^2 = Signal power with movable short in waveguide

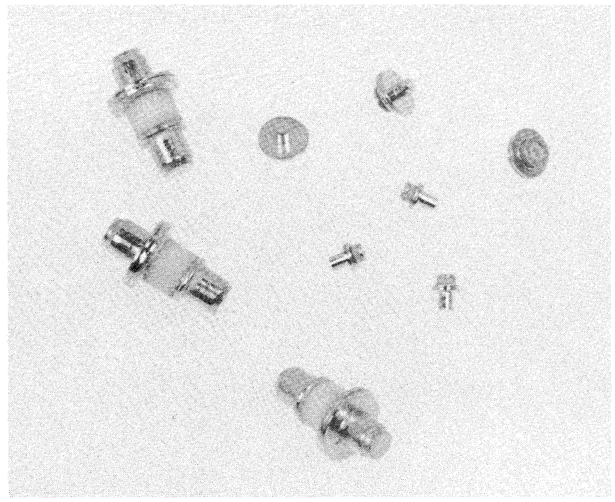
$A^2\Gamma^2$ = Signal power with diode bias at -½ volt.

Procedure

1. Measure test diode for C_{j0} and $C_{J-1/2}$.
2. Match diode in Houlding circuit using E-H tuner with 0 volts bias applied.
3. Bias diode to $-1/2$ volts and measure the reflection coefficient, Γ, caused by the change in diode impedance.
4. Calculate f_{C0} (GHz) $= \dfrac{Fm}{\dfrac{C_{J0}}{C_{J-1/2}} - 1} \times \dfrac{2}{\sqrt{\left(\dfrac{1}{\Gamma}\right)^2 - 1}}$

   where Fm = 10 GHz.
5. Calculate $f_{C-6} = f_{C0} \times \dfrac{C_{J0}}{C_{J-6}}$.

Silicon Parametric Amplifier Varactors



Features

- High Gain at Low Pump Power
- Low Noise
- High Reliability

Description

The Alpha series of silicon parametric amplifier varactors are of the diffused mesa design, utilizing an $N^{1/3}$ diffused layer into heavily doped P type material. The mesa is contacted by a thermocompression bonded gold ribbon.

The superior beta (β) of these diodes imparts high gain to the amplifier even at low pump power. The high figure of merit (F'_C) of these varactors makes them ideally suited for broadband and low noise applications.

This series of varactors denoted by type numbers 5046, 5371 and 5146 has been expanded to include higher cutoff types. The high cutoff types are offered in the 290 outline.

Environmental Capability

Centrifuge	20,000 G
Gross Leak Test	10^{-5} – cc/sec
Fine Leak Test	10^{-8} – cc/sec
High Temperature Storage	200°C
High Temperature Burn-In	100°C, 10 mA, 16 hrs.
Maximum Reverse Leakage Current	10 nA

Characteristics

023 Outline

Type Number	V_B[2] (V) Min.	F_C–3V[3] (GHz) Min.	F'_C – 3[4] (GHz) Min.	F_COV[3] (GHz) Min.	C_J[5] (pF) Min.	Max.	β[6] Min.
D5371A	5.5	100	85	60	0.3	1.0	8
D5371B	5.5	125	110	70	0.3	0.7	8
D5371C	5.5	150	130	80	0.3	0.7	7
D5371D	5.5	175	150	90	0.3	0.6	6
D5046	5.5	150	100	90	0.3	0.8	3
D5046A	5.5	200	130	120	0.3	0.7	3
D5046B	5.5	250	160	150	0.3	0.5	3
D5046C	5.5	300	190	180	0.2	0.40	3

Power Dissipation, P_T(at 25°C) 300mW
Operation Temperature.. + 175°C

082 Outline

Type Number	V_B[2] (V) Min.	F_C–3V[3] (GHz) Min.	F'_C – 3[4] (GHz) Min.	F_COV[3] (GHz) Min.	C_J[5] (pF) Min.	Max.	β[6] Min.
D5146A	5.5	100	85	60	0.3	1.0	8
D5146B	5.5	125	110	70	0.3	0.7	8
D5146C	5.5	150	130	80	0.3	0.7	7
D5146D	5.5	175	150	90	0.3	0.6	6
D5146E	5.5	150	100	90	0.3	0.8	3
D5146F	5.5	200	130	120	0.3	0.7	3
D5146G	5.5	250	160	150	0.3	0.5	3
D5146H	5.5	300	190	180	0.2	0.40	3

Power Dissipation, P_T(at 25°C) 300mW
Operation Temperature.. + 175°C

290 Outline

Type Number	V_B[2] (V) Min.	F_C–3V[3] (GHz) Min.	F'_C – 3[4] (GHz) Min.	F_COV[3] (GHz) Min.	C_J[5] (pF) Min.	Max.	β[6] Min.
DVD-5001	5.5	250	160	150	0.3	0.5	3
DVD-5001A	5.5	300	190	180	0.2	0.40	3

Power Dissipation, P_T(at 25°C) 100mW
Operation Temperature.. + 175°C

Notes:

1. Power dissipation is for continuous operation at 10 GHz.
2. Breakdown Voltage (V_B) is measured 10µA reverse current.
3. Cutoff Frequency (F_C) at specified bias is calculated from Q measured at 10.0 GHz, multiplied by 10.0 GHz.
4. Figure of merit F'_C is the difference in cutoff between – 3V reverse and 1µA forward.

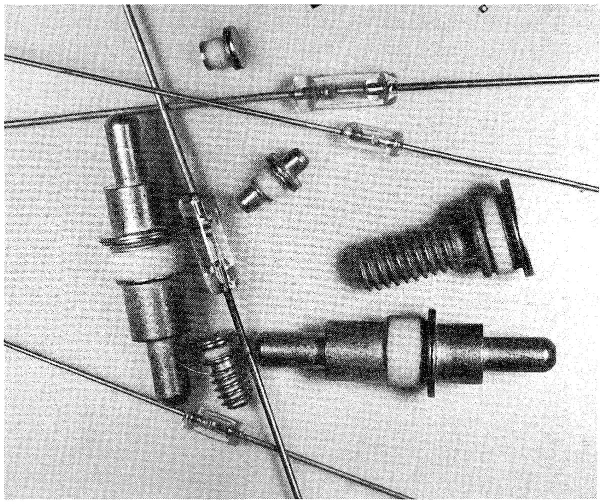
$$F'_C = F_C @ -3V \frac{\beta - 1}{\beta}$$

5. Total Capacitance is measured at 1MHz and 0 bias.
   Junction Capacitance (C_J) is calculated by subtracting the package capacitance from the total capacitance.
   Capacitance selection to ± .05 pF is standard.
6. β is the ratio of the capacitance at 1µA to the capacitance at – 3V.

Section 5
Silicon and GaAs Multiplier and Step Recovery Diodes

Silicon and GaAs Multiplier and Step Recovery Diodes

Step Recovery Diodes, Multichip SRD and SRD Chips



Features

- Low Transition Time
- High Cutoff Frequency
- High Reliability

Description

Alpha Step Recovery Diodes (SRD) are oxide passivated, epitaxial silicon mesa designs. Careful attention to diffusion profiles makes these diodes an ideal choice for high order multiplier circuits. They are available in a broad range of packages or in chip form for those who wish to bond SRDs into their own circuits. Also, multichip packaged devices are available for high power applications.

Application

There are basically four types of multiplier devices in common usage: 1) the resistive multiplier, 2) the varactor (square law or tuning diode) multiplier, 3) the A-Mode multiplier, and 4) the SRD. The resistive multiplier, typically a Schottky diode, is for low order, low power use and has low efficiency. Varactor multipliers are principally used as doublers or up-converters ($N = 2$), while A-Mode multiplier diodes are used on $N \leq 4$ multipliers. The SRD can also be used on $N \leq 4$ multipliers, but its main use is in high order ($N > 4$) multipliers and comb generators where high efficiency is required. Alpha has a complete line of multiplier diodes for each case mentioned above (consult factory).

When an SRD is driven into forward conduction on one half of the RF cycle, the diode stores charge and appears as a low impedance.

On the second half of the cycle, the diode conducts until the stored charge is removed and then switches off very rapidly at a speed governed by the transition time, T_T.

In general it is desirable that the minority carrier lifetime (τ) be greater than 10 times the period of the input frequency, while the transition time (T_T) should be less than the period of the output frequency. Figures 2 and 3 are graphs which can be used to easily determine the limiting values of τ and T_T. Test circuits to determine τ and T_T are shown in Figures 4 and 5. For optimum performance an ideal SRD will be a punch-through device at zero volts (any increase in reverse bias above zero volts will not decrease capacitance) but will have a highly non-linear capacitance increase as the diode is forward biased. In actual practice a step recovery diode will not be zero punch-through but will have $C_{J0}/C_{J6} \leq 1.4$. This can be clearly seen in Figure 1. SRDs are highly efficient, and idlers are not needed although, if used, may further increase efficiency. A typical SRD circuit is shown in Figure 6.

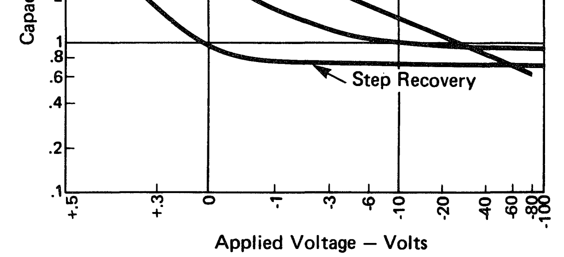


Figure 1. Capacitance vs Applied Voltage for Square Law and A-Mode Multipliers and Step Recovery Diodes

When higher microwave power is desired, the normal SRD may not be useable, since the necessary breakdown voltages may be too high for the transition time required. Alpha has solved this problem by using the multichip approach. The use of two chips provides improvement in both average power handling and peak power handling capability. The chips are electrically in series and thermally in parallel, giving lower thermal resistance than chips which are in series both electrically and thermally. Average power is increased because, for a given RF reactance, each chip can have twice the capacitance of the equivalent single chip device. This results in a four time increase in total device area and, hence, in average power handling capability.

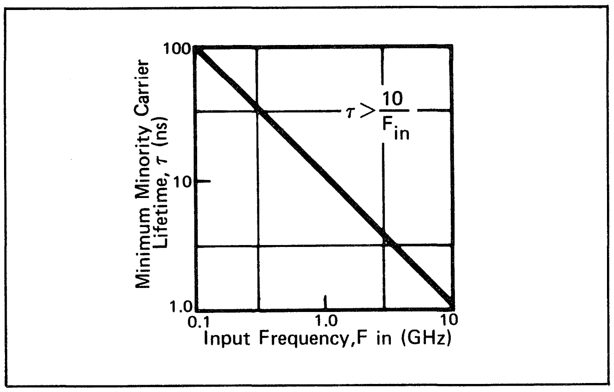


Figure 2. τ vs F in

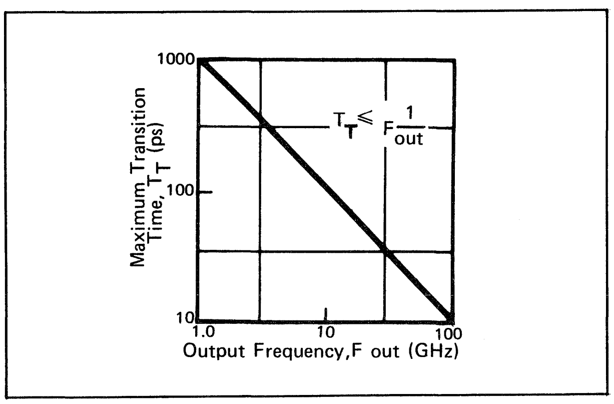


Figure 3. T_T vs F out

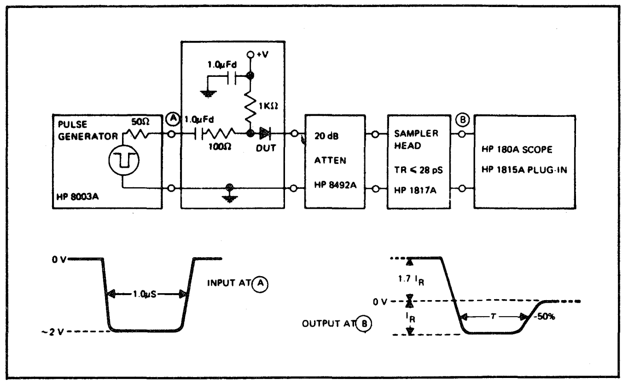


Figure 4. Minority Carrier Lifetime, τ, Test Set-Up

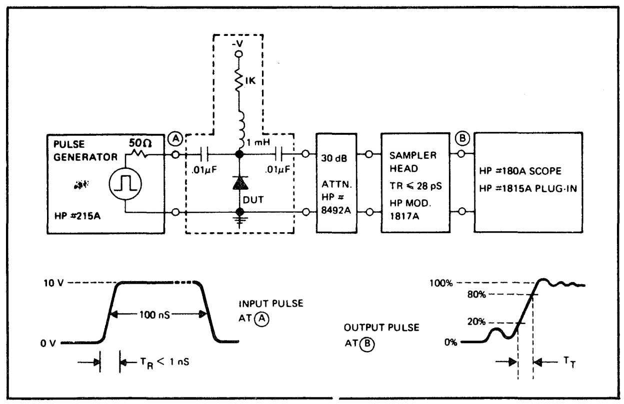


Figure 5. Transition Time, T_T, Test Set-Up

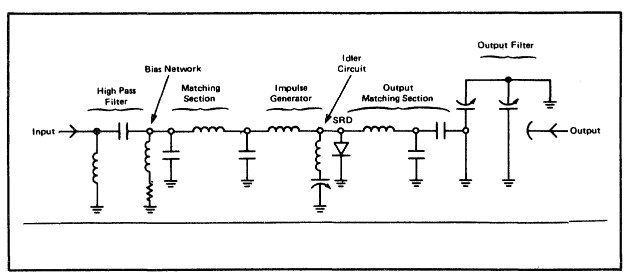


Figure 6. Typical SRD Multiplier

Step Recovery Diodes, Multichip SRD and SRD Chips

Step Recovery Diodes 023-001 Package

Type Number	V_B(1) (Volts) Min.	C_{J-6}(2) (pF)	τ(3) (ns) Min.	T_T(4) (ps) Max.	θ_{Th} (°C/Watt) Typ.	F_{C-6}(5) (GHz) Min.	Typical Input Freq. (GHz)	Typical Output Freq. (GHz)
DVB6100A	15	.25-.50	10	70	60	300		
DVB6100B	15	.50-1.0	10	70	40	300	0.5-3.0	9.0-18.0
DVB6100C	15	1.0-1.5	10	70	30	300		
DVB6101A	30	.25-.50	10	100	60	300		
DVB6101B	30	.50-.75	10	100	45	300		
DVB6101C	30	.75-1.00	10	100	40	300	0.5-3.0	5.0-15.0
DVB6101D	30	1.00-1.25	10	100	35	300		
DVB6101E	30	1.25-1.50	10	100	30	300		
DVB6102A	45	.5-1.0	25	200	50	250		
DVB6102B	45	1.0-1.5	25	200	40	250		
DVB6102C	45	1.5-2.0	25	200	30	250	.25-1.5	2.0-7.5
DVB6102D	45	2.0-3.0	25	200	25	250		
DVB6103A	60	.5-1.0	60	300	30	150		
DVB6103B	60	1.0-1.5	60	300	25	150		
DVB6103C	60	1.5-2.0	60	300	20	150	.10-1.0	1.3-4.0
DVB6103D	60	2.0-3.0	60	300	15	150		
DVB6104A	75	1.5-3.5	100	400	15	125		
DVB6104B	75	3.5-5.5	100	400	15	125		
DVB6104C	75	5.5-7.5	100	400	10	125	0.5-.75	.75-3.0
DVB6104D	75	7.5-10.0	100	400	10	125		

Step Recovery Diode Chips

Type Number	V_B(1) (Volts) Min.	C_{J-6}(2) (pF)	τ(3) (ns) Min.	T_T(4) (ps) Max.	F_{C-6}(5) (GHz) Min.	Typical Input Freq (GHz)	Typical Output Freq (GHz)	Chip Style
CVB1015A		0.25-0.50						150-806
CVB1015B	15	0.50-1.0	10	70	300	0.5-3.0	9.0-18.0	150-801
CVB1015C		1.0-1.5						150-801
CVB1030A		0.25-0.50						150-801
CVB1030B	30	0.50-1.0	10	100	300	0.5-3.0	5.0-15.0	150-801
CVB1030C		1.0-1.5						150-801
CVB1045B		0.50-1.0						150-801
CVB1045D	45	1.0-2.0	25	200	250	.25-1.5	2.0-7.5	150-802
CVB1045E		2.0-3.0						150-802

Notes

1. Measured at $I_R = 10\ \mu A$
2. Measured at 1 MHz, $V_R = 6$ volts
3. Measured at $I_F = 10$ mA, $I_R = 6$ mA (see Figure 4)
4. Measured at $V_R = 10$ volts, $I_F = 10$ mA (see Figure 5)
5. Measured at F = 1 GHz, $V_R = 6$ volts

Step Recovery Diodes, Multichip SRD and SRD Chips

2 CHIP—023-001 Package

Type Number	(1) V_B (Volts)	(2) $C_{j\text{-}6}$ (pF)	(3) τ (ns) Min.	(4) T_T (ps) Max.	θ_{th} (°C/watt) Max.	(5) $F_{C\text{-}6}$ (GHz) Min.	Typical Input Freq. (GHz)	Typical Output Freq. (GHz)
DVB6850A		.25–.50			35			
DVB6850B	30	.50–1.0	10	80	25	250	0.5–3.0	9.0–18.0
DVB6850C		1.0–1.5			20			
DVB6851A		.25–.50			35			
DVB6851B	60	.50–1.0	10	100	25	250	0.5–3.0	5.0–15.0
DVB6851C		1.0–1.5			20			
DVB6852A		0.5–1.0			30			
DVB6852B	90	1.0–1.5	25	200	25	225	.25–1.5	2.0–7.5
DVB6852C		1.5–2.0			20			

2 CHIP—017-001 Package

DVB6860A		0.5–1.0			30			
DVB6860B	90	1.0–1.5	25	250	25	225	.25–1.5	2.0–6.0
DVB6860C		1.5–2.0			20			
DVB6861A		0.5–1.0			18			
DVB6861B	120	1.0–1.5	60	350	15	125	0.1–1.0	1.2–4.0
DVB6861C		1.5–2.0			12			
DVB6862A		1.5–3.5			10			
DVB6862B	150	3.5–5.5	100	450	10	100	.05–.75	.75–2.5

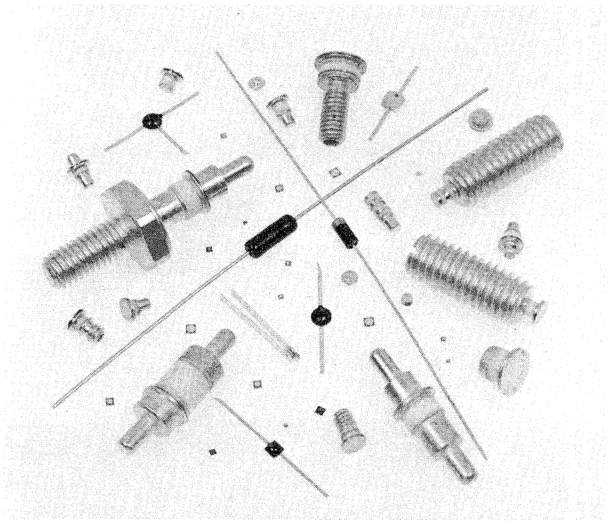
3 CHIP—017-001 Package*

DVB6870A		0.5–1.0			20			
DVB6870B	135	1.0–1.5	25	300	15	220	.25–1.5	1.5–5.0
DVB6870C		1.5–2.0			10			
DVB6871A		0.5–1.0			10			
DVB6871B	180	1.0–1.5	60	400	8	120	0.1–1.0	1.0–3.0
DVB6871C		1.5–2.0			6			
DVB6872A		1.5–3.5			7			
DVB6872B	225	3.5–5.5	100	500	6	100	.05–.75	.75–2.0

Notes
1. Measured at I_R = 10 µA
2. Measured at 1 MHz, V_R = 6 volts
3. Measured at I_F = 10 mA, I_R = 6 mA (see Figure 4)
4. Measured at V_R = 10 volts, I_F = 10 mA (see Figure 5)
5. Measured at F = 1 GHz, V_R = 6 volts

*Four chip versions available for some combinations of V_B and C_{J-6}

A-Mode Multiplier Diodes, Multichip A-Mode Diodes, A-Mode Chips



Features

- High Efficiency
- High Power Handling Capability
- High Reliability

Description

Alpha A-Mode diodes are oxide passivated, epitaxial silicon mesa designs. Careful attention to diffusion profiles makes these diodes an ideal choice for low order multiplier circuits. They are available in a broad range of packages or in chip form for those who wish to bond A-Modes into their own circuits. In addition, multichip packaged devices are available for high power applications.

Application

There are basically four types of multiplier devices in common usage: 1) the resistive multiplier, 2) the varactor (square law or tuning diode) multiplier, 3) the A-Mode, and 4) the step recovery diode. The resistive multiplier (typically a Schottky diode) is for low order, low power and has low efficiency. Varactor multipliers are used as doublers or up converters ($N = 2$), while A-Modes are principally used when high power, high efficiency and wide bandwidth (10 to 20%) is required. The step recovery diode is used mainly for high order ($N \geq 4$) multiplication and as a comb generator. Alpha has a complete line of multiplier diodes for each case mentioned above (consult factory).

The Alpha A-Mode diode combines the characteristics of the step recovery diode and the square law varactor to optimize performance in low order multiplication. In operation the A-Mode diode is driven into forward conduction to use the charge storage characteristics of the step recovery diode, but it also uses the reactance change of the square law device to give good bandwidth in low order operation.

In general it is desirable that the minority carrier lifetime (τ) be greater than ten times the period of the input frequency, while the transition time (T_T) should be less than the period of the output frequency. Figures 2 and 3 are graphs which can be used to easily determine the limiting values of τ and T_T. Test circuits to determine τ and T_T are shown in Figures 4 and 5.

For optimum performance an ideal A-Mode will be a punch-through device at minus 10 volts (any increase in reverse bias above minus 10 volts will not decrease capacitance significantly), but will have a highly nonlinear capacitance increase as the diode is biased toward zero volts. This can be clearly seen in Figure 1. A-Mode diodes are highly efficient, and circuits with 10 to 20% bandwidth are possible. Idlers are needed for $N > 2$. A typical A-Mode circuit is shown in Figure 6.

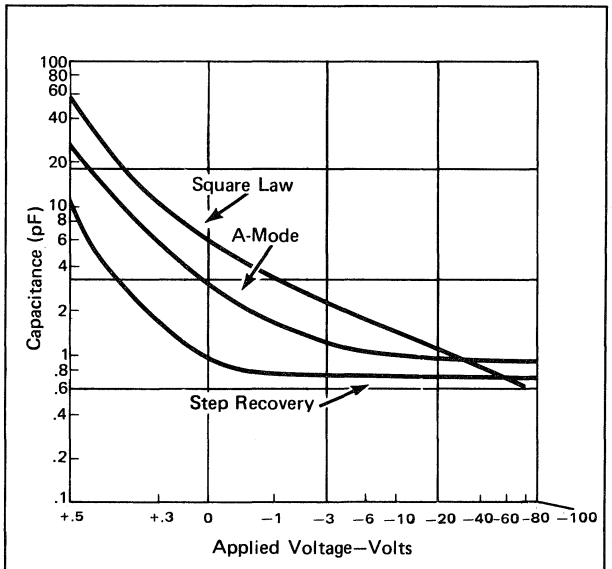


Figure 1. Capacitance vs Applied Voltage for Square Law and A-Mode Multipliers and Step Recovery Diodes

When higher microwave power is desired, the normal A-Mode may not be usable, since the necessary breakdown voltage may be too high for the transition time required. Alpha has solved this problem by using the multichip approach shown in Figure 7. The use of two chips provides improvement in both average power handling and peak power handling capability. For the construction shown on the left side of Figure 7, the chips are electrically in series and thermally in parallel, giving lower thermal resistance than chips which are in series both electrically and thermally. Average power is increased because, for a given rf reactance, each chip can have twice the capacitance of the equivalent single chip device. This results in a four times increase in the device area and in average power handling, compared to a single chip.

Alpha will be glad to discuss your multiplier needs and suggest a suitable device for your particular requirements.

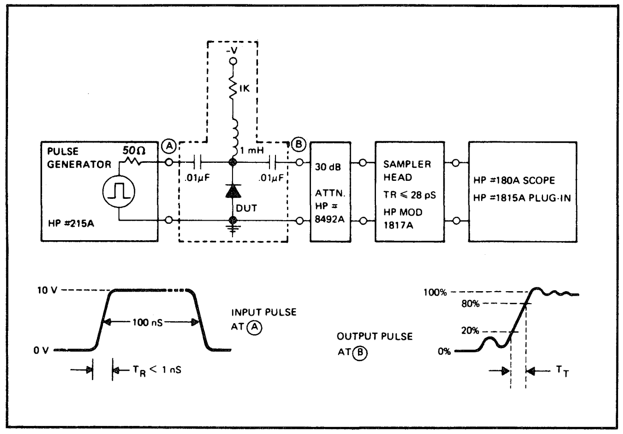


Figure 4. Transition Time, T_T, Test Set-Up

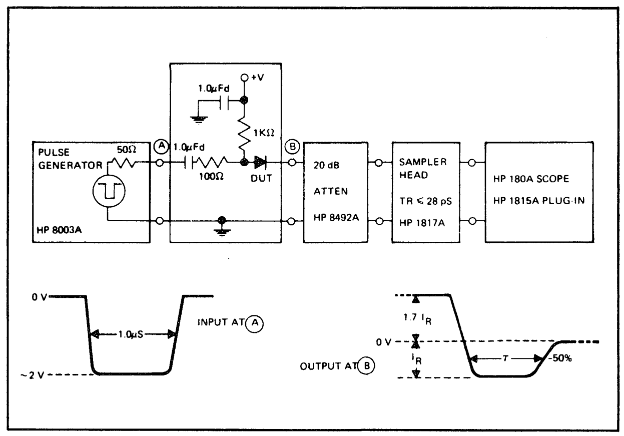


Figure 5. Minority Carrier Lifetime, $\mathcal{T}$, Test Set-Up

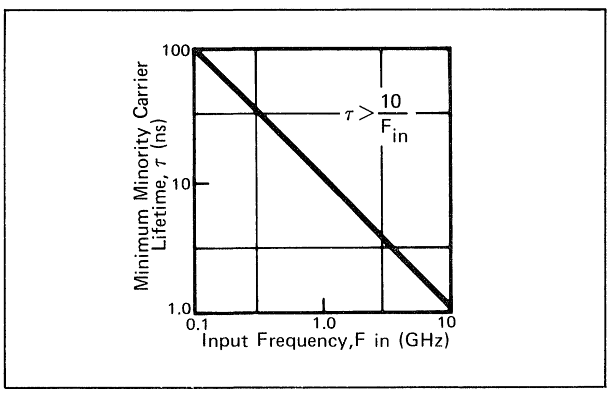


Figure 2. $\mathcal{T}$ vs F_{in}

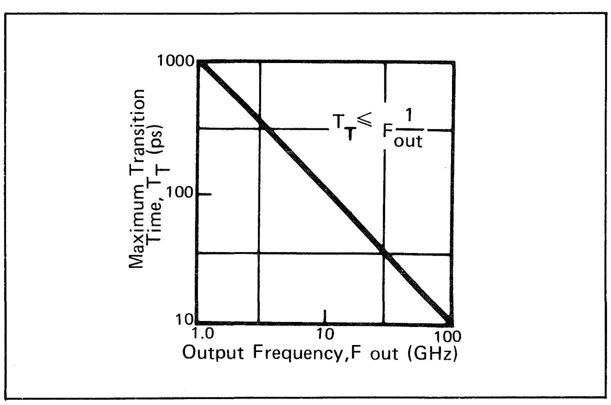


Figure 3. T_T vs F_{out}

A-Mode Multiplier Diodes, Multichip A-Mode Diodes, A-Mode Chips

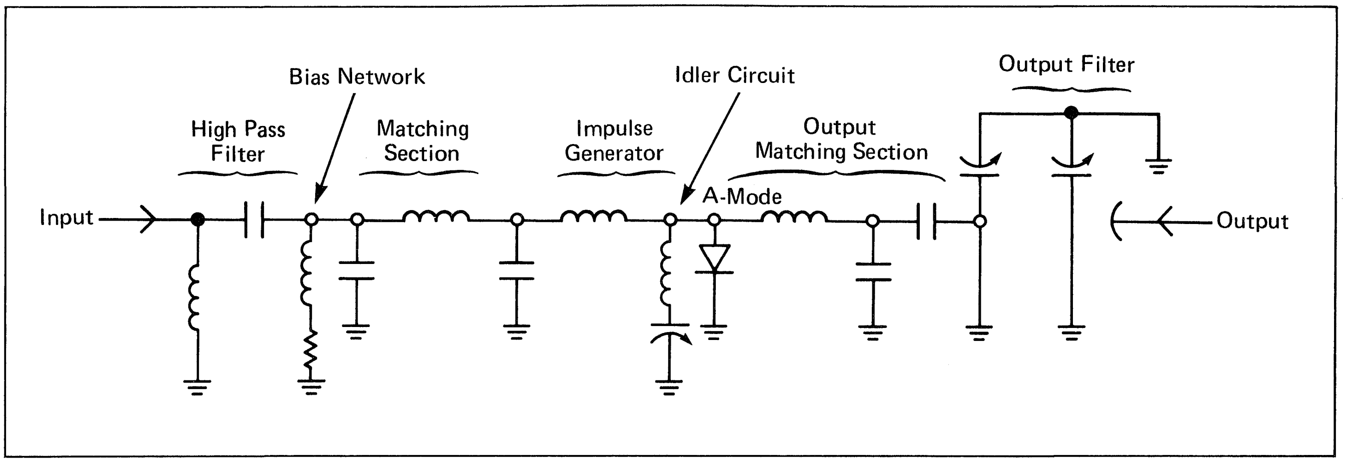


Figure 6. Typical A Mode Multiplier

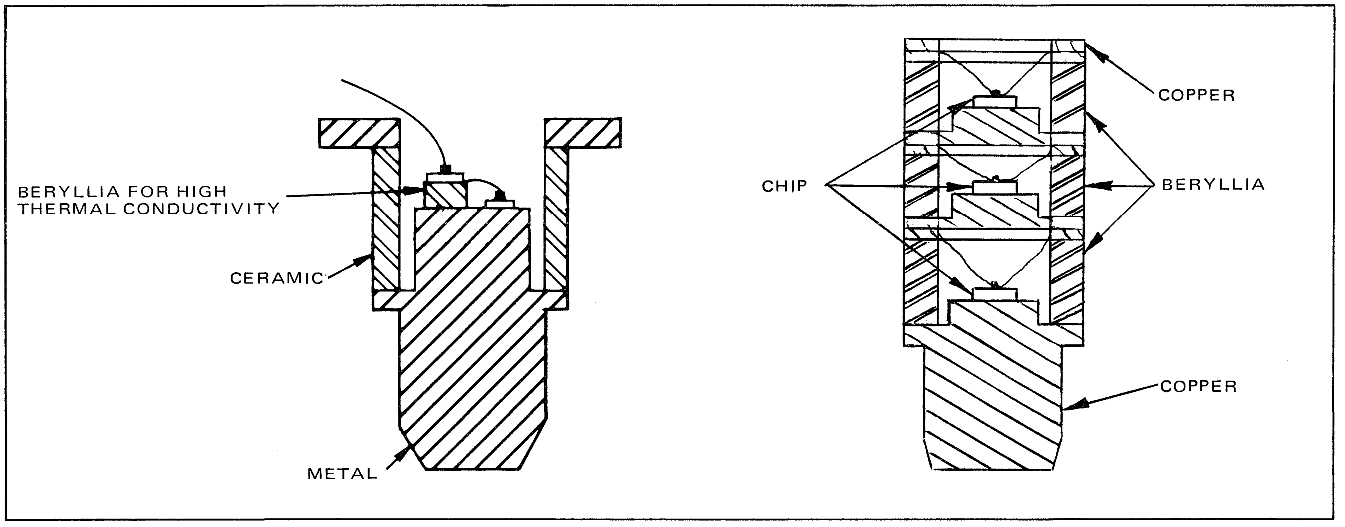


Figure 7. Multichip Packages

A-Mode Multiplier Diodes, Multichip A-Mode Diodes, A-Mode Chips

A-Mode Multiplier Diodes

Type Number	Package Style	Reverse Breakdown Voltage Min. (V)	Junction Capacitance at −6V & 1 MHz (pF)	Cutoff Frequency(1) Min. (GHz)	Minority Carrier Lifetime(2) Min. (ns)	Transition Time(3) Max. (ps)	Output Frequency Range (GHz)	Typical Efficiency as a Tripler(4) %	Thermal Resistance Max. (°C/W)
DVA6735A	023	30	0.25–0.5	200	10	150	12.0–15.0	30	75
DVA6735B	023	30	0.5–1.0	200	10	150	8.0–12.0	35	50
DVA6735C	023	45	0.5–1.0	175	20	200	8.0–12.0	40	50
DVA6735D	023	45	1.0–1.5	160	25	200	5.0–8.0	50	25
DVA6736A	158	60	1.5–2.5	150	60	400	5.0–8.0	45	15
DVA6736B	158	75	1.5–3.0	150	100	750	5.0–7.0	45	15
DVA6736C	158	75	3.0–6.0	120	100	1000	2.0–5.0	50	13
DVA6736D	158	100	5–10	90	150	2000	1.0–2.0	55	11
DVA6737A	117	100	10–15	90	150	2000	0.5–1.0	55	10
DVA6737B	117	125	5–10	60	200	3000	1.0–2.0	65	7
DVA6737C	117	125	10–15	60	200	3000	0.5–1.0	60	7
DVA6737D	117	150	10–20	40	250	5000	0.5–1.0	60	6
DVA6737E	117	175	15–25	20	300	8000	0.5–1.0	65	5

A-Mode Chips

Type Number	Package Style	Reverse Breakdown Voltage Min. (V)	Junction Capacitance at −6V & 1 MHz (pF)	Cutoff Frequency(1) Min. (GHz)	Minority Carrier Lifetime(2) Min. (ns)	Transition Time(3) Max. (ps)	Output Frequency Range (GHz)	Typical Efficiency as a Tripler(4) %
CVA1116A	150-801	30	0.25–0.5	200	10	150	12.0–15.0	30
CVA1116B	150-801	30	0.5–1.0	200	10	150	8.0–12.0	35
CVA1116C	150-802	45	0.5–1.0	175	20	200	8.0–12.0	40
CVA1116D	150-802	45	1.0–1.5	160	25	200	5.0–8.0	50
CVA1116E	150-802	60	1.5–2.5	150	60	400	5.0–8.0	45
CVA1116F	150-802	75	1.5–3.0	150	100	750	5.0–7.0	45
CVA1116G	150-802	75	3.0–6.0	120	100	1000	2.0–5.0	50

Notes:
1. Measured at $V_R = -6$ Volts
2. Measured in Circuit of Figure 5; $I_F = 10$ mA, $I_R = 6$ mA
3. Measured in Circuit of Figure 4; $I_F = 10$ mA, $V_R = 10$ Volts
4. Typical values for use as guidelines in circuit design. These diodes are recommended for multiplication ratios of 2, 3, and 4.

A-Mode Multiplier Diodes, Multichip A-Mode Diodes, A-Mode Chips

Multiplier A-Mode Diodes (2-Chip)

Type Number (023-001 Package)	Reverse Breakdown Voltage Min. (V)	Junction Capacitance at −12V (pF)	Cutoff Frequency(1) Min. (GHz)	Minority Carrier Lifetime(2) Min. (ns)	Transition Time(3) Max. (ps)	Output Frequency Range (GHz)	Available Output Power (W)	Efficiency as a Tripler(4) (%)	Maximum Thermal Resistance (°C/W)
DVA6738A	60	0.3-0.5	180	10	150	9.0-13.0	1	30	50
DVA6738B	90	0.5-1.0	150	30	300	7.0-10.0	5	45	22
DVA6738C	90	1.0-1.5	145	30	300	7.0-9.0	5	45	20
DVA6738D	120	1.0-1.5	140	50	400	5.5-9.0	6	50	18
DVA6738E	120	1.5-2.5	120	60	500	5.0-8.0	7	50	15
DVA6738F	120	2.5-3.5	120	60	700	3.0-5.0	10	50	13
DVA6738G	150	4.0-5.0	70	100	1000	2.0-4.0	20	55	11
DVA6738H	150	8.0-10.0	50	100	1000	1.0-2.5	35	65	7

Notes:
1. Measured at $V_R = -12$ Volts
2. Measured in Circuit of Figure 5; $I_F = 10$ mA, $I_R = 6$ mA
3. Measured in Circuit of Figure 4; $I_F = 10$ mA, $V_R = 10$ Volts
4. Typical values for use as guidelines in circuit design. These diodes are recommended for multiplication ratios of 2, 3, and 4.

Multichip A-Mode Diodes (3 Chip)

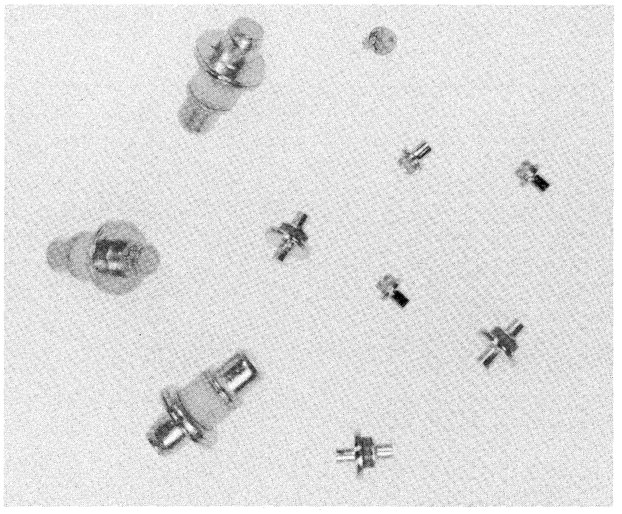
Type Number	Package Style	Reverse Breakdown Voltage Min. (V)	Junction Capacitance at −18V (pF)	Cutoff Frequency(1) Min. (GHz)	Minority Carrier Lifetime(2) Min. (ns)	Transition Time(3) Max. (ps)	Output Frequency Range (GHz)	Available Output Power (W)	Efficiency as a Tripler(4) (%)	Maximum Thermal Resistance (°C/W)
DVA4580A	367-001	135	0.8-1.3	150	20	300	7.0-9.0	7	45	19
DVA4580B	367-001	180	1.0-1.5	140	50	400	5.5-9.0	8	50	16
DVA4580C	367-001	180	1.5-2.5	120	50	500	5.0-8.0	10	50	13
DVA4580D	367-001	180	2.5-3.5	120	50	700	3.0-5.0	15	50	11
DVA4580E	367-001	225	4.0-5.0	70	100	2000	2.0-4.0	30	55	10
DVA4580F	367-001	225	8.0-10.0	50	100	2000	1.0-2.5	50	65	6
DVA6739A	017-001	135	0.8-1.3	150	20	300	7.0-9.0	7	45	19
DVA6739B	017-001	180	1.0-1.5	140	50	400	5.5-9.0	8	50	16
DVA6739C	017-001	180	1.5-2.5	120	50	500	5.0-8.0	10	50	13
DVA6739D	017-001	180	2.5-3.5	120	50	700	3.0-5.0	15	50	11
DVA6739E	017-001	225	4.0-5.0	70	100	2000	2.0-4.0	30	55	10
DVA6739F	017-001	225	8.0-10.0	50	100	2000	1.0-2.5	50	65	6

Notes:
1. Measured at $V_R = -18$ Volts
2. Measured in Circuit of Figure 5; $I_F = 10$ mA, $I_R = 6$ mA
3. Measured in Circuit of Figure 4; $I_F = 10$ mA, $V_R = 10$ Volts
4. Typical values for use as guidelines in circuit design. These diodes are recommended for multiplication ratios of 2, 3, and 4.

GaAs Multiplier Diodes for Millimeter Waves

Features

- Efficient Multiplication to 94 GHz
- Millimeter Wave Packages
- High Reliability and Space Qualified



Description

Alpha offers a line of Gallium Arsenide multiplier varactors specifically designed for low order multiplication at high output frequencies. These varactors are diffused junction epitaxial devices (mesa structure). The circuit designer can take advantage of the diode's high capacitance swing to generate the needed harmonics in doubler and tripler circuits.

These diodes may be used to double, triple, or quadruple the frequency output of Gunn or FET oscillators to produce outputs from 20 to 90 GHz. Alpha's Millimeter Wave Division has successfully used them to fabricate millimeter wave phase shifters, modulators and upconverters as well as multiplier signal sources.

The diodes are offered in the 023 outline for application up to 35 GHz output, the 067 outline for application up to 60 GHz output (the 067 outline has the same interior dimensions as the 082 but has a cathode prong to permit good heat sinking), and the 290 outline which has been used in doubling to 94 GHz and tripling to 130 GHz.

Performance Data

Typical doubler performance is as follows:

Package	F_{out} GHz	P_{out} MW	%	C_{JO} (Typ.)	V_B
023 067 082	20	200	50	.5	35
067 082 290	40	150	40	.3	25
290	80	40	25	.15	15

Characteristics

Package Outline: 023-001

$V_B^{(1)}$(min)	10 Volts				20 Volts			30 Volts		40 Volts	
$C_{J0}^{(2)}$(pF)	0.3–0.35	0.3–0.45	.3–.6	.6–1.0	.3–.45	.3–.6	.6–1.0	.3–.6	.6–1.0	0.3–0.6	0.6–1.0
$P_T^{(3)}$ (max)	200 mW	250 mW	250 mW	300 mW	250 mW	300 mW	350 mW	300 mW	400 mW	350 mW	400 mW
$F_{C-6}^{(4)}$(GHz)											
200			D5244-06	D5254-06		D5245-06	D5255-06	D5246-06	D5256-06	D5249-06	D5259-06
250			D5244-12	D5254-12		D5245-12	D5255-12	D5246-12	D5256-12	D5249-12	
300			D5244-18	D5254-18		D5245-18	D5255-18	D5246-18		D5249-18	
350			D5244-24			D5245-24		D5246-24		D5249-24	
400			D5244-30			D5245-30		D5246-30			
450		D5244-36			D5245-36						
500		D5244-42									
550	D5244-48										

GaAs Multiplier Diodes for Millimeter Waves

Package Outline: 067-001

V_B[(1)](min)	10 Volts				20 Volts			30 Volts		40 Volts	
C_{J0}[(2)](pF)	0.3–0.35	0.3–0.45	.3–.6	.6–1.0	.3–.45	.3–.6	.6–1.0	.3–.6	.6–1.0	0.3–0.6	0.6–1.0
P_T[(3)] (max)	200 mW	250 mW	250 mW	300 mW	250 mW	300 mW	350 mW	300 mW	400 mW	350 mW	400 mW
F_{C-6}[(4)](GHz)											
200			D5002-06	D5005-06		D5006-06	D5007-06	D5008-06	D5009-06	D5018-06	D5019-06
250			D5002-12	D5005-12		D5006-12	D5007-12	D5008-12	D5009-12	D5018-12	
300			D5002-18	D5005-18		D5006-18	D5007-18	D5008-18		D5018-18	
350			D5002-24			D5006-24		D5008-24		D5018-24	
400			D5002-30			D5006-30		D5008-30			
450		D5002-36			D5006-36						
500		D5002-42									
550	D5002-48										

Package Outline: 290-001

V_B[(1)](min)	10 Volts			20 Volts			30 Volts		
C_{J0}[(2)](pF)	0.1–0.2	.2–.3	0.3–0.6	0.1–0.2	.2–.3	0.3–0.6	0.1–0.2	.2–.3	0.3–0.6
P_T[(3)] (max)	150 mW	200 mW	250 mW	200 mW	250 mW	300 mW	200 mW	250 mW	300 mW
F_{C16}[(4)](GHz)									
400	DVF4559-01	DVF4559-05	DVF4559-11	DVF4559-21	DVF4559-25	DVF4559-31	DVF4559-41	DVF4559-44	DVF4559-51
450	DVF4559-02	DVF4559-06		DVF4559-22	DVF4559-26		DVF4559-42		
500	DVF4559-03	DVF4559-07		DVF4559-23			DVF4559-43		
550	DVF4559-04			DVF4559-24					

Notes:

1. Breakdown Voltage (V_B) is measured at 10 microamps reverse current.
2. Total Capacitance is measured at 1 MHz and 0 bias. Junction Capacitance (C_j) is calculated by subtracting the typical package capacitance from the total capacitance. Capacitance selection to = 0.025 pF is standard. Specify C_{J0} center value
   - Self resonant frequency may be calculated from $F_O = \frac{1}{2\pi\sqrt{LC_J}}$ where L is the series inductance.
   - Series resistance may be calculated from $R_S = \frac{1}{2\pi F_C C_J}$
3. P_T(max) is maximum dissipated power at room temperature for the average capacitance range. At maximum dissipated power, junction temperature is 175°C.
4. Frequency Cutoff (F_C) of the diodes is measured by Houlding technique. Deloach measurements are available and are utilized for characterizing low capacitance diodes. See GaAs Parametric Amplifier Varactor data sheet for Technical Note on Frequency Cutoff Measurement.

Environmental Capability

Thermal Shock...................... – 195.8°C to + 100°C
Centrifuge............................20,000 G
Gross Leak Test ....10^{-5} – cc/sec
Fine Leak Test.......................10^{-8} – cc/sec
High Temperature Storage.....200°C

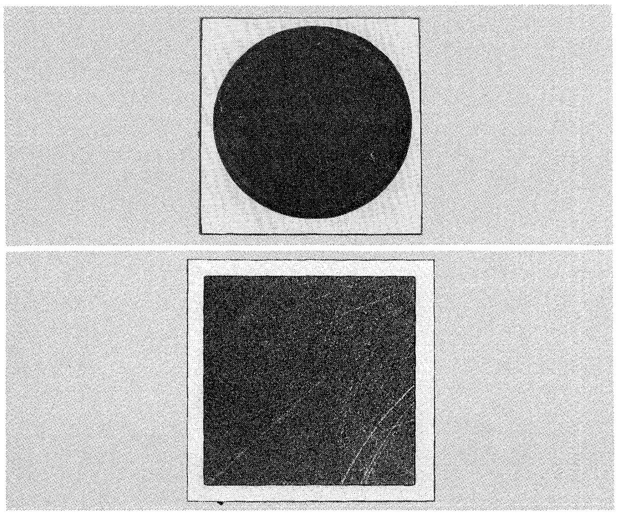
Burn-In

A special variation of this diode family is the only space-qualified, high reliability varactor available today and is used on the ESRO European satellite program.

All GaAs varactors are subjected to burn-in screening prior to final measurements: typical burn-in for C_{J0} = 0.3 pF is: 60 Hz, I_p = 30mA, V_p = 2.5 V (50 ohm load) at 100°C, 16 hours.

Capacitors

Chip MIS Capacitors



Features

- High Reliability Silicon Oxide-Nitride Dielectric
- Low Loss — Typically 0.04 dB in a 50 Ohm System
- Operation Through 26 GHz
- Wide Temperature Operation: – 55°C to 200°C

Types

- SC9002 Series
- SC9103 Series

Description

MIS Chip Capacitors are thin film devices which feature small size and very high Q making them ideal for hybrid microelectronic applications at microwave frequencies.

The SC9002 series have circular metallic top contacts, while the SC9103 series have rectangular metallic top contacts. The latter are especially useful when chip size must be minimized. The periphery of the rectangular contact is typically two mils from the edge of the die. When the capacitor chip is placed close to an adjacent substrate, the lead inductance can be reduced to a very low value.

The devices have a dielectric composed of thermally grown silicon dioxide over which a layer of silicon nitride is deposited. This dielectric possesses a low temperature coefficient of capacitance, very high insulation resistance (typically $> 10^{12}$ ohms), and low dissipation factor. The devices also exhibit excellent long term stability making them suitable for high reliability applications. The capacitors have a high dielectric breakdown which permits the use of thin dielectrics resulting in large capacitance on a small area.

The plated gold metallization on the top face of the chip extends over the entire active area of the device. Gold wire can be readily thermocompression bonded to this metallization or gold ribbon may be used where low inductance is a requirement. The back side of the chip is also gold metallized and is readily solderable. Custom parts can be made having special values of capacitance or working voltage. Special metallization geometries or chip sizes can also be made available upon request.

Applications

Chip and beam-lead MIS capacitors are used extensively in hybrid microwave circuits. Applications include d-c blocking and RF bypassing. They can also be used as fixed capacitance tuning elements in filters, oscillators and matching networks. Chip or beam-lead devices may be used for series microstrip circuits using alumina substrates while chip devices are preferred for teflon fiberglass microstrip where lead flexibility is desired. Chip devices are likewise preferred for shunt mounting. See Application Note 80000 in Section 7 for recommended handling and bonding procedures.

Electrical Characteristics

Capacitance Range[1] .... 0.5 to 1000 pF
Temperature Coefficient .... 50 ppm/°C Typical
Capacitance Tolerance[2] .... ± 20%
Operating Temperature .... – 55°C to 200°C
Dielectric Withstanding Voltage .... 100 Volts
Insulation Resistance .... 10^6 Megohms Typical

Tests on typical MIS capacitors at L- and S-band show insertion loss to be one-half to one-third that of equivalent porcelain type capacitors, without any of the associated resonance problems. Power tests indicate that the only limitation is the actual breakdown voltage of the device (see data section). A typical insertion loss versus frequency graph is shown in Figure 1. These data are taken from an actual test circuit with series mounted beam-lead or chip capacitors on a 50-ohm microstrip transmission line. The apparent higher loss at lower frequencies on the lower capacitance units is strictly due to the capacitive reactance of the capacitor. A typical circuit application is shown in Figure 2.

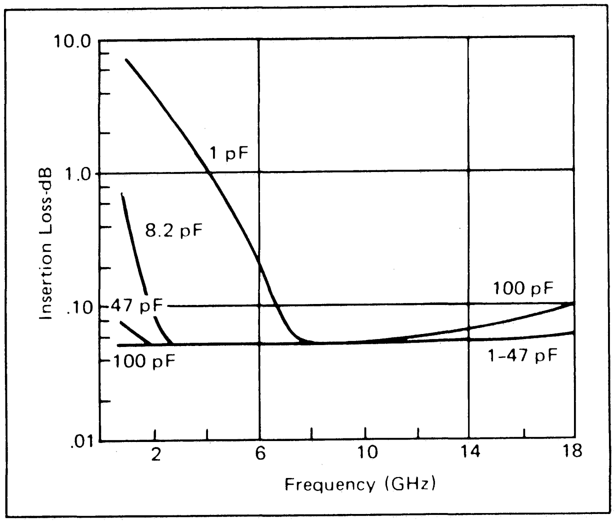


Figure 1. Typical Insertion Loss vs. Frequency (50 ohm System)

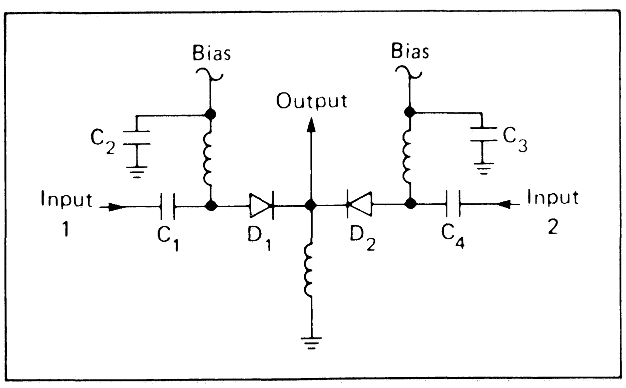


Figure 2. Typical SPDT Switch

C_1, C_4—Chip or Beam Lead MIS Capacitor
C_2, C_3—Chip MIS Capacitor
D_1, D_2—DSG6474 Beam Lead PIN Diode

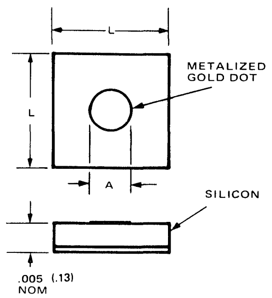
Type Number	Package Style	Capacitance (pF)
SC 9002AM SC 9103 AM	149-801 149-816	0.5 – 1.0
SC 9002BM SC 9103BM	149-801 149-816	1.0 – 2.2
SC 9002CM SC 9103CM	149-801 149-816	2.2 – 4.7
SC 9002DM SC 9103DM	149-801 149-816	5.6 ± 20%
SC 9002EM SC 9103EM	149-802 149-816	6.8 ± 20%
SC 9002FM SC 9103FM	149-802 149-817	8.2 ± 20%
SC 9002GM SC 9103GM	149-802 149-817	10.0 ± 20%
SC 9002HM SC 9103HM	149-803 149-817	15.0 ± 20%
SC 9002JM SC 9103JM	149-803 149-817	22.0 ± 20%
SC 9002KM SC 9103KM	149-805 149-818	33.0 ± 20%
SC 9002LM SC 9103LM	149-805 149-818	47.0 ± 20%
SC 9002MM SC 9103MM	149-805 149-818	68.0 ± 20%
SC 9002NM SC 9103NM	149-806 149-817	100.0 ± 20%
SC 9002OM SC 9103OM	149-806 149-819	150.0 ± 20%
SC 9002PM SC 9103PM	149-806 149-820	220.0 ± 20%
SC 9103QM	149-821	330.0 ± 20%
SC 9103RM	149-822	500.0 ± 20%
SC 9103SM	149-822	750.0 ± 20%
SC 9103TM	149-822	1000.0 ± 20%

Notes:
1. Capacitance measured at 1 MHz, other values available; consult factory.
2. Closer tolerances available on request.

C_1, C_4 — Chip or Beam-Lead MIS Capacitor
C_2, C_3 — Chip MIS Capacitor
D_1, D_2 — DSG6474 Beam-Lead PIN Diode

Chip MIS Capacitors

Outline Drawings

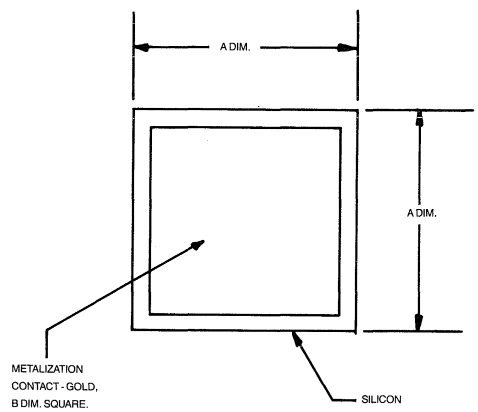


	INCHES		MM	
CHIP STYLE	DIM A	DIM L	DIM A	DIM L
149-801	.002	.012	.05	.30
149-802	.002	.020	.05	.50

149

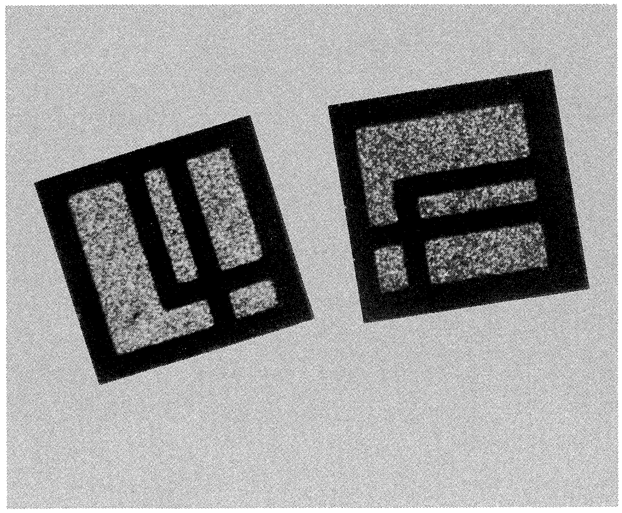
	Inches		MM	
Chip Style	**Dim "A" Min.**	**Dim. "L"**	**Dim "A" Min.**	**Dim. "L"**
149-801	.002	.012	.05	.30
149-802	.005	.020	.13	.51
149-803	.010	.030	.25	.76
149-805	.015	.040	.38	1.02
149-806	.020	.050	.51	1.27

Chip Style	Dim "A" Nominal	Dim "L" ±.002	MM	
149-816	.008	.012	.20	.30
149-817	.014	.020	.36	.51
149-818	.024	.030	.61	.76
149-819	.034	.040	.86	1.00
149-820	.044	.050	1.11	1.27
149-821	.060	.070	1.52	1.78
149-822	.088	.100	2.24	2.54
149-823	.022	.025	.56	.65



149-823

Binary Trimming Capacitors (MIS)



Features

- High Reliability Silicon Oxide-Nitride Dielectric
- Low Loss — Typically 0.04 dB in a 50 Ohm System
- Operation Through 26 GHz
- Wide Temperature Operation: – 55°C to 200°C

Types

- SC9020/22/24 Series

Description

Four capacitors are provided on a single chip, binary weighted, to give 15 different values of capacitance by selective interconnection. These chips are designed for low inductance microwave applications and have the following features:

- Each individual capacitor is accessible from chip edge.
- Connection of two or more capacitors can always be made via a short ribbon at a central point.

The trimming capacitor is an MIS thin film device which has a dielectric composed of thermally grown silicon dioxide over which a layer of silicon nitride is deposited. This dielectric possesses a low temperature coefficient of capacitance, very high insulation resistance (typically $> 10^{12}$ ohms), and low dissipation factor. The device also exhibits excellent long term stability making it suitable for high reliability applications. The capacitor has a high dielectric breakdown which permits the use of thin dielectrics resulting in large capacitance in a small area.

The plated gold metallization on the top face of the chip extends over most of the top surface. Gold wire can be readily thermocompression bonded to this metallization. The back side of the chip is also gold metallized and is readily solderable. Custom parts can be made having special values of capacitance or working voltage. Special metallization geometries or chip sizes can also be made available upon request.

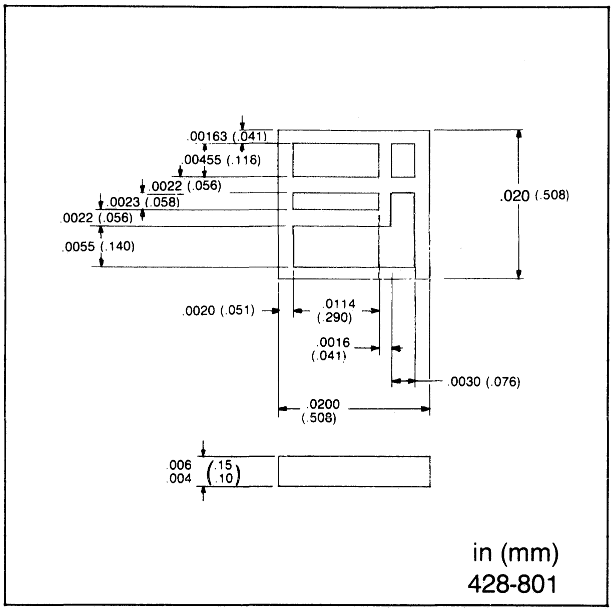
Specifications

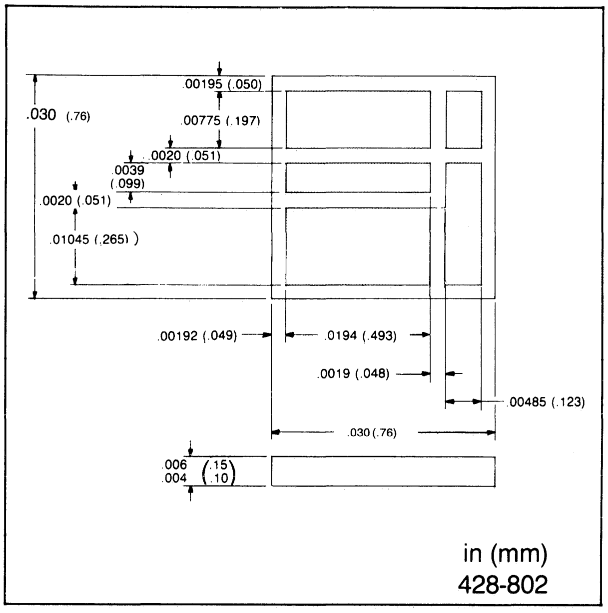
Dielectric Withstanding Voltage .... 100 Volts Min.
Insulation Resistance .... 10^6 Megohms Typical
Operating Temperature Range .... – 55°C to 200°C
Temperature Coefficient, Typ. ....50 ppm/°C
Capacitance .... Per Table
Capacitance Tolerance .... ± 20%

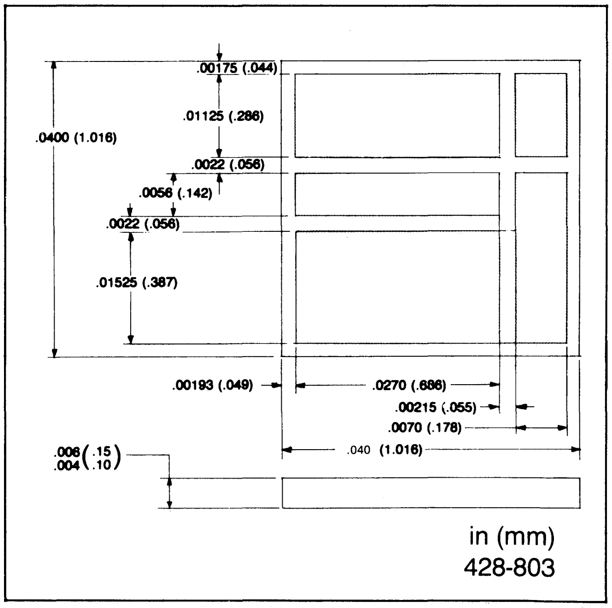
Type No.	Capacitance (pF)	Max. Available Capacitance (pF)	Capacitance Steps (pF)	Package Style
SC 9020A	0.25, 0.50, 1.0, 2.0	3.75	0.25	428-801
SC 9020B	0.50, 1.0, 2.0, 4.0	7.5	0.50	428-801
SC 9020C	1.0, 2.0, 4.0, 8.0	15	1.0	428-801
SC 9022A	0.75, 1.5, 3.0, 6.0	11.25	0.75	428-802
SC 9022B	1.5, 3.0, 6.0, 12.0	22.5	1.5	428-802
SC 9022C	3.0, 6.0, 12.0, 24.0	45	3.0	428-802
SC 9024A	2.0, 4.0, 8.0, 16.0	30	2.0	428-803
SC 9024B	4.0, 8.0, 16.0, 32.0	60	4.0	428-803
SC 9024C	6.0, 12.0, 24.0, 48.0	90	6.0	428-803

Binary Trimming Capacitors (MIS)

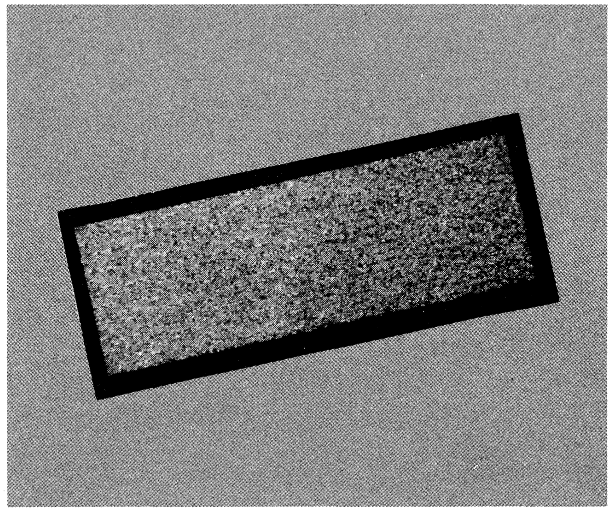
Outline Drawings







FET Chip Mounting Capacitors (MIS)



Features

- High Reliability
- Low Loss
- Operation through 26 GHz
- Wide Temperature Operation

Types

- SC9016
- SC9017

Description

The FET Chip Mounting Capacitor is an MIS thin film device which features small size and very high Q making it ideal for hybrid microelectronic applications at microwave frequencies.

The device has a dielectric composed of thermally grown silicon dioxide over which a layer of silicon nitride is deposited. This dielectric possesses a low temperature coefficient of capacitance, very high insulation resistance (typically $> 10^{12}$ ohms), and low dissipation factor. The device also exhibits excellent long term stability making it suitable for high reliability applications. The capacitor has a high dielectric breakdown which permits the use of thin dielectrics resulting in large capacitance in a small area.

The plated gold metallization on the top face of the chip extends over most of the top surface. Gold wire can be readily thermocompression bonded to this metallization. The back side of the chip is also gold metallized and is readily solderable. Custom parts can be made having special values of capacitance or working voltage. Special metallization geometries or chip sizes can also be made available upon request.

Specifications

Capacitance .... 100 pF
Capacitance Tolerance .... ±20%
Temperature Coefficient, Typ. ....50 ppm/°C
Operating Temperature Range .... −55°C to 200°C
Dielectric Withstanding Voltage .... 50 Volts

Applications

The capacitor is designed to serve as a carrier for FET amplifier chips. As shown in Figure 1, when the FET chip is mounted directly onto the top metal pad of the capacitor, the gate and drain pads are on the same level as the top of the alumina circuit. Therefore, short wire lengths can be used to minimize the lead inductance. The SC9016 is a 10 mil thick chip designed for 15 mil thick alumina, while the SC9017 is a 20 mil thick chip designed for 25 mil thick alumina. When the FET chip is mounted directly onto the top metal pad of the capacitor, the source pads on the FET chip can be wire bonded to the same metal pads, which accomplishes RF bypass to ground via the capacitor.

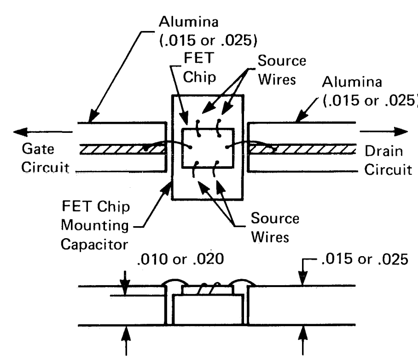
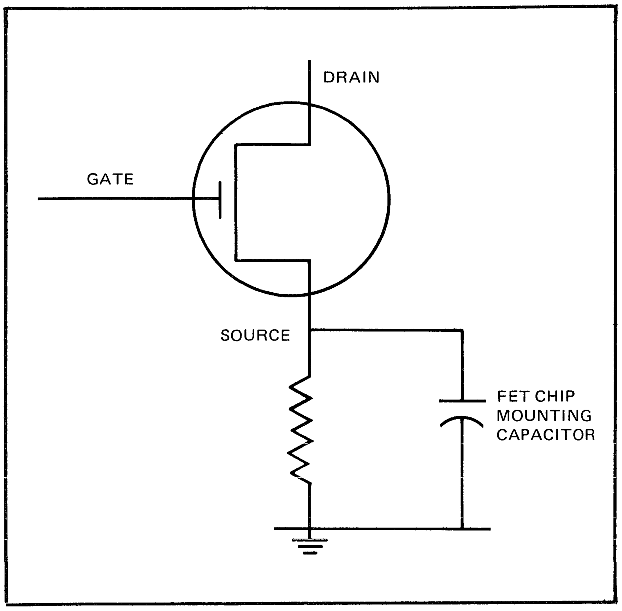


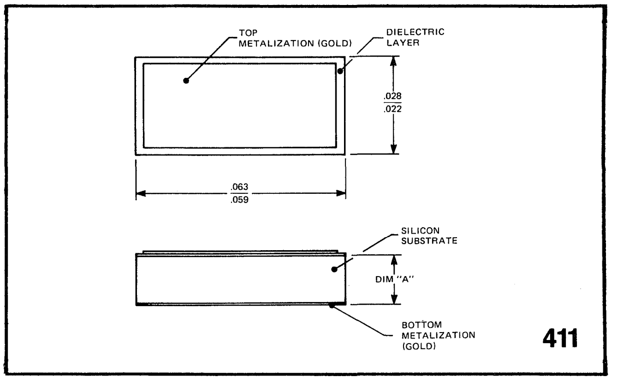
Figure 1

FET Chip Mounting Capacitors (MIS)

Schematic Diagram

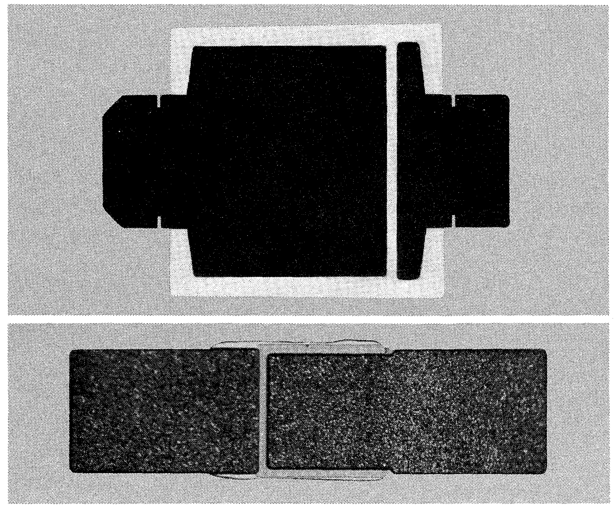


Outline Drawing



Type No.	Style	Dim "A"	For FET Chip Thickness	For Alumina Substrate Thickness
SC-9016	411-801	0.010	0.005	0.015
SC-9017	411-802	0.020	0.005	0.025

Beam Lead MIS Capacitors



Features

- High Reliability Silicon Oxide — Nitride Dielectric
- Low Loss — Typically 0.04 dB in a 50 ohm System
- Operation Through 26 GHz
- Wide Temperature Operation: –55°C to 200°C

Type

- SC 9001 Series

Description

Alpha oxide-nitride dielectric microwave capacitors are available in beam-lead form for ease in mounting. Very high-Q and small size make this family of capacitors ideally suited for microwave applications.

These capacitors have a silicon dioxide-nitride dielectric to assure high reliability and stability as well as low loss at microwave frequencies.

Other size variations, voltage breakdown and capacitance values are available on request.

Electrical Characteristics

Capacitance Range[1] .... 0.5 to 100 pF
Temperature Coefficient .... 50 ppm/°C Typical
Capacitance Tolerance[2] .... ±20%
Operating Temperature .... –55°C to 200°C
Dielectric Withstanding Voltage .... 50 Volts
Insulation Resistance .... 10^6 Megohms Typical

Applications

Beam-lead MIS capacitors are used extensively in microwave circuits. Applications include matching networks, bypass, blocking, and coupling capacitors and tuning elements in filters. Ease of mounting makes beam-lead devices particularly attractive for series microstrip circuits using alumina and quartz dielectrics. The use of beam-lead devices on flexible soft substrates is not recommended due to the high probability of device fracture and failure when the substrate moves during mounting or temperature cycling.

The low inductance of these devices insures that the series resonant frequency will be above X-band, and hence, ripple-free broad band response is assured. A mounted beam-lead capacitor is shown in Figure 1.

See Application Note 80000 in Section 7 for recommended handling and bonding procedures for beam-lead devices.

Type Number	Capacitance (pF)	Style
SC-9001A	0.5 to 1.0	300-801
SC-9001B	1.0 to 2.2	300-801
SC-9001C	2.2 to 4.7	300-801
SC-9001DM	5.6 ± 20%	300-801
SC-9001EM	6.8 ± 20%	300-801
SC-9001FM	8.2 ± 20%	300-801
SC-9001GM	10 ± 20%	300-803
SC-9001HM	15 ± 20%	300-803
SC-9001JM	22 ± 20%	300-803
SC-9001KM	33 ± 20%	300-803
SC-9001LM	47 ± 20%	300-803
SC-9001MM	68 ± 20%	300-804
SC-9001NM	82 ± 20%	300-804
SC-9001OM	100 ± 20%	300-804

Notes:
1. Capacitance measured at 1 MHz, other values available; consult factory.
2. Closer tolerances available on request.

Beam-Lead MIS Capacitors

A typical application is shown in Figure 2. MIS capacitors are frequently used in this type of circuit. Tests on typical MIS capacitors at L- and S-band show insertion loss to be one-half to one-third that of equivalent porcelain type capacitors, without any of the associated resonance problems. Power tests indicate that the only limitation is the dielectric withstanding voltage of the device (see data section). A typical insertion loss versus frequency graph is shown in Figure 3.

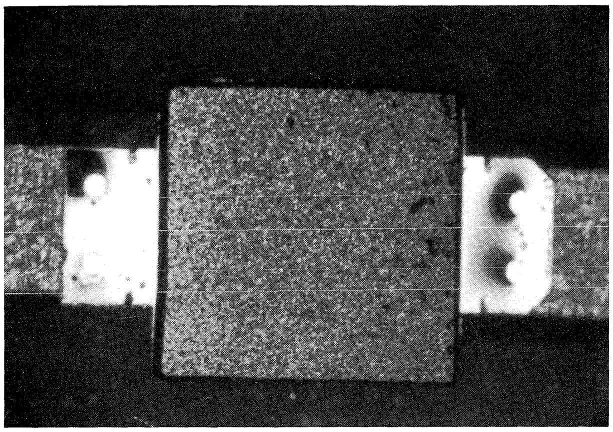


Figure 1. Photograph of a B-L Cap Mounted (Style 300-803)

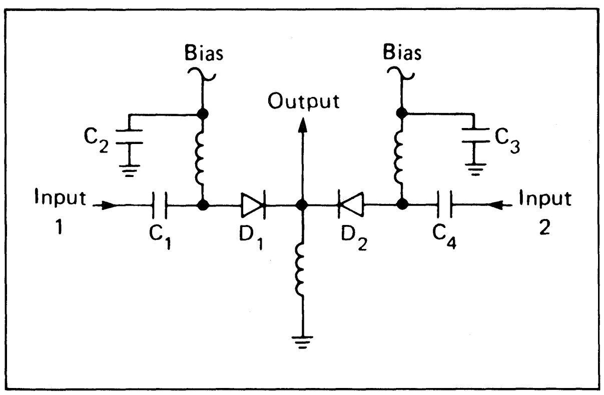
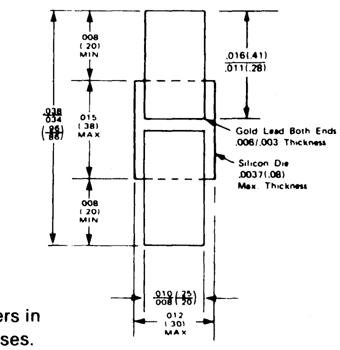


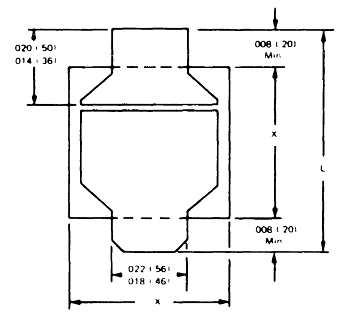
Figure 2. Typical SPDT Switch

Outline Drawings



Note: Millimeters in parentheses.

300-801



	Inches		MM	
Outline	**"X" Max.**	**"L"**	**"X" Max.**	**"L"**
300-803	.036	.055/.050	.89	1.42/1.27
300-804	.045	.065/.050	1.14	1.65/1.50

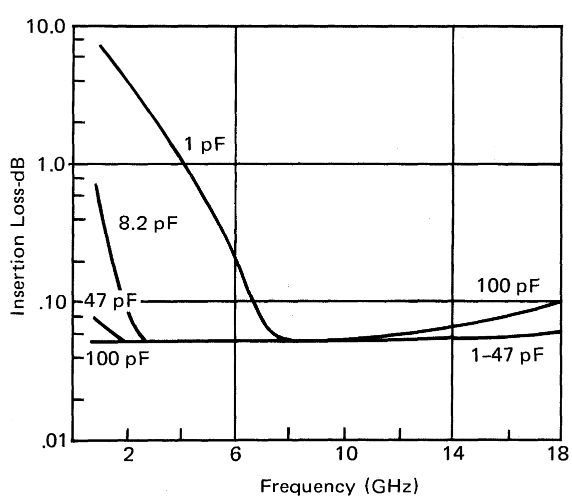
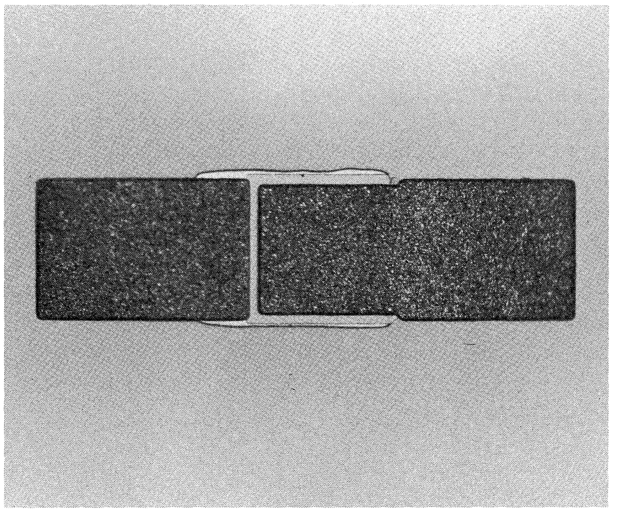


Figure 3. Typical Insertion Loss vs. Frequency (50 ohm System)

Millimeter Wave Beam-Lead MIS Capacitors

Features

- Miniature Beam-Lead Compatible with Thin Microstrip Lines
- High Reliability Silicon Oxide-Nitride Dielectric
- High Series Resonance — Operation through 100 GHz
- High Q — Extremely Low Loss
- Wide Temperature Operation: – 55°C to 200°C



Type

- SC9100 Series

Description

Alpha oxide-nitride dielectric microwave capacitors are available in beam-lead form for ease in mounting on sapphire and quartz circuits. The very high Q and small size make this product ideally suited to millimeter applications.

The width of the beam of this capacitor is 3 mil. This minimizes discontinuities on millimeter wave circuits which typically have 50 ohm transmission lines of similar size.

Applications

Beam-lead MIS capacitors are used extensively in microwave circuits where a series capacitance is indicated. Applications include matching networks, blocking, bypass, and coupling capacitors, as well as tuning elements in filters. The low inductance and capacitance of this series insures that the series resonant frequency will be close to 100 GHz. Hence, ripple-free response is assured.

A particularly useful result of beam-lead processing is that the devices have uniform electrical characteristics. This is especially desirable in the production of millimeter circuits where series inductance and capacitance must be tightly controlled. There is an additional advantage in the elimination of having to utilize chip and wire techniques in the assembly sequence. Such operations generally disrupt the work flow by requiring at least two pieces of assembly equipment.

Electrical Characteristics

Capacitance Range ....0.1 to 1.5 pF
Temperature Coefficient ....50ppm/°C Typical
Operating Temperature .... – 55°C to 200°C
Dielectric Withstanding Voltage .... 50 Volts
Insulation Resistance .... 10^6 Megohms Typical
Series Inductance ....0.02nH Typical

Type Number	Capacitance	Style
SC9100-01	.1 to .3	300-807
SC9100-02	.3 to .5	300-807
SC9100-03	.5 to .7	300-807
SC9100-04	.7 to .9	300-807
SC9100-05	.9 to 1.1	300-807
SC9100-06	1.1 to 1.3	300-807
SC9100-07	1.3 to 1.5	300-807

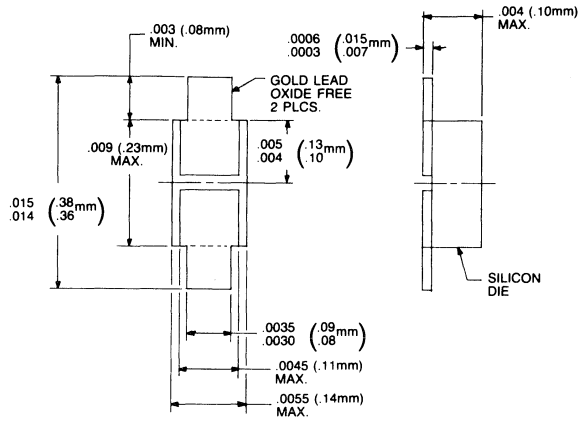
Note: The capacitance and the dielectric withstanding voltage are measured on 100% of the units. Data can be made available on request for a nominal charge.

Millimeter Wave Beam-Lead MIS Capacitors

Mounting Procedures

The recommended mounting procedure for these devices is thermocompression bonding on a hard surface. The capacitor has a 3 × 3 mil solid gold beam surface on each side of the device for bonding. The capacitor can easily be picked up by placing a hot bonding tool (350-450°C) on one of the gold beams. A two mil diameter, flat tungsten carbide tool is recommended . Force should be about 50 grams. After the device is picked up by the tool, it can easily be transferred to the desired bonding position. The capacitor is designed to be placed across a 5-8 mil wide gap printed on a transmission line. Note that the gap on the capacitor is located in the center of the silicon body.

Outline Drawing



300-807

Section 7
Bonding Methods, Testing Procedures, and High Reliability Capabilities

Bonding Methods, Testing Procedures, and High Reliability Capabilities

Application Note 80000: Bonding Methods: Diode Chips, Beam-Lead Diodes, and Capacitors

Diode Chips

HANDLING

Alpha chips are shipped in plastic chip trays containing up to 400 individual devices. The chips may be removed from the tray and positioned for inspection or bonding using tweezers or a vacuum pickup. Particular care must be exercised to avoid any mechanical damage to the active junction area when handling chips. In addition, if tweezers are used, care must be taken to avoid excessive force which might result in nicks or cracks.

Special handling precautions are also required to avoid electrical damage by static discharge. For package opening instructions see Figure 4.

DIE ATTACH

The recommended method for attaching Alpha semiconductor chips to substrates is by means of a solder preform or silver epoxy. Basically this method involves the use of the preform or epoxy to form a joint between the gold metallized base of the chip and the metallized area of the substrate. Recommended preform materials are: Gold (80%) — Tin (20%); Gold (89.5%) — Gallium (0.5%) — Germanium (10%); or Gold (90%) — Germanium (10%). These are available from Alpha Metals*, Jersey City, New Jersey. Recommended silver epoxy is Epo-tek H31D Single Component from Epoxy Technology Inc.

PROCEDURE (SEE FIGURE 1)

The substrate may be heated directly by placement on a heater strip or hot plate. Resistance heating may also be used, in which case the localized heat is supplied by passing current through the appropriate metallized portion of the substrate by use of two contact electrodes. Hot gas heating may also be used, in which case the localized heat is supplied by a jet flow of heated forming gas or nitrogen.

Temperatures of approximately 280°C for gold-tin, 350°C for gold-gallium-germanium and 380°C for gold-germanium are recommended. A 100°C bake for 1 hour is recommended for silver epoxy.

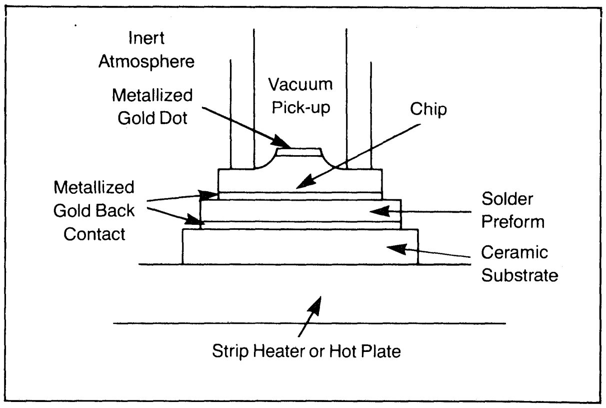


Figure 1. Die Attach Procedure

Exact temperatures should be determined empirically for the particular conditions at hand. The bonding should be done in an atmosphere of nitrogen or forming gas. Both solder preform and chip may best be handled by means of a vacuum pickup. A preform is placed on the desired location of the substrate followed by the chip. Appropriate force is maintained between substrate and chip while the preform melts and wets both substrate metallization and chip. The force, approximately 50 grams, is maintained until the preform solidifies. Cooling may be accelerated through use of a blast of inert gas.

LEAD BONDING

Wire or ribbon leads should be attached to the chip and the substrate by use of thermocompression bonding. As with the beam-lead devices, this method involves pressing the gold lead against the gold metallized area on the chip or substrate under proper conditions of heat pressure and scrub to effect a bond.

PROCEDURE (SEE FIGURE 2)

Gold should be used for the lead wire or ribbon. Though either ball bonding or wedge bonding may be used, the latter is generally preferred since smaller bond areas are possible with consequent less parasitic capacitance. The bonding tool is tungsten carbide, and the detail tip design is dependent upon the dimensions of the lead material to be bonded. A tip temperature of 350°C to 400°C with approximately 50 grams pressure is recommended. This temperature may be reduced by heating the substrate to 325°C or using ultrasonics for a scrub. Generally, a satisfactory bond is attained with a bonding time of 2–3 seconds. Optimum conditions should be determined by trial and error to adjust for differences in chip configurations, substrate condition and other variables.

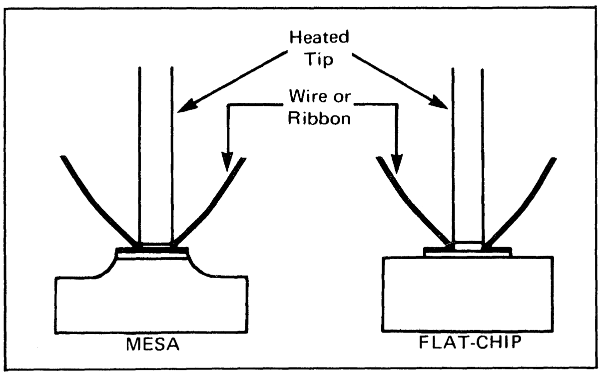


Figure 2. Lead Bonding Procedure

EQUIPMENT

Equipment for die attachment and lead bonding is commercially available from several manufacturers and varies in sophistication from laboratory setups to automated machines.

*Alpha Metals is not related in any way to Alpha Industries.

Beam-Lead Diodes and Capacitors

Due to their small size beam-lead devices are fragile and should be handled with extreme care. The individual plastic packages should be handled and opened carefully, so that no undue mechanical strain is applied to the packaged device. It is recommended that the beam-lead devices be handled through use of a vacuum pencil using an appropriate size vacuum needle to handle beam-lead chips or a pointed wooden stick such as a sharpened Q-tip or match. The device will adhere to the point and can easily be removed from the container and positioned accurately for bonding without damage. Such handling should be done under a binocular microscope with magnification in the range of 20X to 30X.

Special handling precautions are also required to avoid electrical damage, such as static discharge. For Bubble pack package opening instructions see Figure 5.

BONDING

Alpha beam-lead devices can best be bonded to substrates by means of thermocompression bonding. Essentially this type of bonding involves pressing the gold beam of the device against the gold plated metallized substrate under proper conditions of heat and pressure so that a metallurgical bonded joint between the two occurs.

PROCEDURE

The beam-lead devices to be bonded should be placed on a clean, hard surface such as a microscope slide. It is recommended that the beam side of the device be down so that this side will be towards the substrate when bonded. The device can be picked up by pressing lightly against one beam with the heated tip. The substrate can then be appropriately positioned under the tip and the device brought down against the substrate, with proper pressure applied by means of the weld head.

A bonding tip temperature in the 350°C to 450°C range is recommended along with a bonding force of 50 to 70 grams. The bonding time is in the range of 2 to 3 seconds. Optimum bonding conditions should be determined by trial and error to compensate for slight variations in the condition of the substrate, bonding tip, and the type of device being bonded. (See Figure 3.)

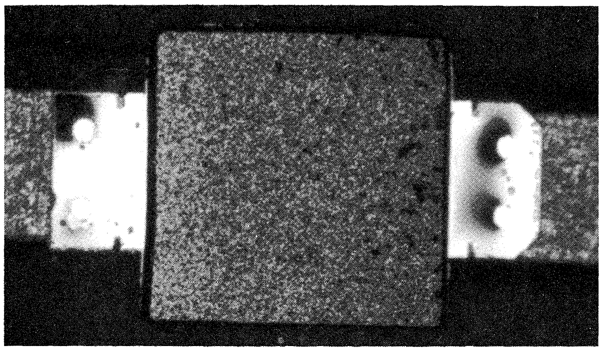


Figure 3. Photograph of a Bonded Beam-Lead Capacitor

EQUIPMENT

The heat and pressure are obtained through use of a silicon carbide bonding tip with a radius of two to three mils. Such an item is available from several commercial sources. In order to supply the required tip-travel and apply proper pressure, a standard miniature weld head can be used. Also available is a heated wedge shank which is held by the weld head and in turn holds the tip and supplies heat to it. The wedge shank is heated by means of a simple AC power supply or a pulse type heated tool.

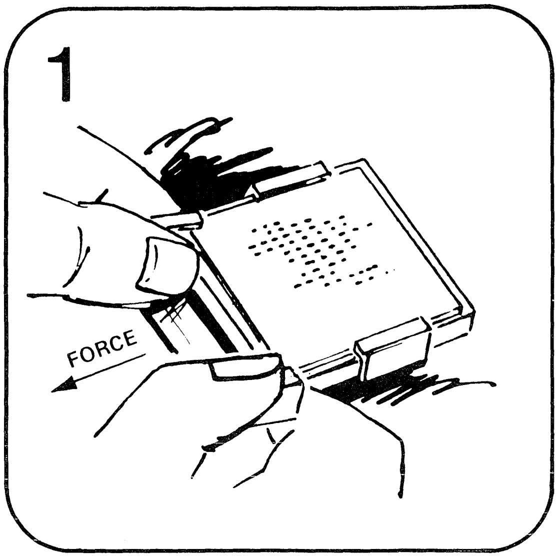
SUBSTRATE

For optimum bonding a gold plated surface at least 100 microinches thick is necessary. Although it is possible to bond to relatively soft metallized substrate material such as epoxy-fiberglass, etc., optimum bonding occurs when a hard material such as ceramic can be used.

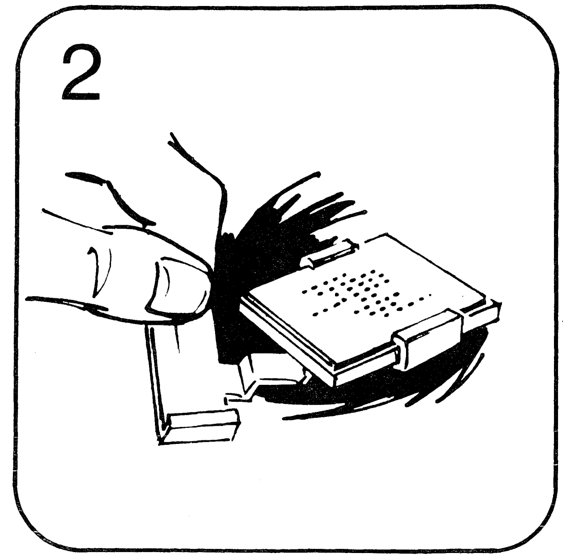
QUALITY

If a good bond has been obtained, it is impossible to separate the beam-lead device from the metallized substrate without damage. If the device is destructively removed, the beam will tear away, leaving the bonded portion attached to the substrate. In bonding the high value capacitors, it is important that the bond be made at the ends of the beams.

Application Note 80000: Bonding Methods: Diode Chips, Beam-Lead Diodes, and Capacitors

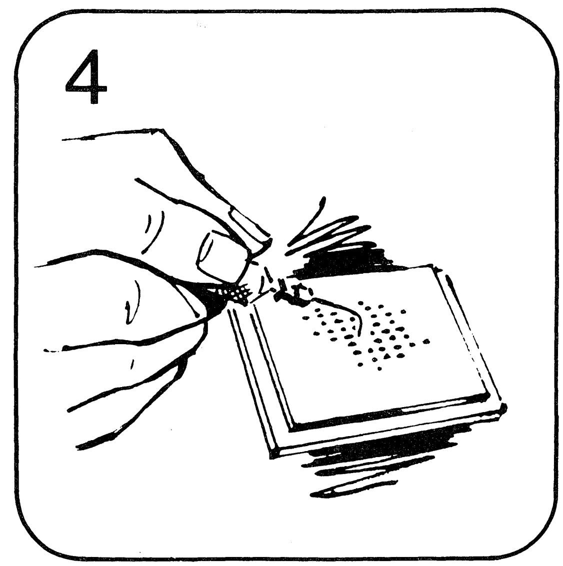


1. Place package on table top. There are two interlocking fasteners. Turn package so that interlocking side is facing down.
2. Grip one section of the plastic fasteners; with thumbs hold package when applying force.
3. Pull one plastic fastener from package.



Remove both plastic fasteners.

Remove lid from waffle.



Remove chip from waffle at work station with vacuum pick-up.

Figure 4. Diode Chip Waffle Package Opening Instructions

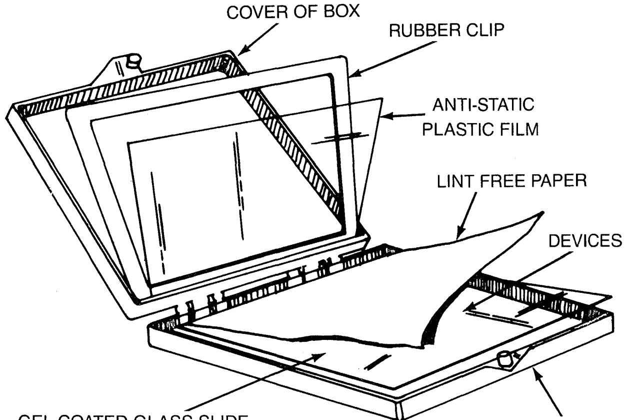
Application Note 80000: Bonding Methods: Diode Chips, Beam-Lead Diodes, and Capacitors

Beam-Lead Packaging

Alpha beam-lead diodes and capacitors are shipped in various package styles depending upon the customer's preference. See Beam-Lead Diodes and Capacitors Bonding Procedure (page 7-3) for proper device handling.

TYPE 1 (GEL-PAK)

This is a 2″ × 2″ black plastic conductive box. The beam-leads are mounted on a gel-coated glass slide. The devices are covered with a piece of lint-free release paper, on top of which is placed a piece of anti-static plastic film. The glass slide and paper are held down by a rubber clip which runs along the perimeter of the box. The cover of the box is snapped shut and taped to prevent opening during shipment.



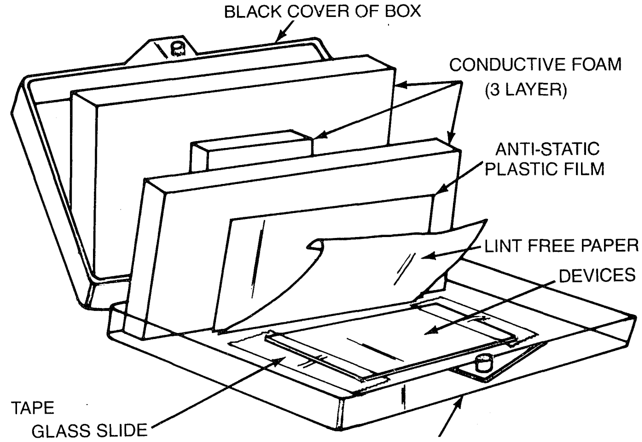
Drawing #1

TYPE 2 (GEL-PAK)

For larger beam-leads, a piece of foam is substituted for the rubber clips to ensure that devices will not be released from the gel during shipment.

TYPE 3

Some customers prefer shipment of beam-leads on glass slides without gel. In this case, a glass slide is taped to the bottom of a 2″ × 3″ plastic box, and the units are placed on the glass slide. Pieces of lint-free release paper and anti-static plastic film are placed on top of the glass slides. Three pieces of anti-static foam are placed within the box as a filler to prevent the devices from moving. The box is snapped shut and taped to prevent movement during shipment. The lower part of the box is clear to allow the incoming inspection groups to count the units without opening the box. The upper part of the box is black conductive plastic material.



Drawing #2

CAUTION: Care must be taken in removing foam, film, and lint-free release paper, because if units fall off the glass slide they may get stuck to tape.

One advantage of this packaging is that the devices can be transferred directly from the glass slide to the circuit.

The sequence is as follows:

1. Open the box.
2. Carefully remove the foam, plastic and release paper.
3. Use an X-acto knife to cut the tape holding the glass slide and beam-lead devices.
4. A hot bonding tool may then be used to pick up the beam-lead from the glass slide and place it directly across the gap in the circuit.

Reliability Testing and Screening of Semiconductors

I. Introduction

This article describes the use of screening tests to improve the reliability of microwave diodes. Screening is a special form of 100% testing that is growing in use because of increased requirements for reliability of military and space vehicle systems.

To be most effective, screening tests should be part of a complete reliability effort which includes sound device design, high standards of workmanship during processing and assembly, and accurate documentation of customer and internal testing and reporting requirements.

Alpha Industries has the experience, personnel and facilities required to implement the complete reliability effort required for reliable devices.

II. Types of Testing

Since a specific test may be performed for a variety of reasons, the most frequently performed categories of testing are described below.

QUALITY CONFORMANCE TESTING

The most common type of testing of semiconductors is quality conformance testing (also called lot acceptance testing). This is testing performed on a large sample or on 100% of the lot to determine that the devices in the lot meet critical electrical and mechanical dimensional requirements. In MIL type specifications the essential electrical requirements (Group A Tests) are supplemented by various environmental tests (Group B and C Tests) with smaller sample sizes required as part of quality conformance testing. These Group B and Group C Tests measure the capability of the device to operate satisfactorily after exposure to environmental stresses such as temperature cycling, shock, vibration, etc.

QUALIFICATION TESTING

A second basic type of testing is qualification testing. This type of testing is used to determine that the manufacturer of a device can supply devices that meet the full electrical and environmental capability requirements of the customer's specification. In MIL type specifications this testing is required before a device manufacturer is placed on a QPL (Qualified Products List). In MIL type specifications periodic requalification may be required after interruptions in production or after specified time intervals. The actual tests performed are the same Group A, B and C Tests mentioned above in lot quality conformance testing. However, the sample sizes are usually larger in qualification testing and additional tests not normally performed as part of quality conformance testing may be required.

SCREENING

The third basic type of testing is variously called screening, preconditioning, reliability testing or burn-in. The purpose of this testing is to eliminate marginal devices that might be field failures. The assumptions behind screening tests are two-fold. The first assumption is that under operating conditions there are many failures in a lot, relatively speaking, in the first few hours of operation. After this initial period (called infant mortality) there are few failures over a long period of operation (called constant failure rate period). At the end of the device life the failure rate rises again. The combination of declining initial failure rate, constant failure rate and increasing failure rate at end of life result in what is called the "bath-tub curve."

The second assumption behind screening tests is that the characteristics of a lot of devices will not be uniform. If the lot is subjected to an appropriate stress level for some screening test such as constant acceleration, a percentage of devices will be destroyed. If the same screening test is then repeated at the same stress level, a much smaller percentage of devices (zero devices in the ideal case) will fail after the second test. The stress level may be chosen because it represents a worst case field environment. Usually, however, it is chosen on the basis of experience with device capability. For example, it is known that well bonded semiconductor devices will withstand 20,000 G constant acceleration. Therefore, any devices that fail at this stress level are considered to be faulty in workmanship and therefore are not suitable for critical use. (These substandard devices are called "sports" or "mavericks" because they are different from the remainder of the lot).

Both of the assumptions behind screening (early failures and lot non-uniformity) have been verified for many different kinds of stresses applied to many different kinds of devices. Consequently, screening tests are increasingly used for devices intended for critical uses. Most new MIL specifications (JAN-TX specifications) incorporate screening requirements.

CHOICE OF SCREENING TESTS

There is no universal screening test or sequence of tests. A test that is very effective on some types of devices may be ineffective or even destructive on others.

The screening tests to be used for a particular device depend on device design and construction, the type of application and environmental conditions, and the criticalness of the application to mission success. For example, the screening tests used for a device intended for a non-redundant circuit in a long operating life unmanned space vehicle will be much more extensive than the screening tests used for a device intended for field replaceable sockets in ground based equipment.

There are certain sequences of screening tests that are widely used. MIL-S-19500, the general specification for diodes and transistors, has preferred screening sequences of increasing severity for JAN-TX, JAN-TXV and the new JANS types. MIL-STD-883, the military standard for test methods for hybrid circuits also contains preferred sequences of screening tests which have been used for discrete devices.

III. Types of Screening Tests

The various screening tests can be grouped by the nature of the tests and the characteristics of the device they are designed to evaluate. These groupings are:

Thermal Tests (Including Burn-In)
Mechanical Tests (e.g., Constant Acceleration)
Package Integrity Tests (e.g., Leak Test)
Visual and Radiographic Examination

The various tests with comments on their application and limitations are described below.

THERMAL TESTS

The rationale behind thermal screening tests is that applied temperature and/or electrical stress will cause latent defects such as poor semiconductor passivation or metallization to become actual defects.

High Temperature Storage/Stabilization Bake

High temperature storage is a simple form of accelerated life testing. The time is usually 24 to 96 hours in non-operating condition. This test is consequently inexpensive to perform and is usually included in screening cycles. The temperature used varies from 100°C to 200°C depending on device construction. Higher temperatures, provided they are within device capability, will be more effective than lower temperatures in detecting marginal devices.

Temperature Cycle/Thermal Shock

This test consists of subjecting devices to repeated alternate exposures to high and low temperature. Normally the devices are kept in air, but on some devices — particularly those with glass bodies — the devices may be immersed alternately in hot and cold liquids. The repeated rapid change in temperature (usually −65°C to +150°C in air or 0°C to 100°C in liquid) will cause mechanical stresses in glass to metal or ceramic to metal package seals and deterioration in semiconductor metallization and bonding. Temperature cycling should therefore be followed by package leak testing as well as electrical testing.

Burn-In

For most devices burn-in is the most meaningful test. It may be done at room temperature or at high temperature. The type of electrical stress applied depends on the device. Commonly used burn-in conditions are steady state reverse voltage (often called HTRB-High Temperature Reverse Bias), steady state forward current, or an AC signal consisting of forward current and reverse voltage (usually switched at a 60 Hz rate for economy of testing).

The burn-in period will vary from 24 hours to 1,000 hours. On tests with longer burn-in periods the devices are usually read at intermediate points in time. The test results are then examined to see that the expected phenomenon of early failure or infant mortality is actually taking place. In other words, the percentage of failures occurring or the change in device electrical characteristics should be less in the second period of burn-in than in the first period of burn-in.

MECHANICAL STRESS TESTS

Mechanical stress tests subject devices to a high mechanical stress which may destroy semiconductor bonds or cause other damage.

Constant Acceleration

This is the most widely used mechanical test. Usually it is applied to one axis of the device for one minute at a stress level of 20,000 G's or higher. This test is not a simulation of ordinary field environments where only a few G's of acceleration may be experienced. It is, rather, a workmanship test. Experience indicates that devices with good bonds will successfully withstand exposure to high G levels, and devices with poor bonds will not.

The constant acceleration test has two limitations. The first is that as devices are made smaller in volume and mass the effect of constant acceleration becomes diminished, and the test is less effective. The second limitation is that some devices such as pressure constant diodes have no bond to the semiconductor. The constant acceleration test, if used on these devices, is ineffective or even destructive.

Vibration Tests

Vibration tests are performed on devices in the operating or non-operating mode and with a variety of vibration conditions — variable sinusoidal frequency, random frequency or fixed frequency (known as vibration fatigue). Monitored vibration will detect temporary changes in mechanical structure of a device but is very expensive to perform because of instrumentation requirements and testing procedures.

Because of their small mass and dimensions, microwave semiconductors are capable of withstanding, without change, any ordinary field vibration environments. Therefore, vibration is not commonly used in screening.

Shock Tests

Mechanical shock (typically consisting of 0.5 to 1.0 millisecond pulses of 500 to 1500 G level) is occasionally used as a screening test. It is particularly suitable for evaluating the mechanical ruggedness of pressure contact devices, in place of the constant acceleration test used on bonded devices.

PACKAGE INTEGRITY TESTS

Leak testing is the most common screening test for device packages. Normally, both fine and gross leak tests are performed on packaged devices. However, glass bodied devices usually fail on gross leak test or not at all. Therefore, fine leak testing is not necessary for less critical applications of these devices.

Leak testing requires careful consideration of the available test methods in order to be effective. The two fine leak test methods use radioactive gas or helium as tracer gas. The radioactive gas method is more sensitive but requires AEC licensed equipment and personnel that most semiconductor companies do not have in house. The helium gas method is, therefore, commonly used. Helium leak testing cannot be used with epoxy sealed units or with some types of ceramics which absorb the helium tracer gas and cause spurious test results.

Gross leak test methods include various hot liquids and penetrant dyes. Penetrant dyes are suitable for glass bodied devices, and the heated fluorocarbon method is most suitable for opaque devices.

All leak testing relies on the storage of a tracer fluid or gas in the internal cavity of the device being tested. As semiconductor device packages become smaller the sensitivity of the leak test is decreased. With cavity-less devices such as encapsulated beam-lead diodes, no leak testing can be done.

Leak testing is most appropriate for devices with high resistivity semiconductor material such as PIN devices or high voltage breakdown devices. Low resistivity or low voltage devices such as point contact and Schottky diodes do not require leak testing for most applications.

Leak testing should be done in the screening cycle after mechanical and thermal cycle tests so that package damage may be detected. With cavity-less or small cavity devices, a substitute for leak testing is moisture resistance testing. Since this is a destructive test, it can only be done on a sample basis. However, a relatively small sample can provide an indication of the package integrity on a device lot intended for a critical application.

PHYSICAL INSPECTION

Visual inspection before sealing (or immediately after sealing for glass bodied devices) is one of the most commonly used screening tests. This test is being added to new MIL specifications (JAN-TXV) and is required on many new programs. Although there are elaborate inspection criteria specified in the test methods of MIL-STD-750 and MIL-STD-883, these criteria are not written specifically for microwave devices. For maximum value of precap visual inspection, a set of criteria designed for the specific device should be prepared and approved by both supplier and user before inspection of the devices. Visual inspection will indicate general quality of workmanship as well as the presence of any potential defects such as loose conductive material or foreign matter that might cause semiconductor deterioration after sealing.

Radiographic Examination

An alternate or supplement to precap visual inspection is radiographic examination. This method is valuable in that there is a record of the inspection results. For many devices the method lacks sensitivity. This is particularly true of devices with small cavities and self-contained heat sinks where the opaque heat sink material masks the cavity. Since silicon is transparent to X-rays, bonds to the silicon cannot be readily examined. Solder, gold and other high density materials show up readily, and the detection of such material in a loose condition is a principal goal of this type of inspection.

SEM Inspection

A special type of physical examination is performed with the scanning electron microscope (SEM). This test method is destructive, but it is valuable in evaluating metallization characteristics of sample semiconductor chips for wafer approval. The SEM method of examination is also valuable in failure analysis of devices for observation and recording of defects.

IV. Individual Device Rejection Criteria After Testing

For some tests such as leak testing or radiographic testing, inspection criteria are included in the test method. Most other test methods will require an electrical test to be performed after the environmental stress. The choice of tests governs the sensitivity and expense of the tests. The simplest criterion is that of Go-No-Go testing to fixed limits after stress testing. The basic assumption is that devices will be either good devices or catastrophic failures.

A more sophisticated criterion is noting the change in one or more electrical parameters of a device tested before and after the environmental stress and discarding those devices that change more than a predetermined amount (or delta limit). The assumption here is that some devices in the lot will change significantly but not catastrophically. When only a few devices from the lot change, they should be rejected because they still are different from the rest of the lot, even though they still meet the electrical limits of the basic specification. The increase in test sensitivity is matched by an increase in test cost, because all devices must retain identity through the testing cycle, and electrical test measurements must be recorded. A theoretical defect of this criterion is that if there is not extensive knowledge of the device being tested, the delta limit may be too tight, thus rejecting good, stable devices, or too loose and thus accepting poor, unstable devices. A refinement of the delta method suitable for large lots undergoing screening tests for critical applications is to determine delta criteria based on the behavior of the lot being tested. Such a method requires close monitoring of test results during the test program as well as extensive experience with the device being tested.

V. Lot Rejection Criteria After Testing

Rejection criteria for individual devices within a lot were discussed above. Another criterion that is often used is to specify an allowable percentage failure of the lot and reject all lots with more than the allowed percentage of failures. This percentage is known as a PDA (Percent Defective Allowed).

A PDA may be applied to a single test such as burn-in or a sequence of tests. Sometimes there are PDAs for individual tests and a relaxed PDA for the overall sequence of tests. The assumption behind the PDA criterion is that good devices from a lot with a high percentage of defects are potentially less reliable than good devices from a lot with a low percentage of defects. The difficulty with this criterion is determining what the PDA should be. It is usually set arbitrarily and modified by test experience if necessary.

Probably the most appropriate use of the PDA criterion is the use of a relaxed PDA after initial submission to a stress such as burn-in and a tightened PDA for rejected lots resubmitted to the same stress. The lower failure rate requirement for the second submission makes it mandatory that the devices have a decreasing failure rate, which is the true indication of successful screening.

VI. Test Sequence

The sequence of screening tests is critical and is usually specified in MIL type specifications. The sequence specified in MIL-S-19500 for example is (1) Precap Visual Inspection (2) Thermal Stress (Stabilization Bake, Temperature Cycle) (3) Mechanical Stress (Constant Acceleration) (4) Seal Test (5) Burn-In and (6) Radiographic and External Visual Examination.

The rationale for this sequence is that mechanical stress should be applied after any structural weakening due to thermal stress. Leak testing should monitor the effects of thermal and mechanical stresses on the devices. Final physical examination of the device should be after all other testing.

VII. Semiconductor Chip Screening

Unmounted semiconductor chips are screened for the same reasons as discrete diodes. The 100% screening tests that are performed on chips are limited in number for two reasons. First, since the chips are unmounted, no screening tests are necessary for package characteristic tests. Therefore, diode package leak tests or mechanical tests such as constant acceleration are not required. Second, because of the difficulty of making good electrical contact to unmounted chips, burn-in cannot be performed.

The standard 100% chip screening tests are, therefore, stabilization bake, temperature cycle, and visual inspection. Test conditions are the same as described above for discrete diodes.

In addition to the 100% testing on individual chips, there may be tests performed on a sample basis. These tests are destructive and are done to evaluate the wafer from which a particular lot of chips is taken. Wafer evaluation tests include electrical tests, chip mountability tests and life tests. Electrical tests include such measurements as high frequency performance, which cannot be readily or accurately measured on chips. A sample of chips is mounted in diode packages in order to make these measurements.

Chip mountability tests are made in order to insure that the chips may be securely bonded to the substrate and that wire or ribbon may be bonded to the diode chip junction area. These tests are performed by mounting the chips on a test substrate and then determining the breaking strength of the chip to substrate or ribbon to chip bond.

Life tests such as HTRB may be performed on a sample of chips by mounting them in diode packages. The discrete diode packages are readily handled during the operating life test, and electrical measurements are easily made. The life test results on the sample of chips can then be used to predict the performance of that lot of chips in actual use.

VIII. Screening Cycles for Specific Devices

The screening cycle for a specific device should be specified only after consideration of many factors. The application will determine the reliability level needed, the level of environmental stresses expected and the feasibility of replacement in case of failure. The design and construction of the device will determine what potential failure mechanisms must be monitored. For example, screening cycles will vary depending on whether the device is a gallium arsenide Gunn diode, a beam-lead Schottky diode, a PIN diode or a point contact diode.

Alpha Industries has prepared recommended screening cycles for general use for a wide variety of microwave semiconductor devices. The recommended screening cycles are based on over 15 years of high reliability diode screening experience on American and European space programs and many missile and aerospace programs. Alpha Industries' engineers will be pleased to review customer program and application requirements to tailor screening procedures to exact customer needs at minimum cost.

IX. Alpha Facilities and Experience

Alpha Industries has complete in-house equipment for screening and burn-in of all types of microwave diodes. This capability insures complete testing and rapid and economical handling of customer screening requirements.

Alpha engineering and quality assurance personnel are experienced in the testing of Alpha's complete line of microwave diode types. This experience is readily available to customers extending from initial specifying of screening cycles to final test reports in special format.

Introduction

Alpha Industries, Inc. has been a major supplier of microwave devices, components, and subsystems for high-reliability space and missile programs for over 15 years. Alpha's reputation for meeting stringent military requirements has enabled the company to participate in the growth of space business.

Alpha's large, professional staff includes personnel with experience in semiconductor wafer preparation, device assembly, and electrical and environmental testing. A team consisting of the necessary disciplines is available to determine the manufacturing procedure and testing requirements of the customer application. This customer service ensures delivery of Alpha's products with the highest reliability.

Reliability Testing and Screening Procedures

Screening tests are used to verify the reliability of microwave products. Screening is a special form of 100% testing that is growing in use because of increased requirements for reliability of military and space vehicle systems. To be most effective, screening tests should be a part of a complete reliability effort that includes sound device design, high standards of workmanship during processing and assembly, and accurate documentation of customer and internal testing and reporting requirements.

TESTING

A specific test may be performed for a variety of reasons. There are several categories of tests that can be performed. The most frequently performed categories of testing are described below.

Quality Conformance Testing

Quality conformance testing, also called lot acceptance testing, is performed on a large sample of the lot to determine whether the devices in the lot meet critical electrical and mechanical requirements. In MIL Tests, specifications of the essential electrical requirements (Group A Tests) are supplemented by various environmental tests (Group B and C Tests) with smaller sample sizes required as part of quality conformance testing.

These group B and C Tests measure the capability of the device to operate satisfactorily after exposure to environmental stresses such as temperature cycling, shock, and vibration. These test conditions are simulations of potential or accelerated field environments.

Qualification Testing

Qualification testing is used to determine whether a device can meet electrical and environmental requirements of the customer specifications. This testing is required before a device manufacturer is placed on a Qualified Products List (QPL). The tests are performed on larger sample sizes and additional tests may be required.

SCREENING

Screening (also called pre-conditioning, reliability testing, or burn-in) is performed to eliminate marginal devices that might result in field failures. There are two assumptions considered during screening tests:

Early Failures: In the initial operation period of equipment, there is a higher rate of component failures. The surviving components have significantly lower rates in the subsequent operation.

Non-Uniformity of devices within a lot: The characteristics of devices within a lot may vary one from another. When a lot of devices is subjected to a screening test such as constant acceleration, a small percentage of the lot may show significant changes in characteristics. These devices, called "Mavericks" or "Sports", are considered potential long term failures and are not suitable for critical use.

Both of the assumptions behind screening tests have been verified for many different types of stresses and devices. Screening tests are increasingly performed on devices intended for critical uses. Most new MIL specifications incorporate screening requirements. There is no universal set of screening tests. The device design, construction, type and importance of the application, and the environmental conditions in use are considered when choosing a screening test sequence. Screening procedures include:

- Thermal Tests
- Mechanical Tests
- Package Integrity Tests
- Visual Inspection and Radiographic Examination

The screening cycle for a specific device should be specified only after consideration of the many factors mentioned. Alpha Industries' experienced staff has prepared recommended screening cycles for general use in a wide variety of microwave devices. The recommended screening cycles are based on experience with high-reliability products in American and European space programs. Alpha's engineers will provide consultation to review the customer program and device application, manufacturing procedure, and testing requirements.

High Reliability Capabilities For Space and Military Applications

Facilities and Testing Equipment

Alpha Industries has in-plant facilities for performing all standard electrical tests for microwave diodes, millimeter wave products, and other microwave components. Alpha also has extensive environmental and screening test equipment. This equipment allows 100% JANTXV* type screening, the most widely used screening test sequence in American aerospace programs, to be performed in-house. Alpha's capabilities ensure complete control over testing procedures. Sample environmental tests for lot acceptance are also performed in-house.

Certain special equipment, such as radiographic equipment and PIND testing, is not available at Alpha. Tests requiring such equipment are performed at outside laboratories specializing in this type of testing. These laboratories are certified by the American government for such testing. When testing is performed at labs, all data is recorded and analyzed by Alpha personnel.

Test equipment available for burn-in screening and operational life tests include circuits for reverse voltage, forward current, or 60Hz forward and reverse combined. These electrical stresses can be applied at room temperature or elevated temperature as required. The choices offered allow for tests most suitable according to device characteristics and circuit application.

*JANTXV Semiconductor Screening Test Sequence
1) Pre-Seal Visual Inspection
2) Stabilization Bake After Sealing
3) Temperature Cycling
4) Constant Acceleration
5) Leak Test
6) Electrical Test on Critical Parameters
7) Electrical Burn-in
8) Electrical Retest on Parameters

Screening, quality conformance testing, and qualification testing are performed at Alpha according to the following military standards:

- MIL-STD-202
- MIL-STD-453
- MIL-STD-454
- MIL-STD-461
- MIL-STD-462
- MIL-STD-750
- MIL-STD-781
- MIL-STD-785
- MIL-STD-810
- MIL-STD-883
- MIL-S-19500
- MIL-M-38510
- MIL-I-45208
- MIL-Q-9858A
- DOD-D-1000

The equipment available at Alpha Industries is listed in Table 1.

TABLE 1 TESTING, SCREENING, AND INSPECTION METHODS

METHOD	SCREENING PROCEDURES	IN-HOUSE	APP. LAB
1038	Burn-In	X	
1051	Thermal-Shock (Temperature Cycling)	X	
1071	Hermetic Seal	X	
2006	Constant Acceleration	X	
2052	Particle Impact Noise Detection		X
2074	Visual Pre Cap Inspection	X	
2076	Radiographs		X
2081	Forward Instability Shock		X
2082	Backward Instability Vibration		X
	EMI		X
	Thermal-Vacuum		X
	Sinusoidal Vibration		X

METHOD	LOT EVALUATION PROCEDURES	IN-HOUSE	APP. LAB
1001	Barometric Pressure	X	
1021	Moisture Resistance	X	
1027	Operational Life	X	
1032	Storage Life	X	
1041	Salt Atmosphere	X	
1056	Thermal Shock (Glass Strain)	X	
2016	Mechanical Shock		X
2017	Die Shear Test	X	
2026	Solderability	X	
1037	Bond Strength Test	X	
2046	Vibration Fatigue		X
2056	Vibration Variable Frequency		X
2077	Scanning Electron Microscope	X	

Semiconductor Division Capabilities

Alpha's Semiconductor Division has supplied devices for high-reliability space and missile programs for over a decade. These programs include both Silicon and Gallium Arsenide (GaAs) semiconductor material. Many types of diode packages such as ceramic body, stripline construction, and beam-lead devices have been tested. In addition, diodes have been tested for all types of microwave frequency circuit functions such as mixers, detectors, tuning of oscillators, paramps, multipliers, limiters, harmonics generation, and noise sources. Alpha's experience with such a wide variety of devices on critical programs indicates its ability to fabricate and test microwave diodes for any high-reliability program required.

Unmounted Semiconductor Device Screening

The screening tests performed on unmounted semiconductor chips are limited in number in comparison to the tests for other devices. Since the chips are unmounted, no screening tests are necessary for package characteristic tests. Diode package leak tests or mechanical tests are not required. Burn-in is also not performed on unmounted chips because of the difficulty of making good electrical contact. The standard 100% chip screening tests are stabilization bake, temperature cycling, and visual inspection. In addition to the testing of individual chips, there may be tests performed on a sample basis to evaluate the wafer taken from a particular lot. These tests are destructive in nature. Wafer evaluation tests include electrical tests, chip mountability, and life tests.

Electrical tests include measurements such as high-frequency performance. Since high-frequency performance cannot be accurately measured on chips, a sample of chips is mounted in diode packages to make these measurements. Chip mountability tests are done to ensure that the chips are securely bonded to the diode chip junction area. The breaking strength of the chip-to-substrate or ribbon-to-chip bonds is determined when the chips are mounted on a test substrate.

Life tests may be performed on a sample of chips by mounting them in diode packages. The discrete diode packages are readily handled during the operational life test and electrical measurements are easily made. The life test results on the same sample of chips can then be used to predict the performance of that lot of chips in actual use.

Screening cycles will vary depending on whether the device is a Gallium Arsenide Gunn diode, a beam-lead Schottky diode, a PIN diode, or a point contact diode. During wafer processing, device assembly, and test phases, Alpha's professional team monitors the operations and test results.

Reliability for Epoxied Beam-Lead Packages

The reliability of the epoxied beam-lead devices may be characterized by the applicable methods and procedures contained in the military semiconductor specifications, MIL-S-19500, MIL-STD-750, and MIL-STD-202. These specifications call out the conditions of mechanical, thermal, and other environmental tests common to semiconductor products. The subject devices have been designed to withstand the reliability levels of the above mentioned conditions, where appropriate to the particular device in question.

Field Information

Alpha has been supplying epoxied beam-lead devices in large quantities since 1970. Epoxied beam-lead devices have been used in a variety of applications where a high degree of reliability is required, including satellite equipment. Alpha has received no information to date of any field failures concerning these applications.

Temperature and Humidity

The following test summary shows the results of temperature and humidity testing on both epoxied and unepoxied ceramic mounted beam-lead devices. It should be noted that the 20,000 hour data on high temperature storage results in a Mean Time Between Failure (MTBF) of 175,000 hours (at 90% confidence levels) for both epoxied and unepoxied devices calculated separately or 350,000 hours for both groups combined.

Table 2 illustrates Semiconductor Life Test Summaries.

TABLE 2 **Semiconductor Life Test Summaries**

Device Type Number	Device Type	Total Life Test Hours Accumulated	
		High Temp. Storage Life	Operating Life
DMF4007-9	Beam-Lead Schottky	386,000 0 failures	383,000 3 failures
DMF6106-83	Bonded Schottky	80,000 0 failures	80,000 0 failures
D5092-71	Point Contact Diode	309,540 0 failures	—
DLA4721-98	PIN Limiter	32,000 0 failures	45,000 0 failures
DVB6145-85	Step Recovery Diode	110,000 0 failures	110,000 0 failures
DVH6178-27	Silicon Tuning Diode	43,520 1 failure	18,360 1 failure
DKV6520-59	Hyperabrupt Tuning Diode	6,120 1 failure	17,760 0 failures
DMA6081-96	Noise Diode Silicon	6,000 0 failures	6,000 0 failures
DVE4558-89	Paramp Multiplier Gallium Arsenide	—	62,000 0 failures
DVE4550-81	Tuning Diode Gallium Arsenide	—	12,000 0 failures
SC9001-	Beam-Lead Capacitor	—	28,704 0 failures

Technological Information

The metallization on the silicon, i.e. the barrier metal, is evaporated titanium. Covering the evaporated titanium is a film of molybdenum followed by a layer of gold. For certain specialized applications where different barrier heights are desired, molybdenum-gold or platinum-titanium-molybdenum-gold may be used.

The basic passivation or protective layer is silicon nitride. Alpha beam-lead Schottky diodes are basically planar devices. The beam-lead devices are bonded to the substrate by means of thermo-compression bonding. This type of bonding involves pressing the gold beam of the devices against the gold plated metallized substrate under controlled conditions of heat and pressure. This process causes an intermolecular bonded joint between the two devices to occur.

The protective covering used with mounted beam-lead Schottky diodes is epoxy. The epoxy is a two part system designated as XR-54 and manufactured especially for Alpha Industries by Fenwal Incorporated, Ashland, MA 10721. The black coloring material is manufactured by Plastic Molders Supply Company, 74 Fourth Ave., Fanwood, N.J. and is designated as type MS-4640E. The black coloring material is added to the epoxy at the time of mixing.

Failure Modes

The most commonly experienced failure mode is degradation of reverse breakdown voltage. This is usually caused by damage due to application of excessive voltage as a result of mishandling.

The excess voltage may be caused by static discharge or by transients after the devices have been installed in the equipment. This problem is common to all high-frequency mixer and detector diodes. If the damage is severe, degradation of noise figure will also occur.

Table 3 illustrates test summaries for beam-lead Schottky quads D5847 mounted on ceramic substrate-epoxied.

TABLE 3 Test Summary: Beam-Lead Schottky Quads D5847 Mounted on Substrates

Subgroup	Test Sequences	Conditions	Qty Tested	Qty Failed
1	Temperature Cycle MIL-STD-750 Method 1051F	– 65C to + 150C 110 Cycles	60	0
	Moisture Resistance MIL-STD-202 Method 106	10 Days	60	1

Beam-Lead Schottky Diode D5827A Mounted On Ceramic Substrate-Epoxied

Subgroup	Test Sequences	Conditions	Qty Tested	Qty Failed
1	Temperature Cycle MIL-STD-750 Method 105	– 65C to + 150C 110 Cycles	15	0
	Moisture Resistance MIL-STD-202 Method 106	10 Days	15	0
2	High Temperature Storage**	150C 20,000 hours	20	0

Beam-Lead Schottky Diode D5827A Mounted On Ceramic Substrate-Epoxied

Subgroup	Test Sequences	Conditions	Qty Tested	Qty Failed
1	Temperature Cycle MIL-STD-750 Method 1051F	– 65C to + 150C	18	0
	Moisture Resistance MIL-STD-202 Method 106	10 Days	18	0
2	High Temperature Storage**	150C 20,000 hours	20	0

**Read at intermediate points with no failures.

Alpha Industries is an active participant in military and space programs requiring high-reliability capabilities. Table 5 explains the numerous programs and capabilities in which Alpha has been involved.

High Reliability Capabilities For Space and Military Applications

TABLE 4

Program Participation and Capabilities

Semiconductor Division

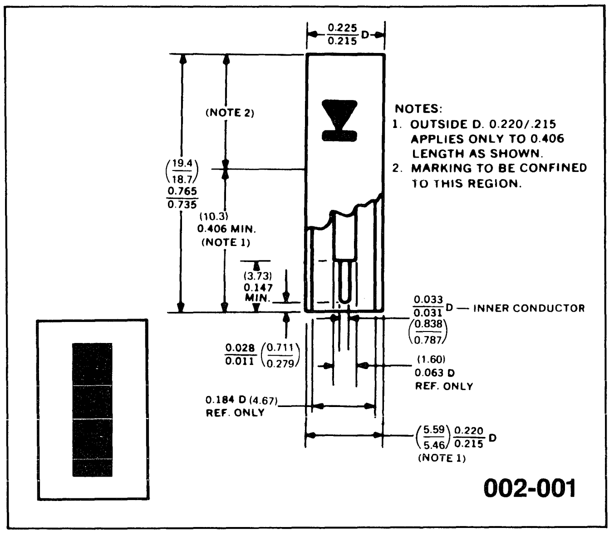
Program	Material	Diode Construction	Function
ECS/OTS	GaAs	Ceramic Body Metal Terminals	Multiplier
ECS/OTS	GaAs	Ceramic Body Metal Terminals	Paramp
ECS/OTS	GaAs	Ceramic Body Flexible Leads Welded On Terminal	Tuning Diode
ECS/OTS	Silicon	Ceramic Body Metal Terminals	Schottky Mixer Diode
G STAR	GaAs	Ceramic Body Metal Terminals	Multiplier
G STAR	GaAs	Ceramic Body Metal Terminals	Paramp
HARPOON	Silicon	Ceramic Body Metal Terminals	Limiter
SIRIOS	Silicon	Glass Body Axial Leads	Hyperabrupt Tuning Diode
MINUTEMAN	Silicon	Glass Body Axial Leads	Hyperabrupt Tuning Diodes
HARM	Silicon	Beam-Lead	PIN Diode
MINUTEMAN	Silicon	Beam-Lead Mounted	Schottky Mixer Diode
BATSON	Silicon	Glass Body Axial Leads	Noise Diodes
HARM	Silicon	Glass Body Axial Leads	Tuning Diode
BATSON	Silicon	Glass Body Axial Leads	Schottky Diode High Voltage
AUSSET INTELSAT	Silicon	Ceramic Body Metal Terminals	Step Recovery Diode
CLASSIFIED	Silicon	Beam-Lead	Capacitor
CLASSIFIED	Silicon	Ceramic Body Metal Terminals	PIN Diode
CLASSIFIED	Silicon	Beam-Lead Mounted in Ceramic	PIN Diode
CLASSIFIED	Silicon	Glass Body Axial Leads	Step Recovery Diode
CLASSIFIED	Silicon	Chip Mounted on Ceramic Substrate	Limiter
CLASSIFIED	Silicon	Glass Body Axial Leads	Point Contact Mixer Diode
CLASSIFIED	Silicon	Ceramic Body Metal Terminals	Schottky Mixer Diode
CLASSIFIED	Silicon	Glass Body Metal Terminals	Hyperabrupt Tuning Varactor

Section 8
Alpha Microwave Diode Packages

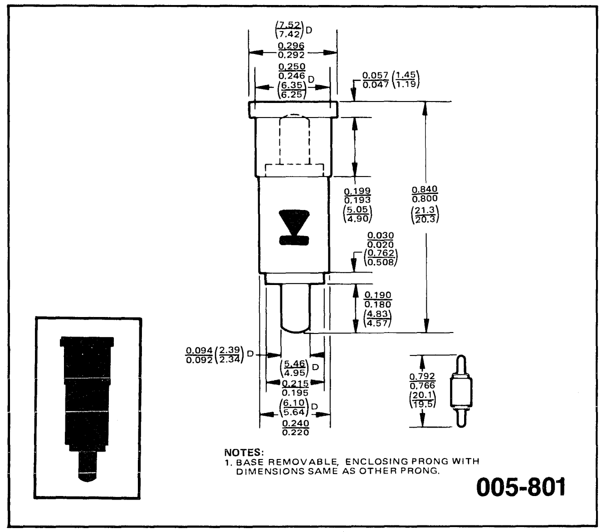
Alpha Microwave Diode Packages

Outline Drawings

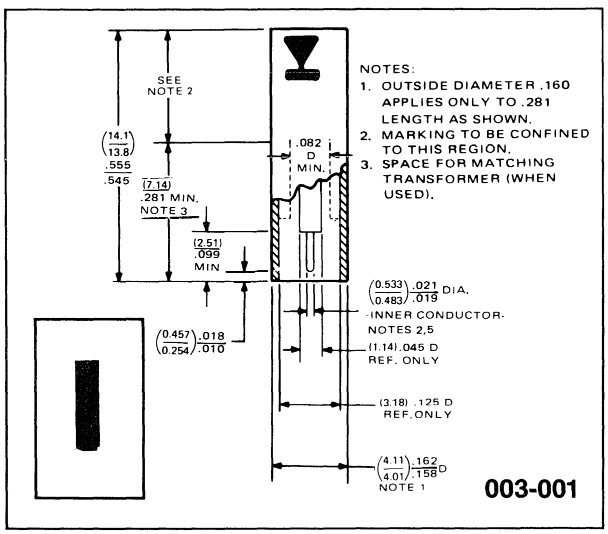
The following outline drawings show the most commonly used Alpha microwave diode packages. The outlines are listed numerically by package number, and dimensions are listed in both inches and millimeters. Package parasitics are also listed where applicable.



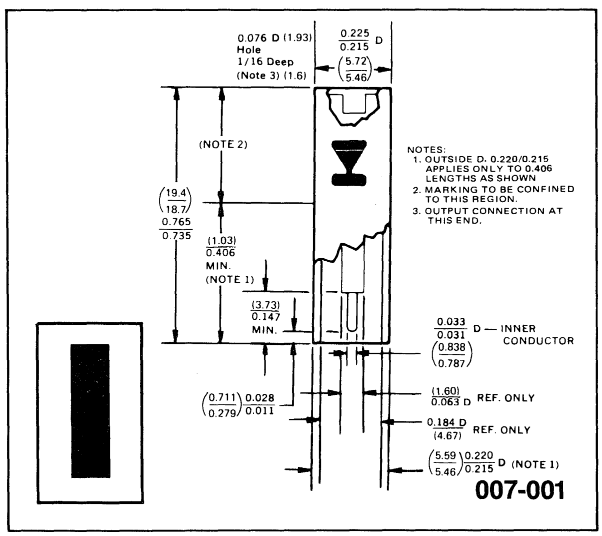
002-001



005-801

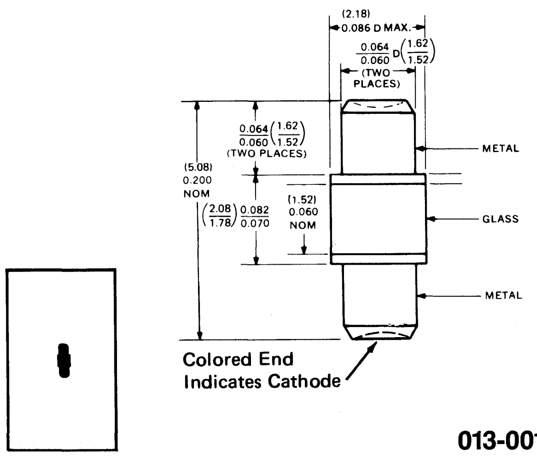


003-001

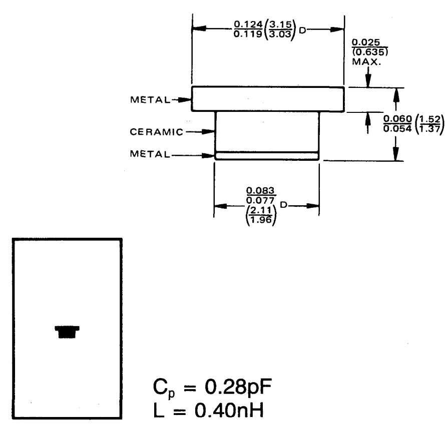


007-001

Note: Millimeters in parentheses.

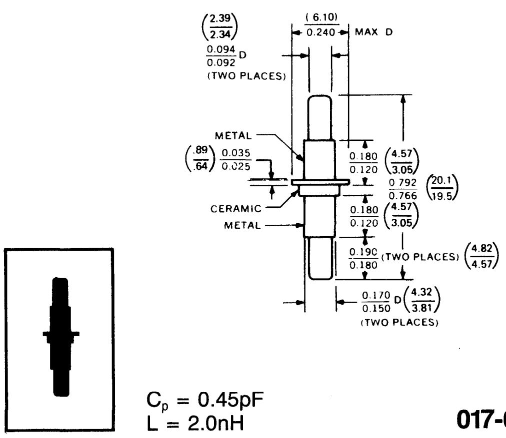


013-001



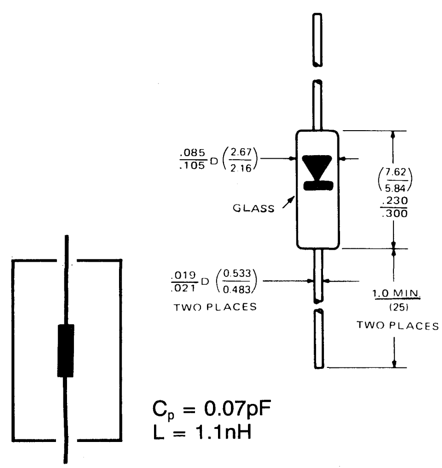
C_p = 0.28pF
L = 0.40nH

048-001



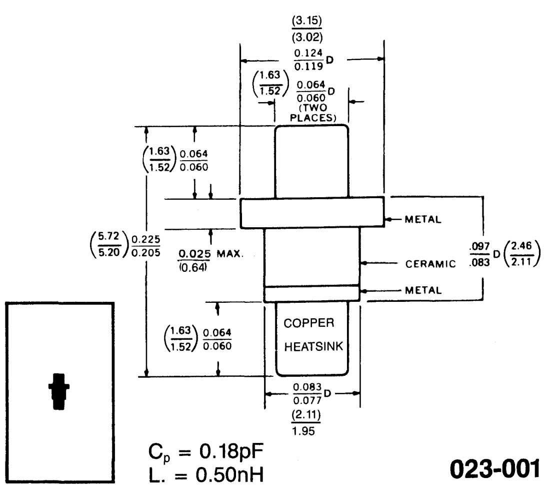
C_p = 0.45pF
L = 2.0nH

017-001



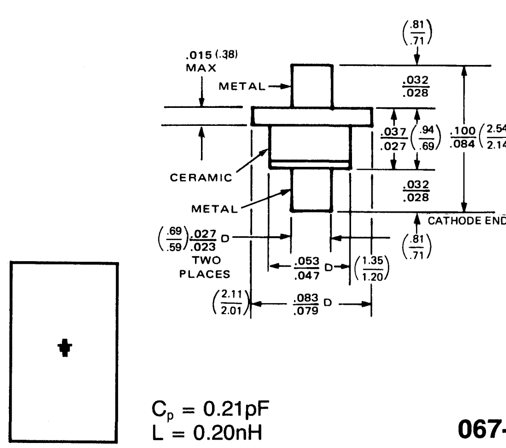
C_p = 0.07pF
L = 1.1nH

062-001



C_p = 0.18pF
L. = 0.50nH

023-001

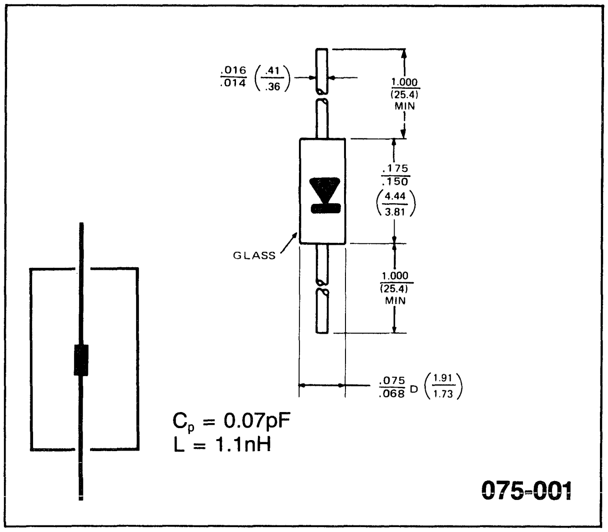


C_p = 0.21pF
L = 0.20nH

067-001

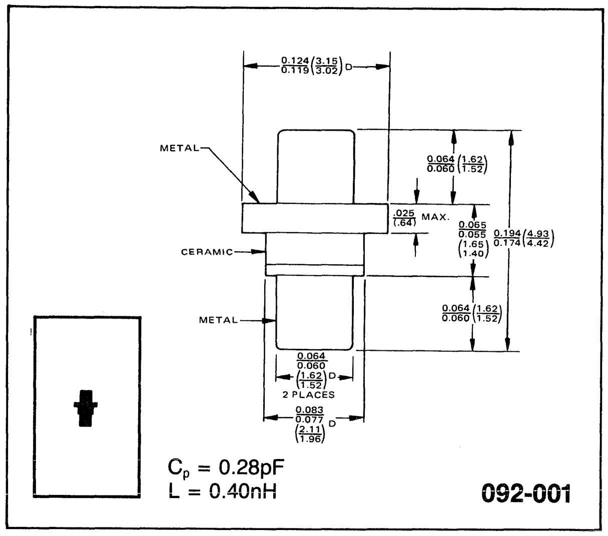
Note: Millimeters in parentheses.

Outline Drawings



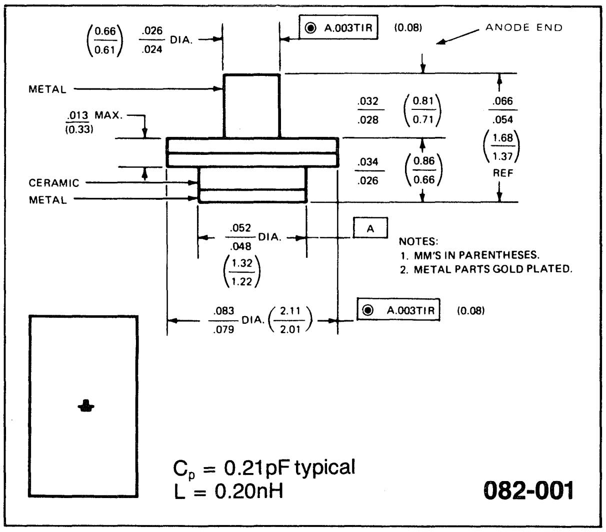
C_p = 0.07pF
L = 1.1nH

075-001



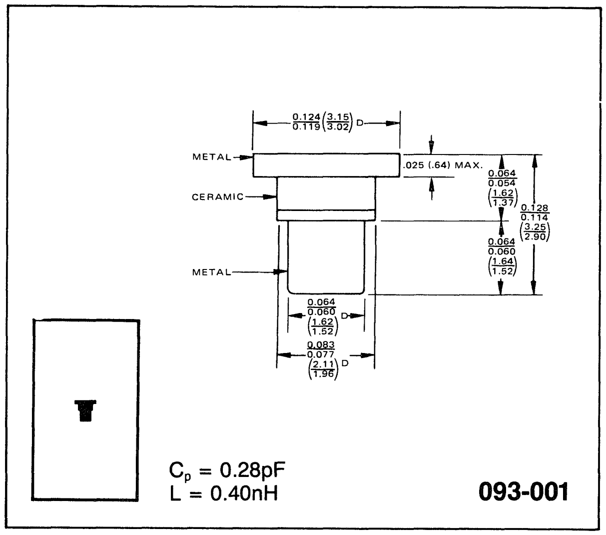
C_p = 0.28pF
L = 0.40nH

092-001



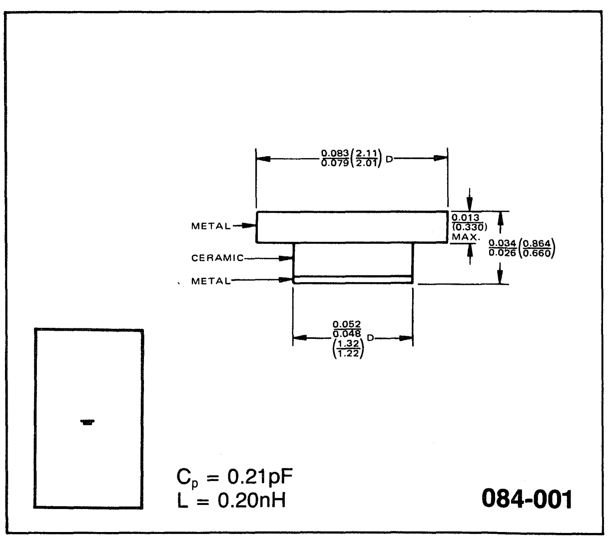
C_p = 0.21pF typical
L = 0.20nH

082-001



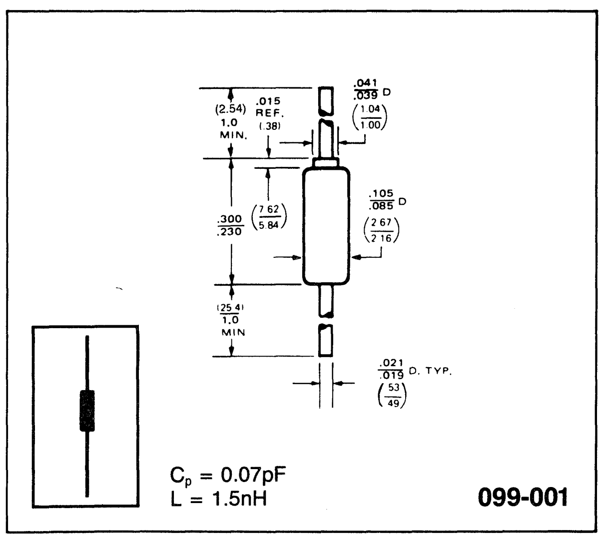
C_p = 0.28pF
L = 0.40nH

093-001



C_p = 0.21pF
L = 0.20nH

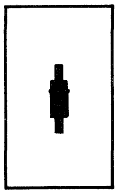
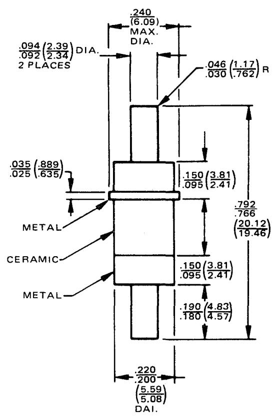
084-001



C_p = 0.07pF
L = 1.5nH

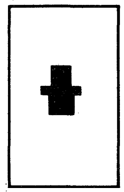
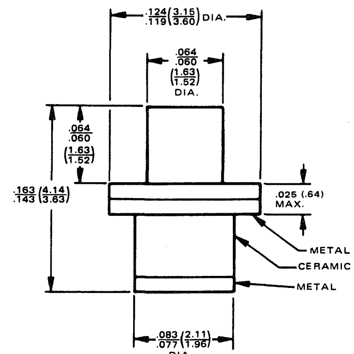
099-001

Note: Millimeters in parentheses.

C_p = 1.0pF

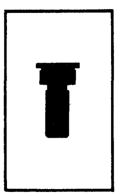
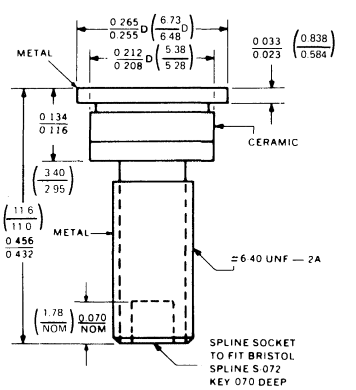
116-001

NOTES:
1. .064/.060 (1.63/1.52) and .083/.077 (2.11/1.96) DIA CONCENTRIC WITHIN .008 (.2032) TIR

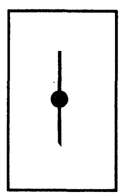
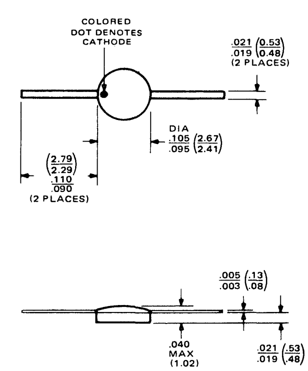
C_p = 0.18pF
L = 0.50nH

119-001

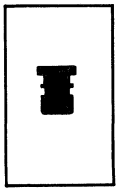
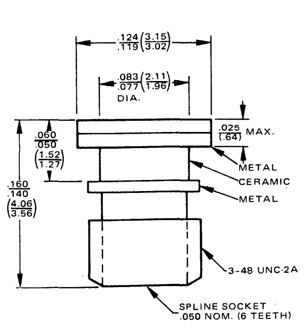
C_p = 1.0pF
L = 0.6nH

117-001

C_p = 0.10pF
L_p = 0.6nH

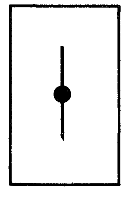
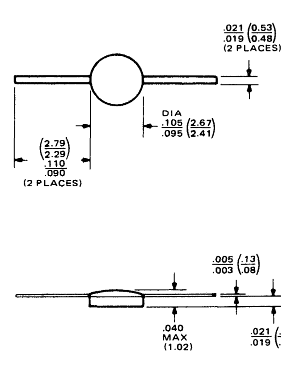
130-011

NOTES:
1. 3-48 THD .124/.129 (3.15/3.28) DIA. CONCENTRIC WITHIN .008 (.2032) TIR

C_p = 0.28pF
L = 0.30nH

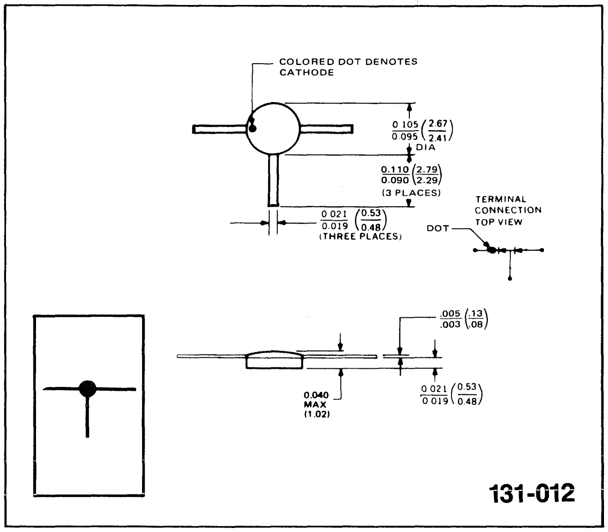
118-001

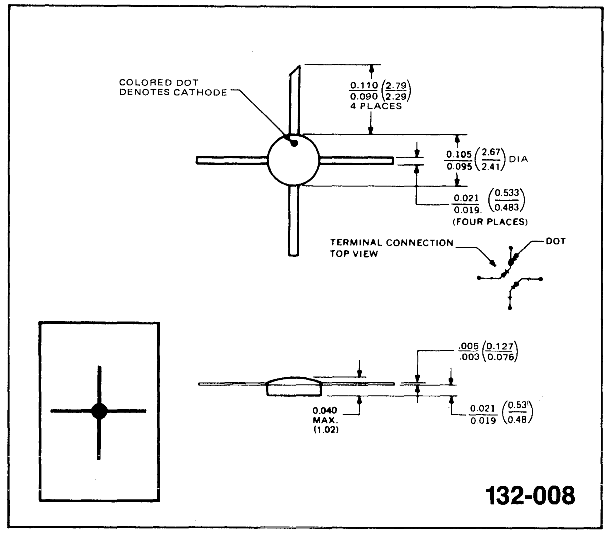



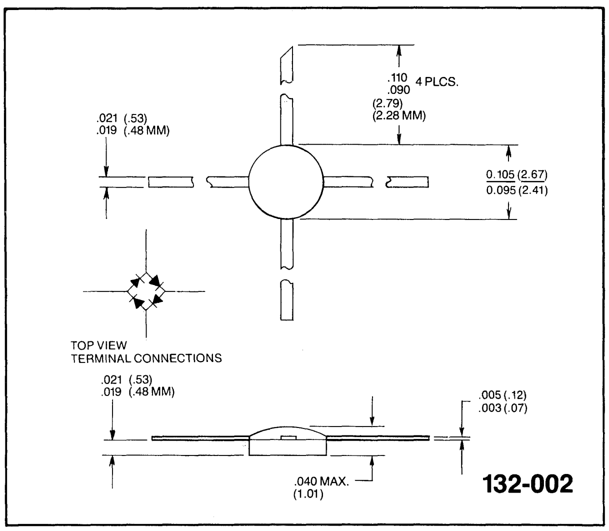
130-025

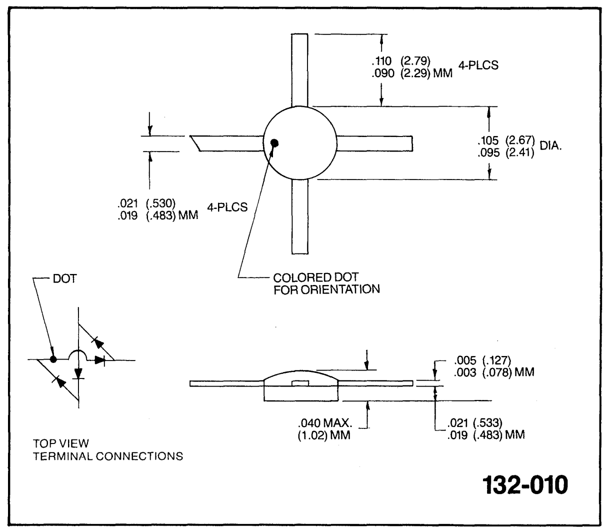
Note: Millimeters in parentheses.

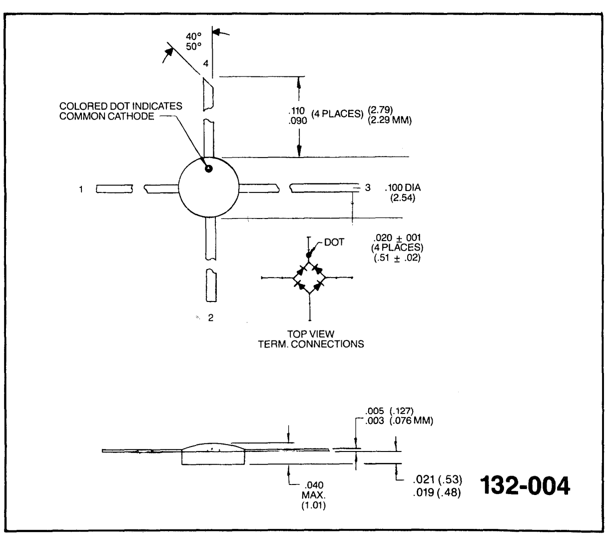
Outline Drawings

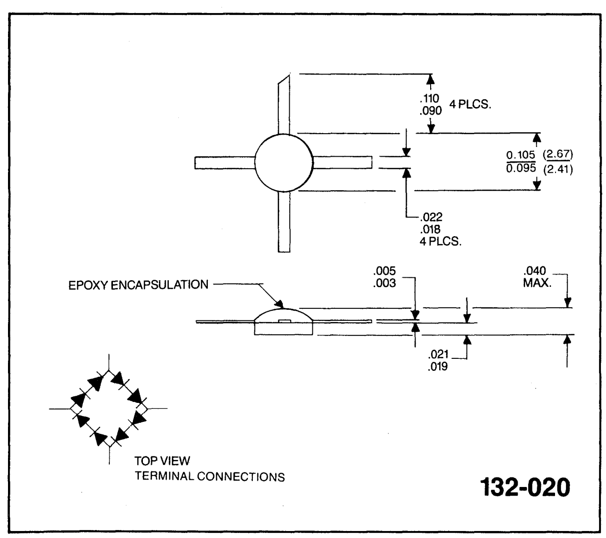




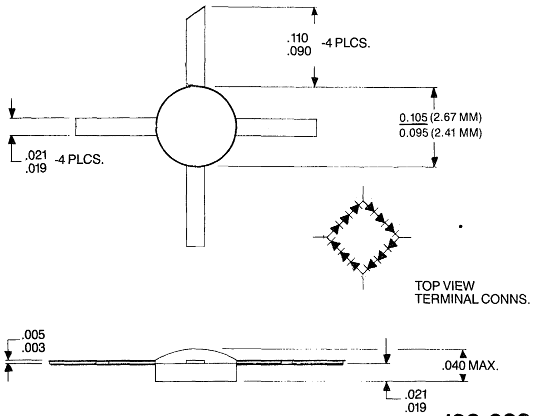




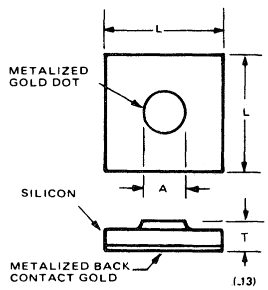




Note: Millimeters in parentheses.

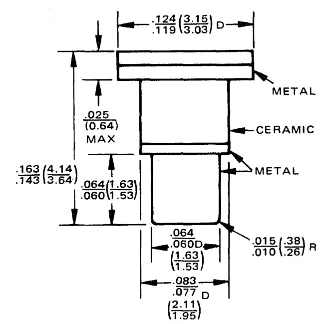


132-022



	INCHES		MM	
CHIP STYLE	DIM A	DIM L	DIM A	DIM L
150-801	.002	.012	.05	.30
150-802	.002	.020	.05	.50
150-803	.002	.030	.05	.76
150-804	.002	.035	.05	.89
150-805	.002	.040	.05	1.02
150-806	.0011	.012	.02	.30
150-807	.002	.010	.05	.25
150-808	.00125	.010	.03	.25
150-809	.002	.018	.05	.45
150-810	.00125	.009	.03	.22
150-811	.00125	.012	.03	.30
150-812	.0025	.015	.06	.38

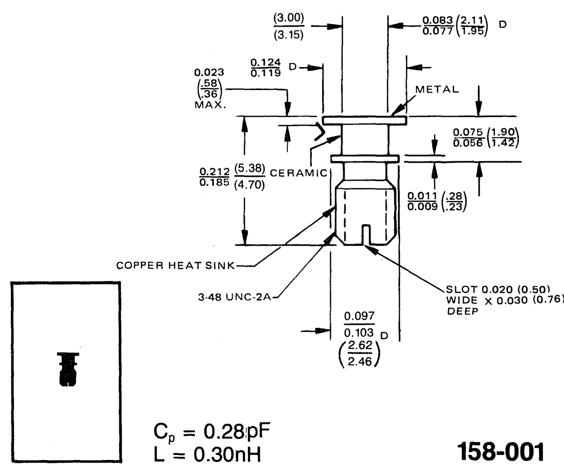
150



NOTES:
1. .062 AND .121 DIA SHALL BE CONCENTRIC WITHIN .008 TIR

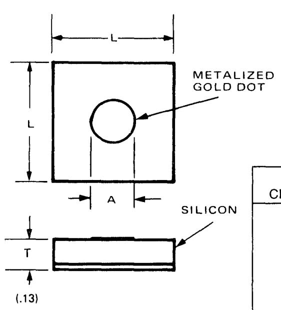
C_p = 0.18pF
L = 0.50nH

135-001



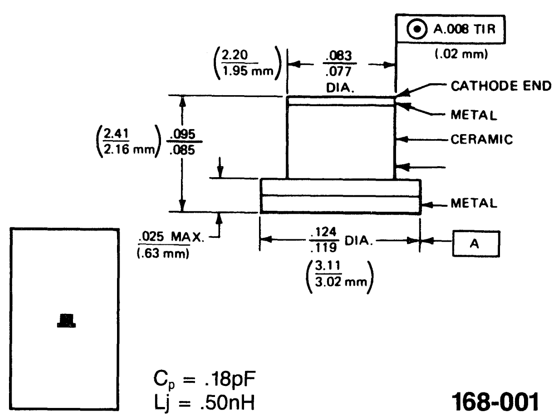
C_p = 0.28pF
L = 0.30nH

158-001



	INCHES		MM	
CHIP STYLE	DIM A	DIM L	DIM A	DIM L
149-801	.002	.012	.05	.30
149-802	.002	.020	.05	.50
149-803	.002	.030	.05	.76
149-804	.002	.035	.05	.89
149-805	.002	.040	.05	1.02
149-806	.002	.050	.05	1.27
149-807	.002	.054	.05	1.37
149-809	.002	.018	.05	.46
149-811	.009	.020	.23	.51
149-812	.0095	.020	.24	.51
149-813	.0095	.020	.24	.51
149-814	.004	.015	.10	.38
149-815	.004	.015	.10	.38
149-816	.002	.020	.05	.51

149

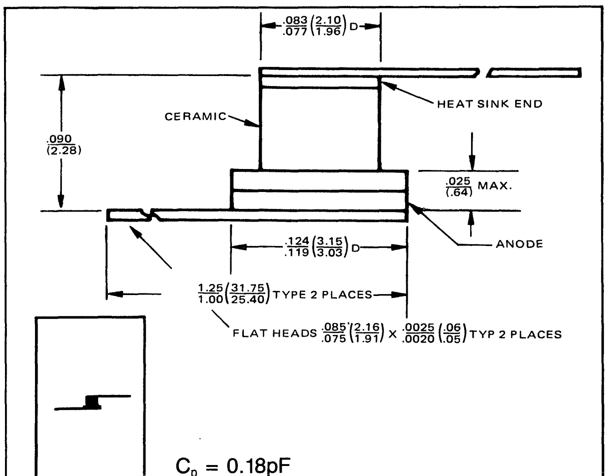


C_p = .18pF
Lj = .50nH

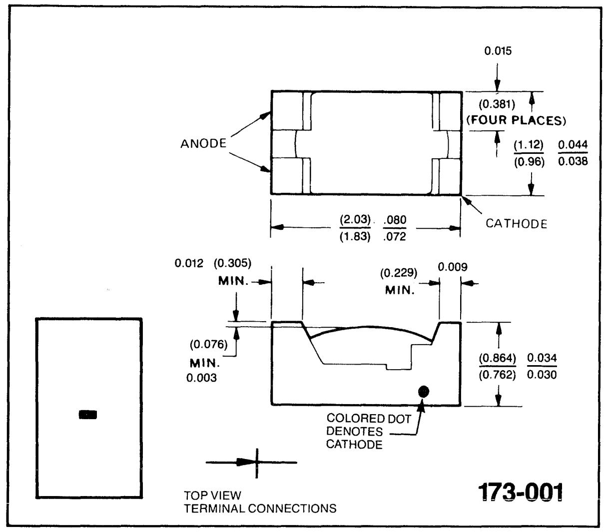
168-001

Note: Millimeters in parentheses.

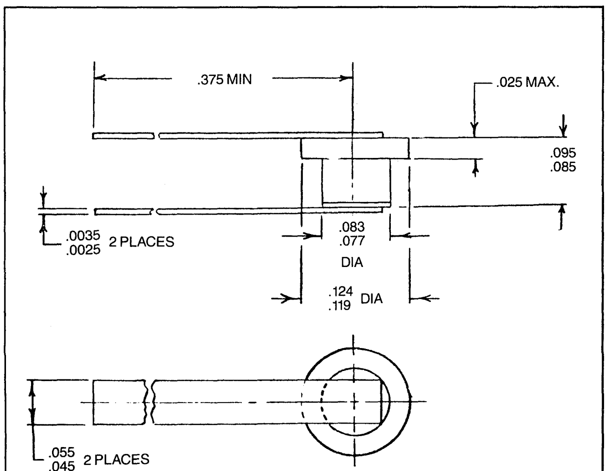
Outline Drawings



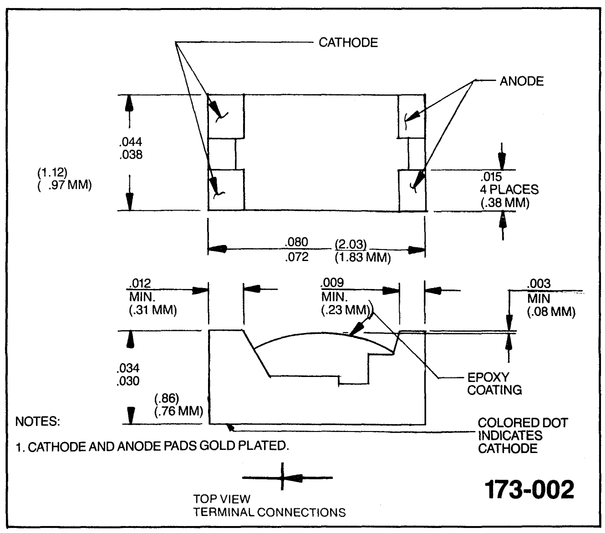
168-801



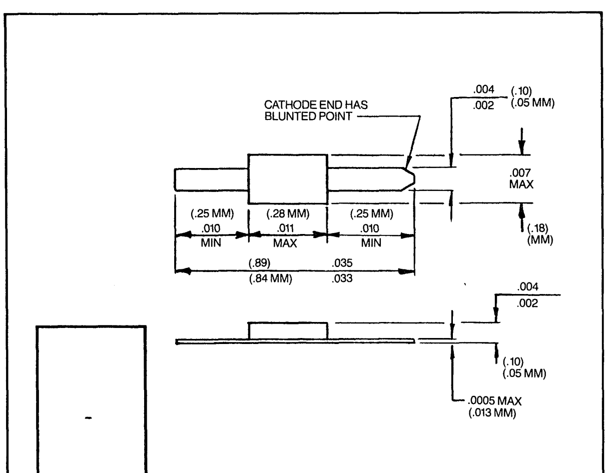
173-001



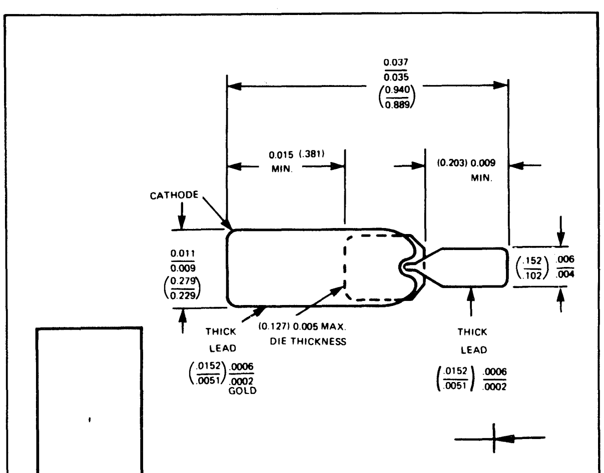
168-802



173-002

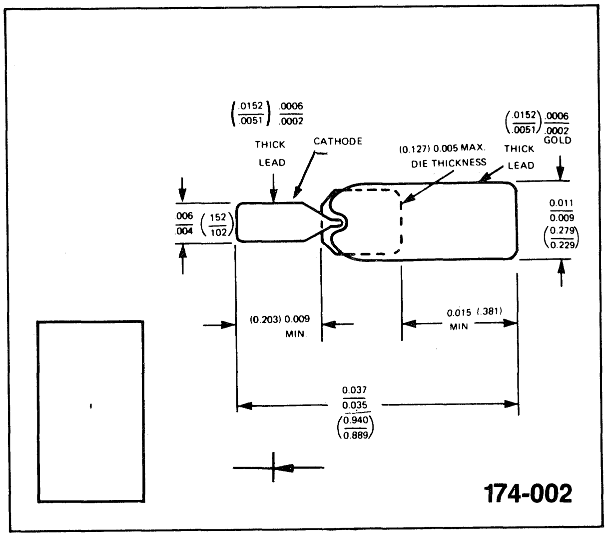


169-001

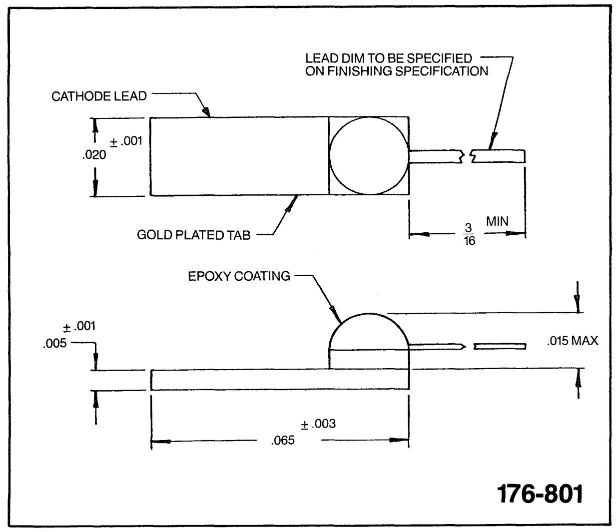


174-001

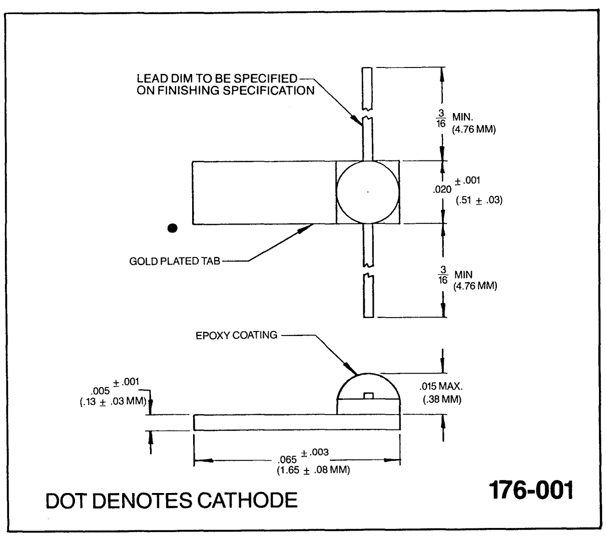
Note: Millimeters in parentheses.



174-002

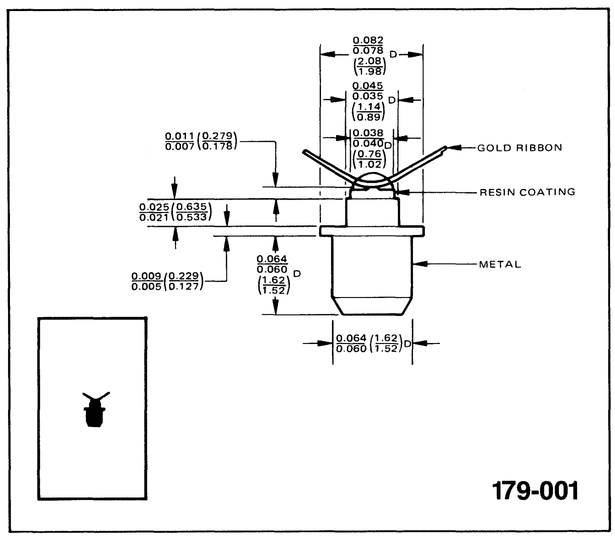


176-801

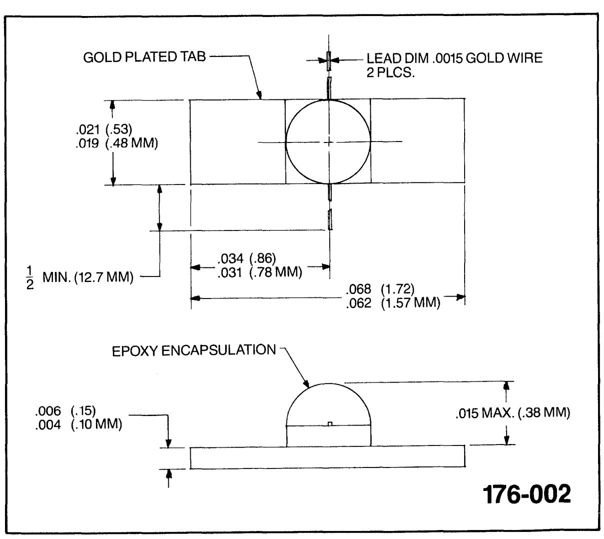


DOT DENOTES CATHODE

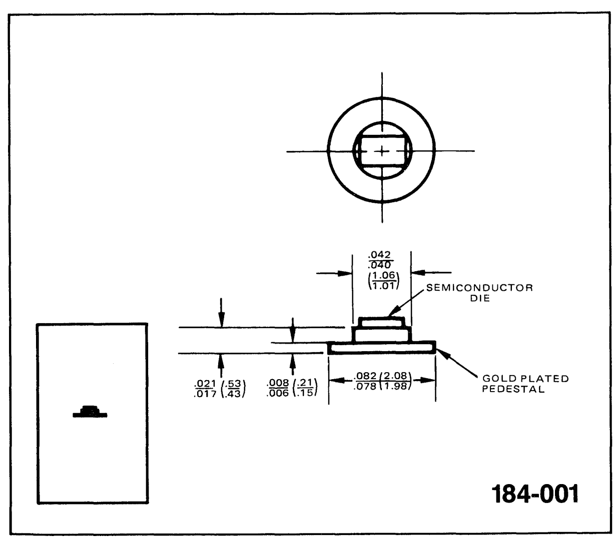
176-001



179-001



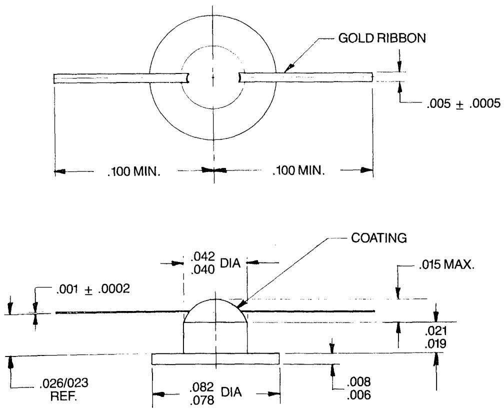
176-002



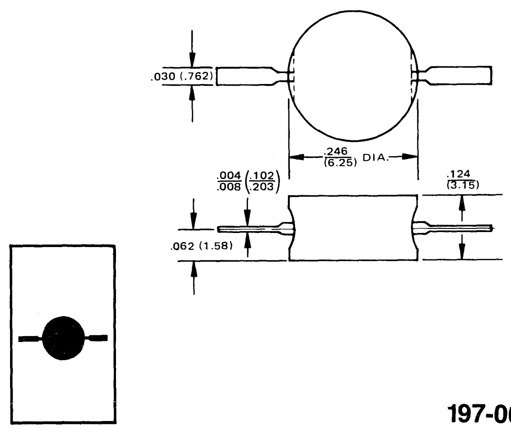
184-001

Note: Millimeters in parentheses.

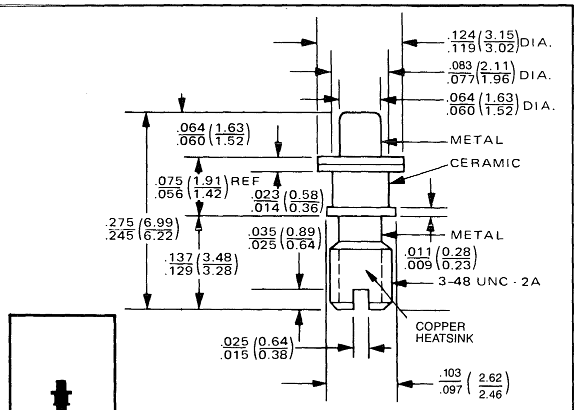
Outline Drawings



184-804

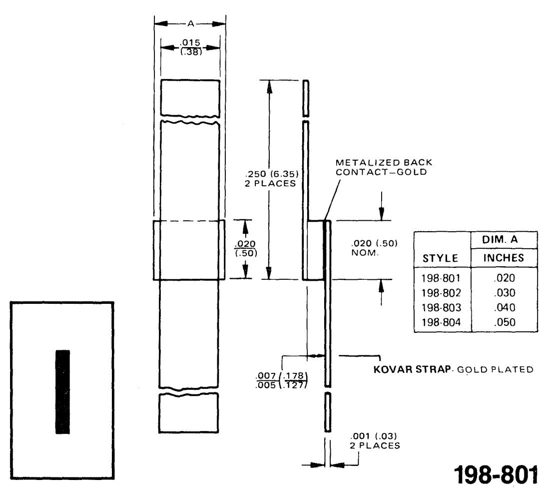


197-001



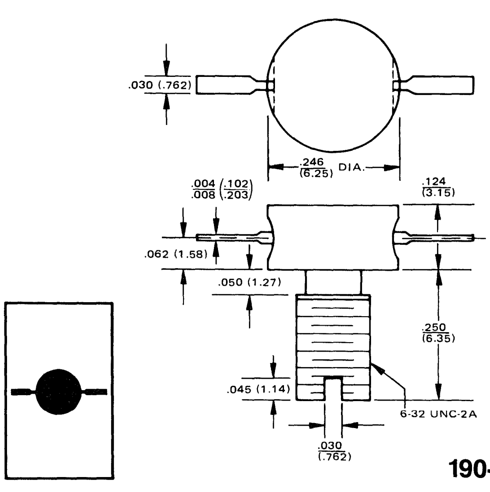
NOTES:
1. ALL METAL SURFACES GOLD PLATED
2. 3-48 TND AND .064/.060 DIA CONCENTRIC WITHIN .008 TIR

C_p = 0.28pF L = 0.30nH **188-001**

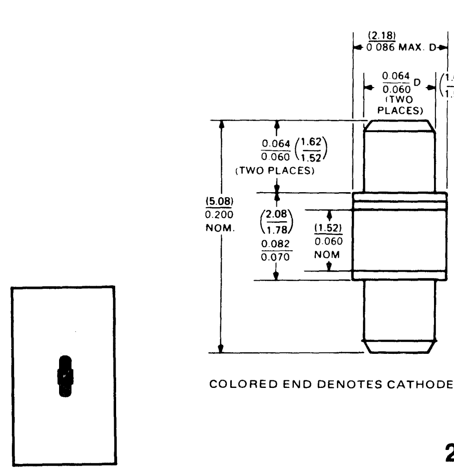


STYLE	DIM. A INCHES
198-801	.020
198-802	.030
198-803	.040
198-804	.050

198-801

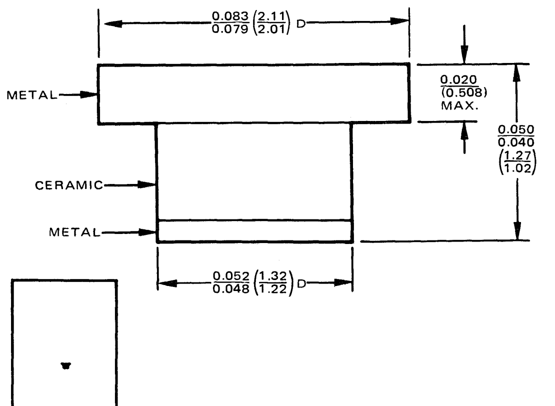


190-001



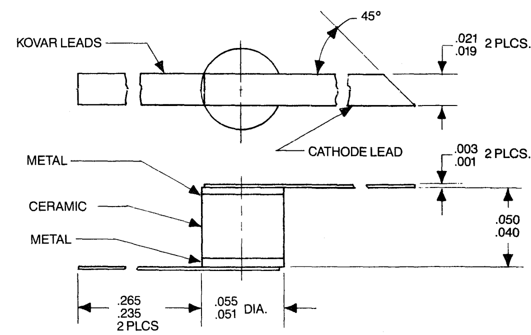
207-001

Note: Millimeters in parentheses.



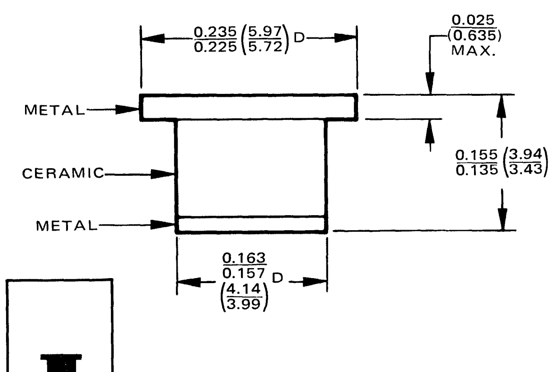
C_p = 0.135pF
L = 0.25nH

237-001



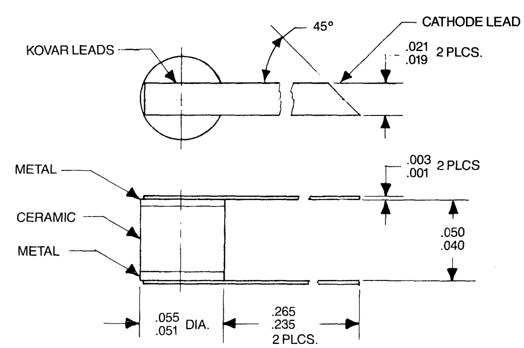
NOTES:
1. METAL PARTS GOLD PLATED.

247-802



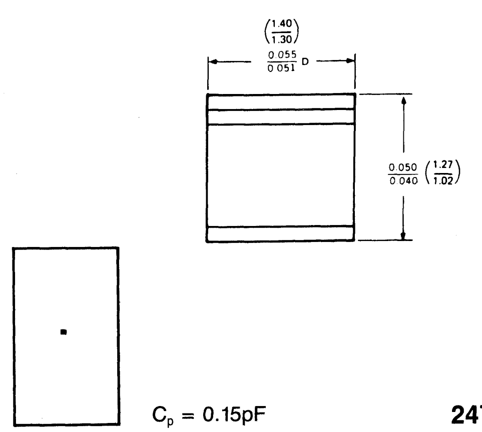
C_p = 0.35pF

240-001



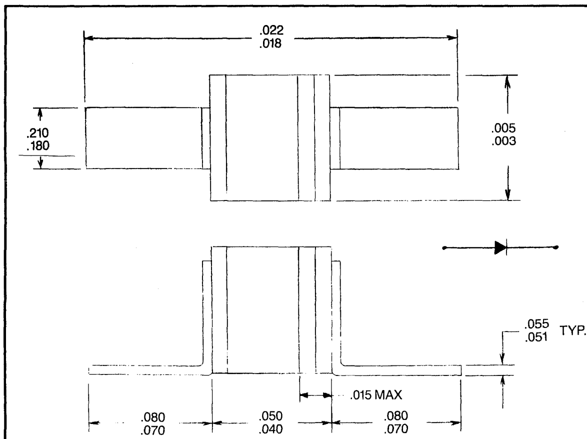
NOTES:
1. METAL PARTS GOLD PLATED.

247-805



C_p = 0.15pF

247-001

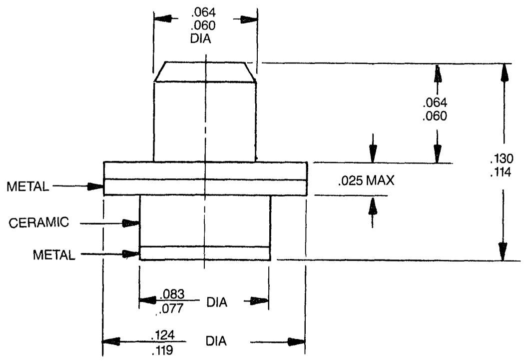


NOTES:
1. THE SOLDER SEALED END OF THE DIODE IS THE CATHODE END OF THE DEVICE.

247-807

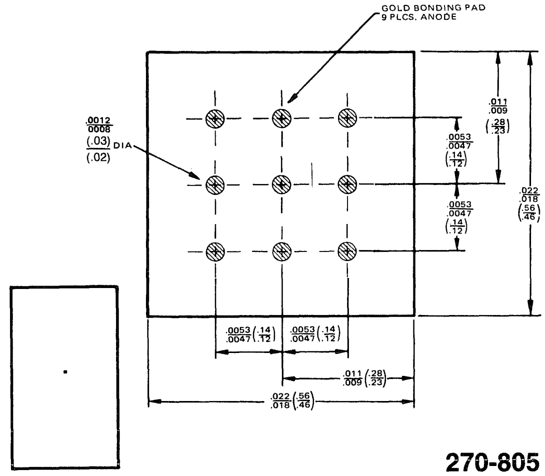
Note: Millimeters in parentheses.

Outline Drawings

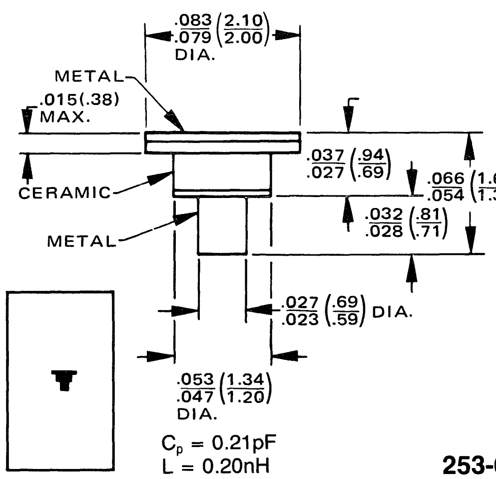


NOTES:
1. METAL PARTS GOLD PLATED.

248-001

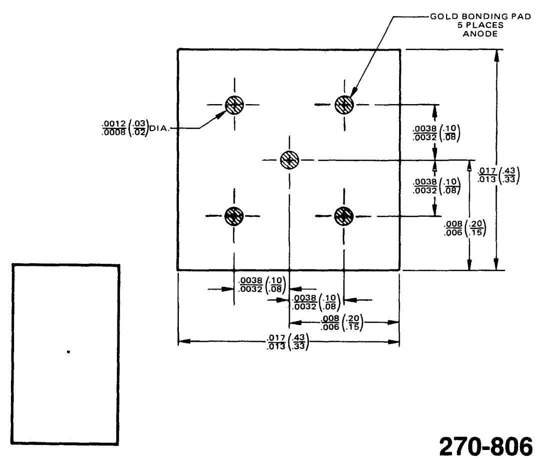


270-805

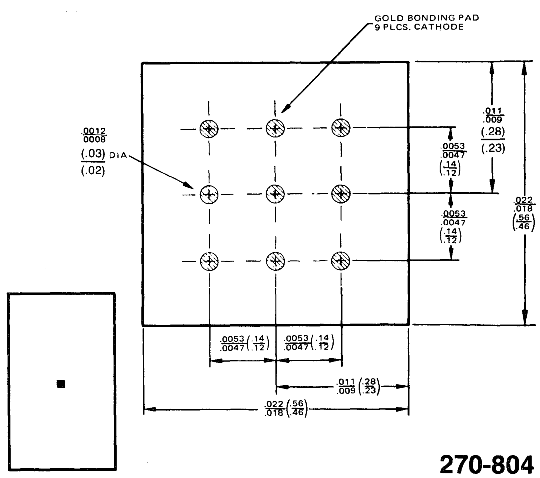


C_p = 0.21pF
L = 0.20nH

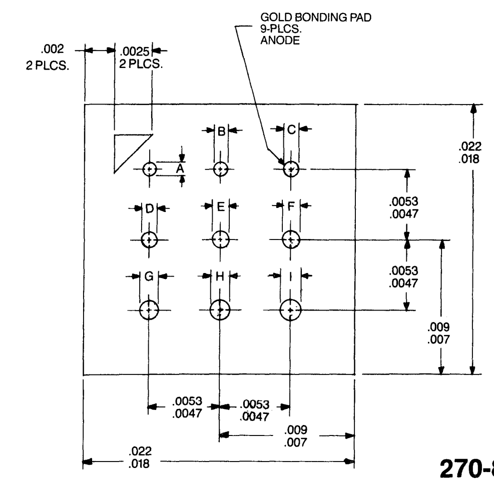
253-001



270-806

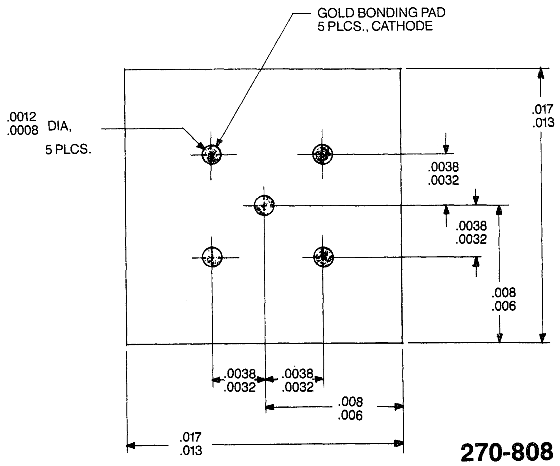


270-804

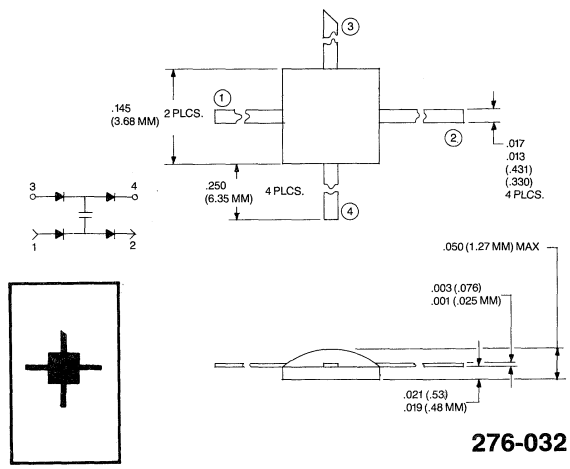


270-807

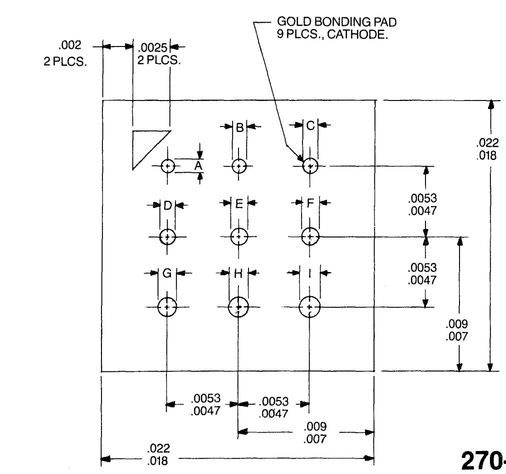
Note: Millimeters in parentheses.



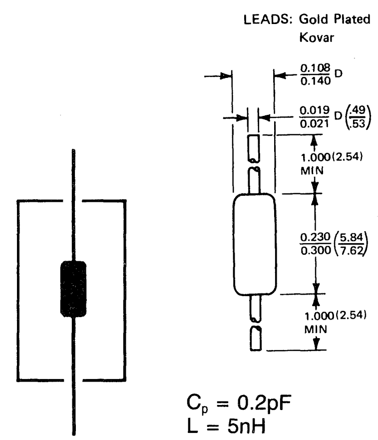
270-808



276-032

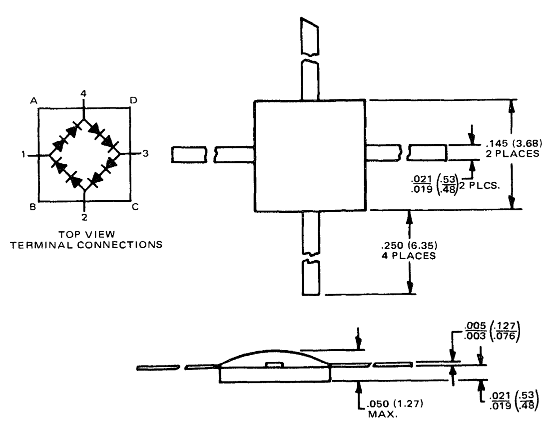


270-809

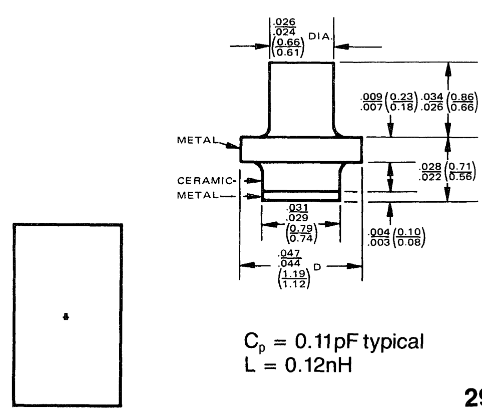


C_p = 0.2pF
L = 5nH

287-001



276-020

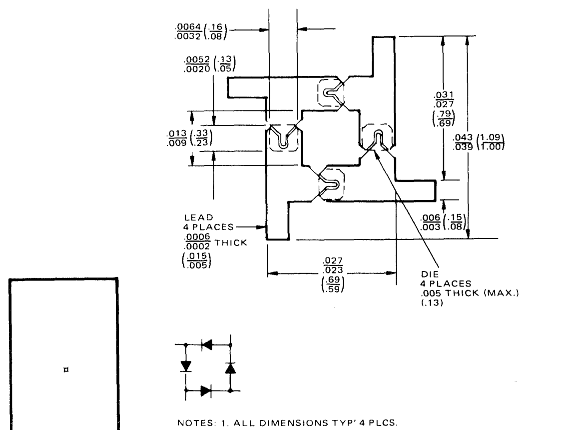


C_p = 0.11pF typical
L = 0.12nH

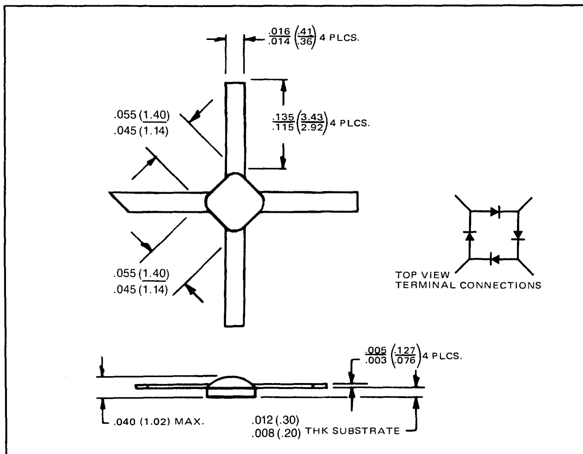
290-001

Note: Millimeters in parentheses.

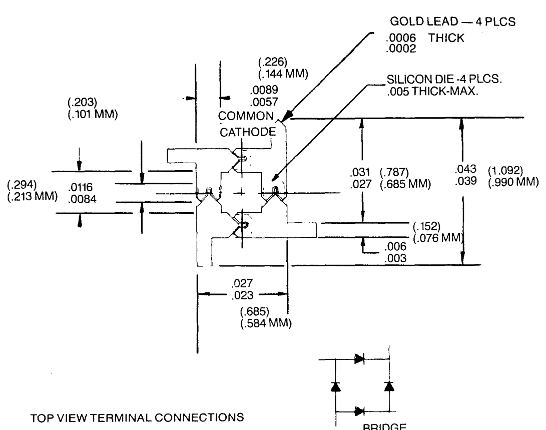
Outline Drawings



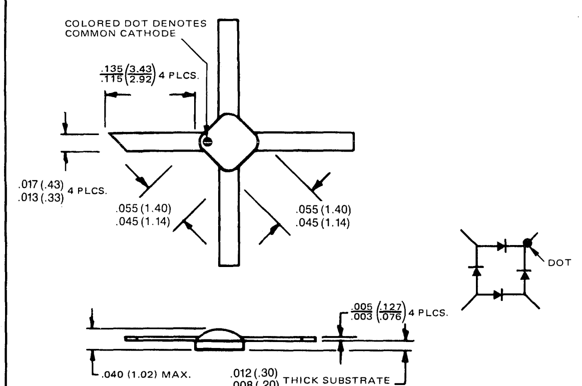
294-003



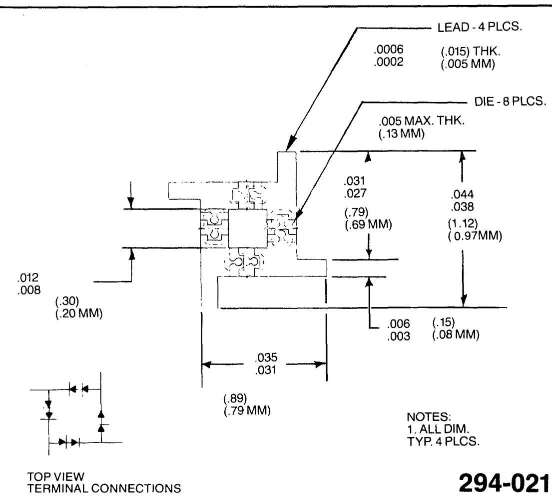
295-002



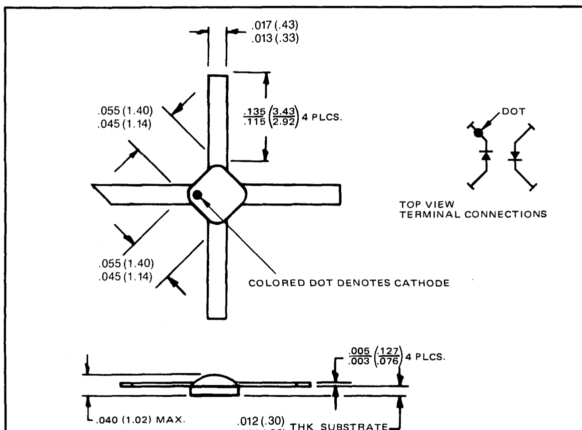
294-004



295-004

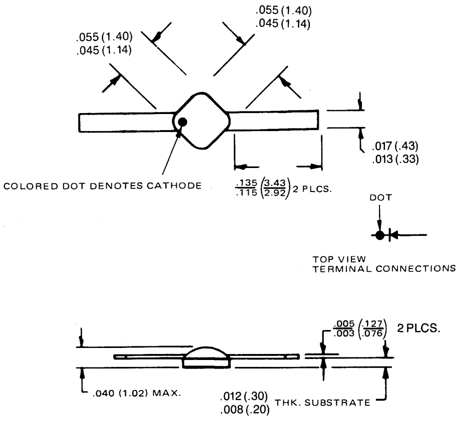


294-021

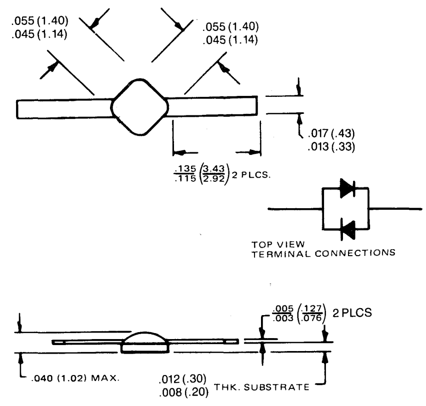


295-008

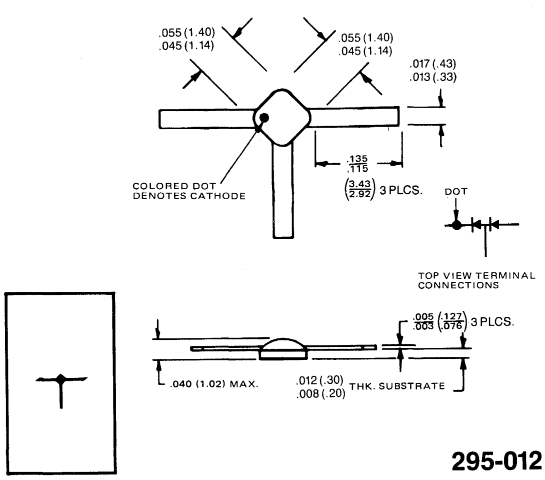
Note: Millimeters in parentheses.



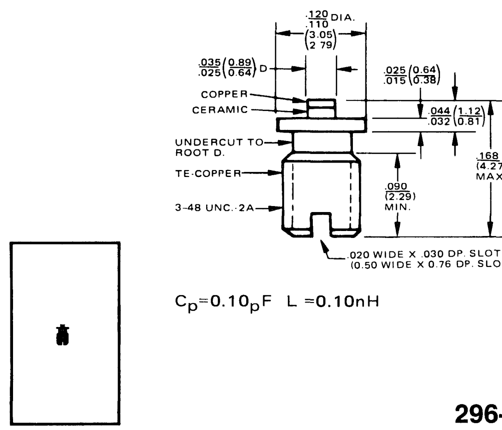
295-011



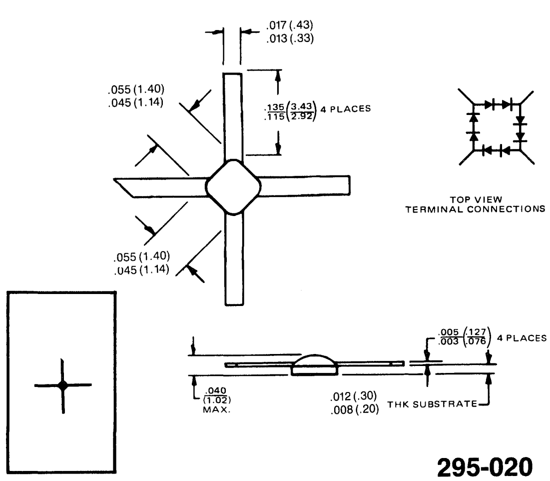
295-025



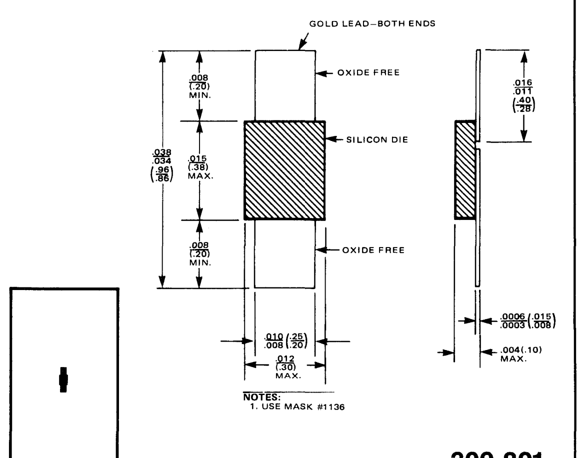
295-012



296-001



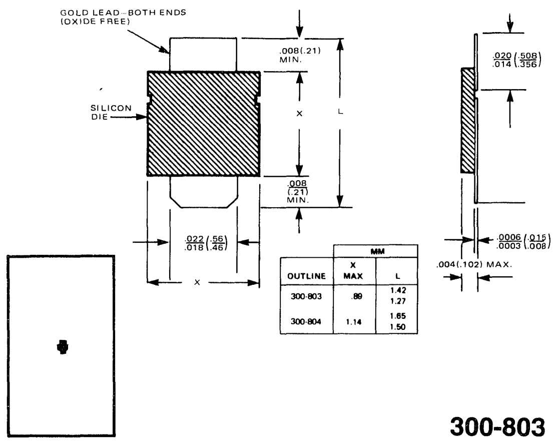
295-020



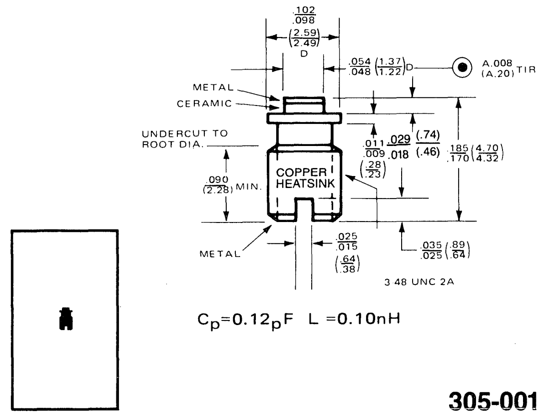
300-801

Note: Millimeters in parentheses.

Outline Drawings

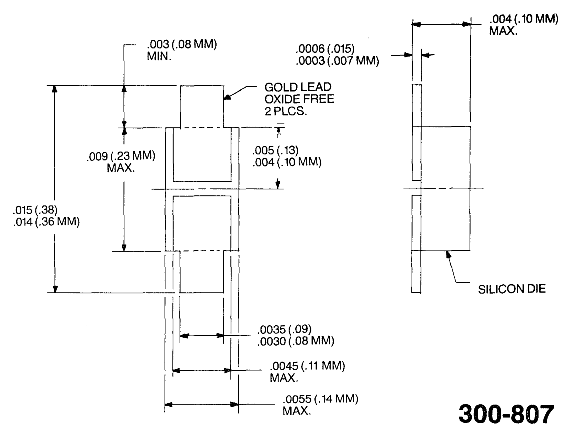


300-803

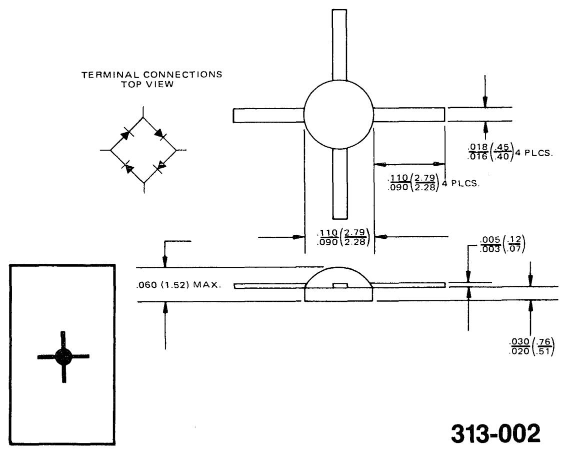


C_p=0.12pF L =0.10nH

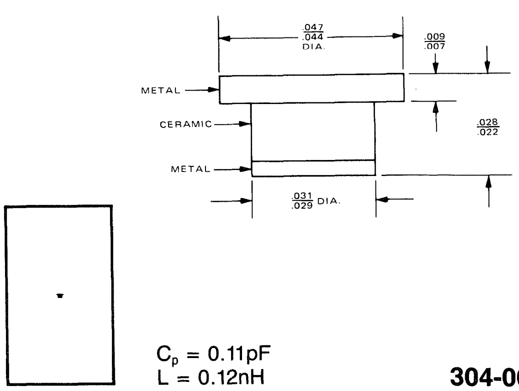
305-001



300-807

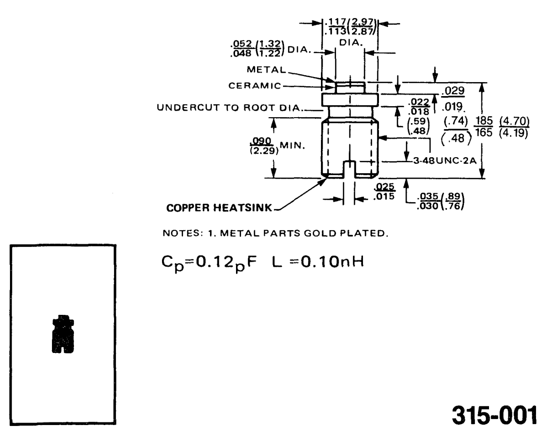


313-002



C_p = 0.11pF
L = 0.12nH

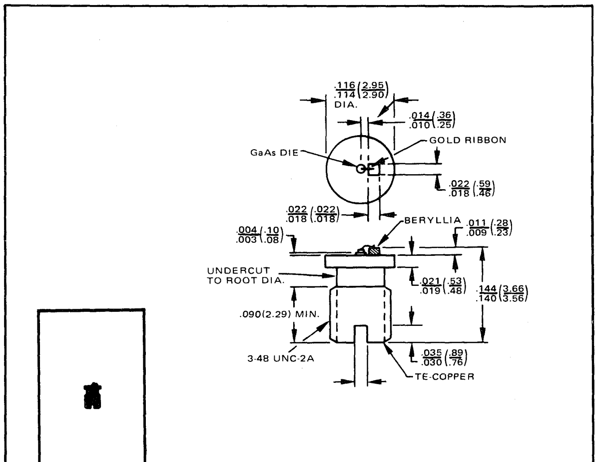
304-001



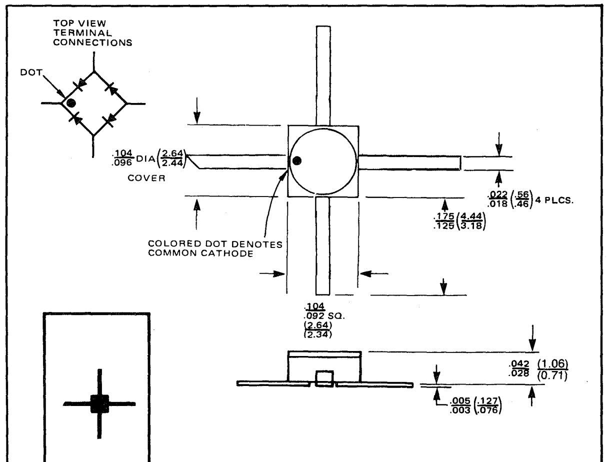
C_p=0.12pF L =0.10nH

315-001

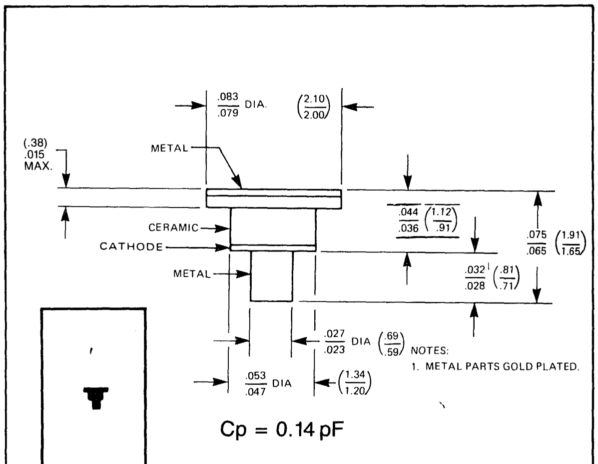
Note: Millimeters in parentheses.



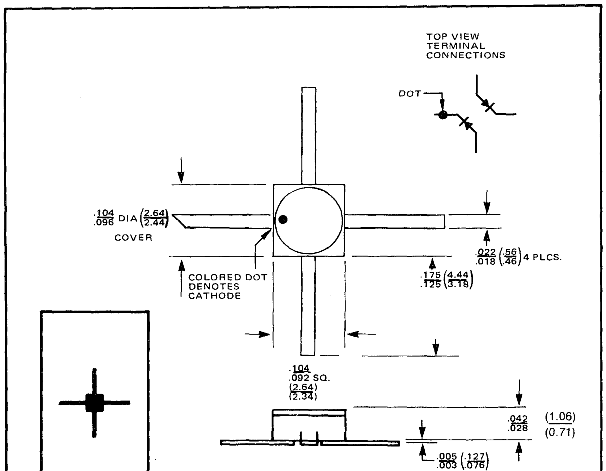
316-901



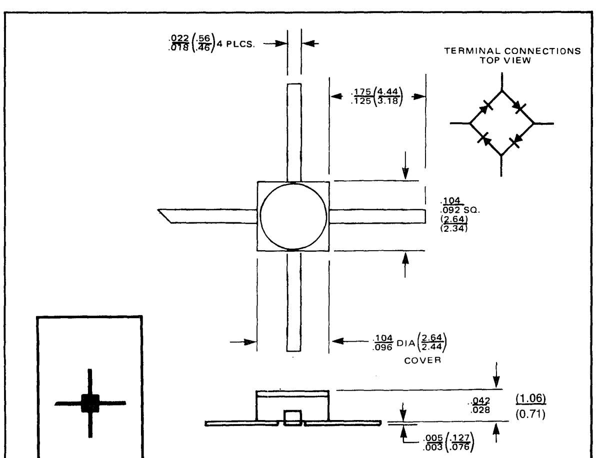
325-004



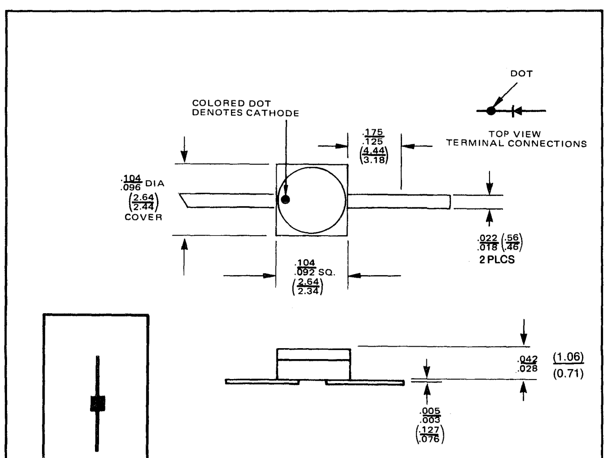
320-001



325-008



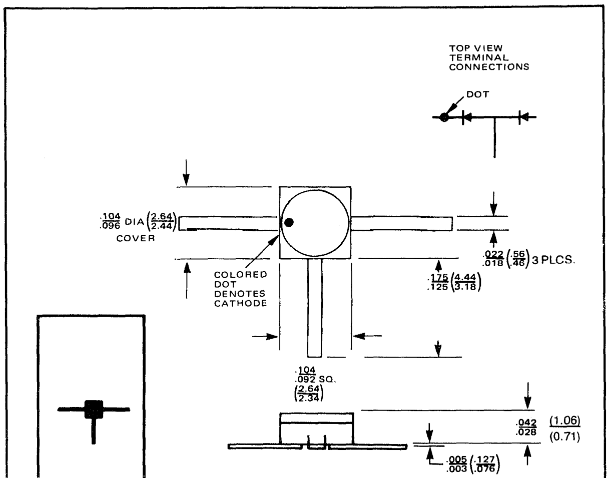
325-002



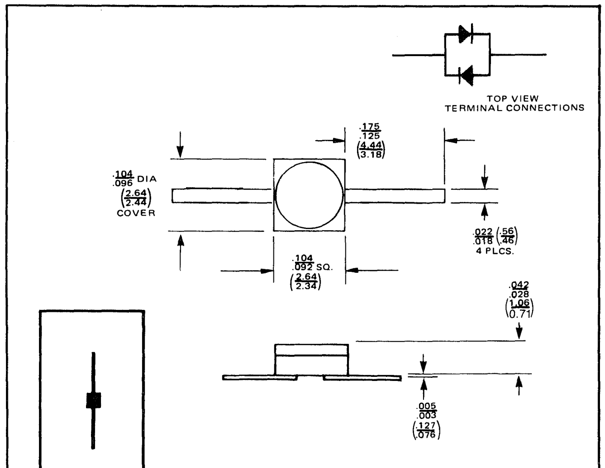
325-011

Note: Millimeters in parentheses.

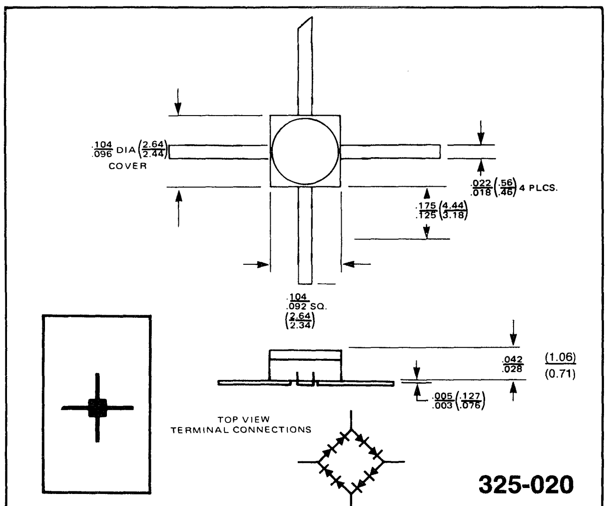
Outline Drawings



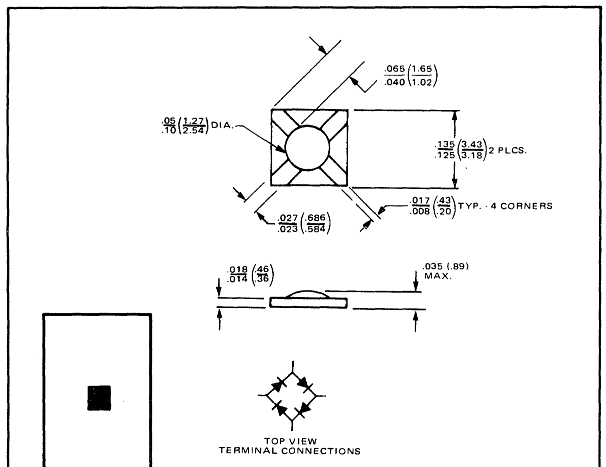
325-012



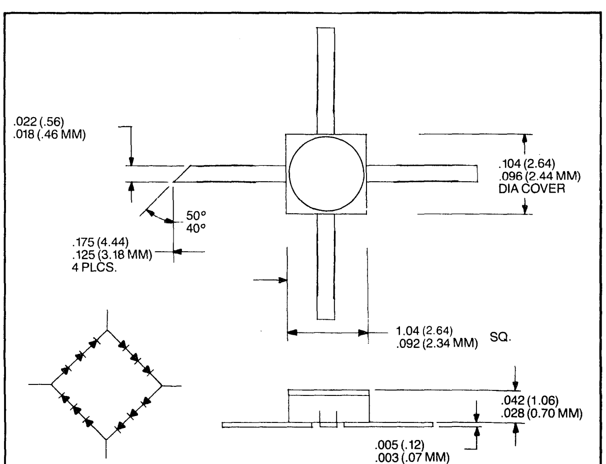
325-025



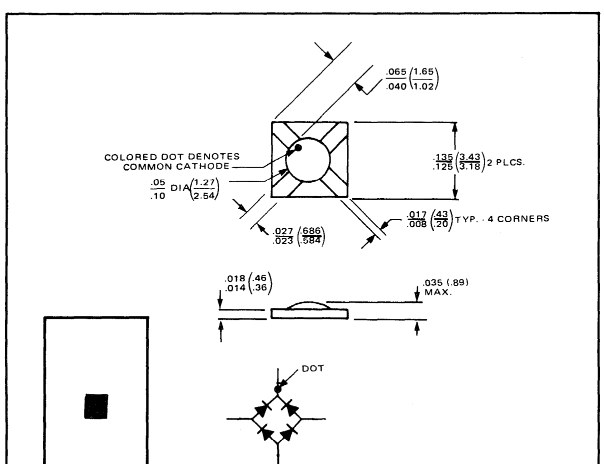
325-020



337-002

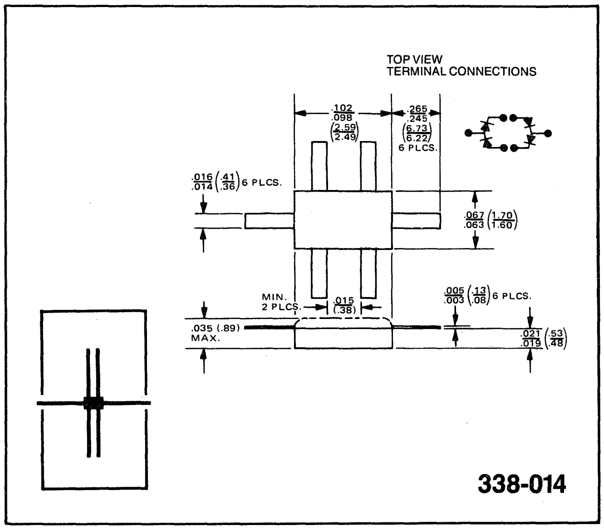


325-022

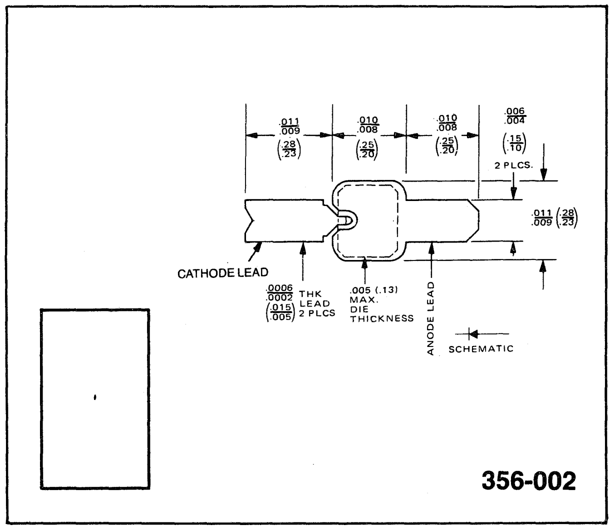


337-004

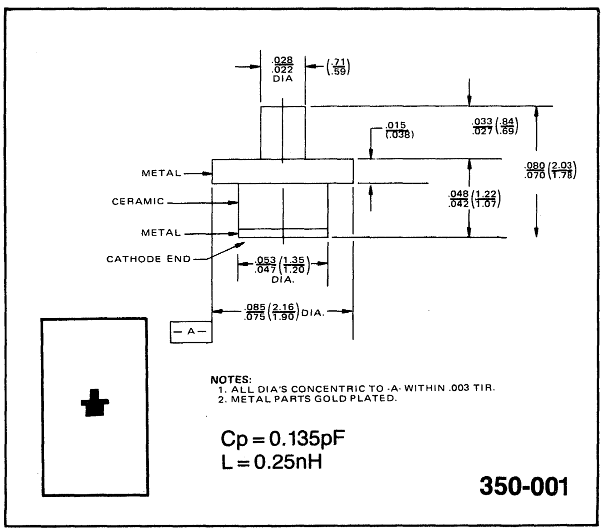
Note: Millimeters in parentheses.



338-014



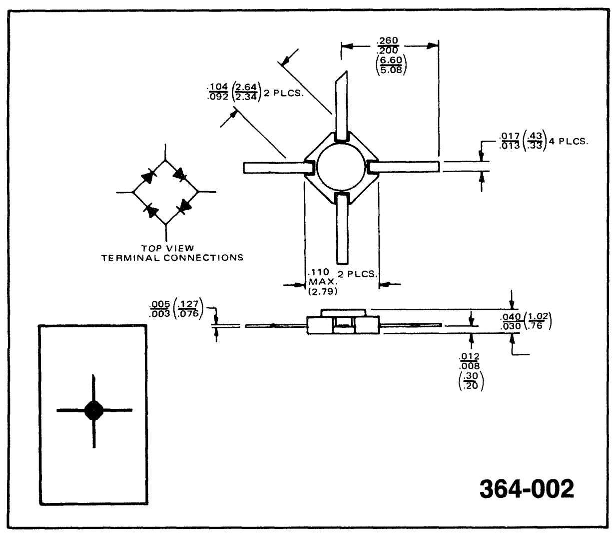
356-002



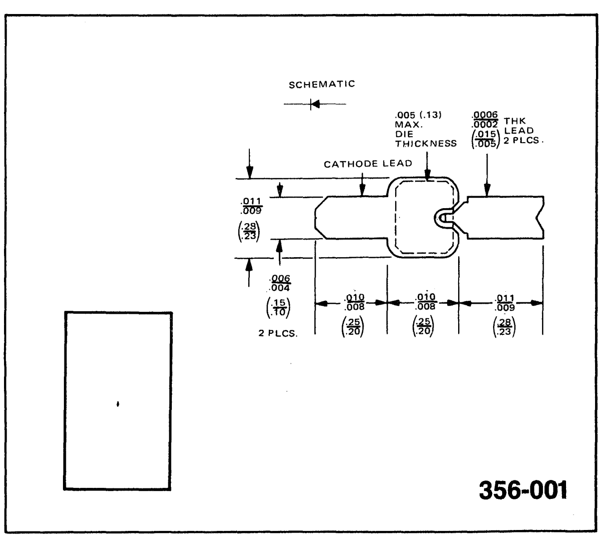
NOTES:
1. ALL DIA'S CONCENTRIC TO -A- WITHIN .003 TIR.
2. METAL PARTS GOLD PLATED.

Cp = 0.135pF
L = 0.25nH

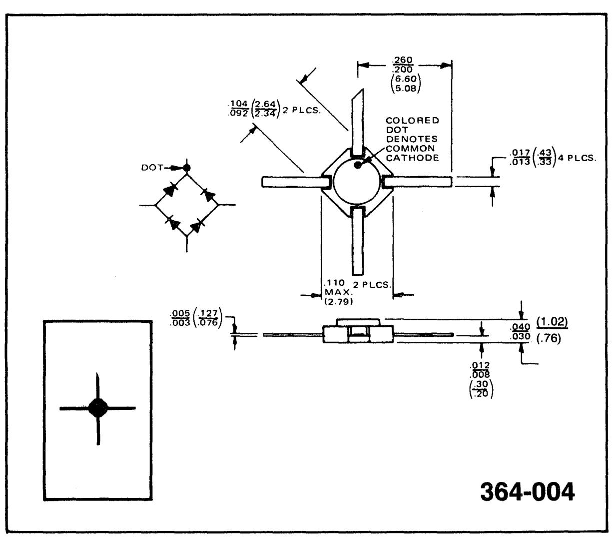
350-001



364-002

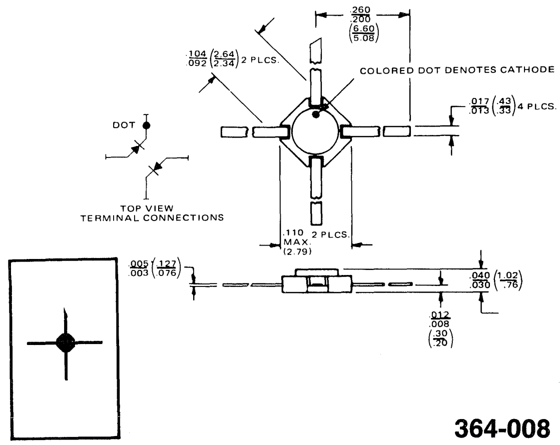


356-001

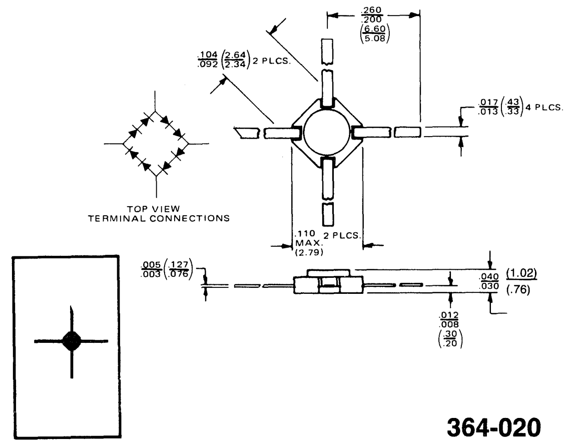


364-004

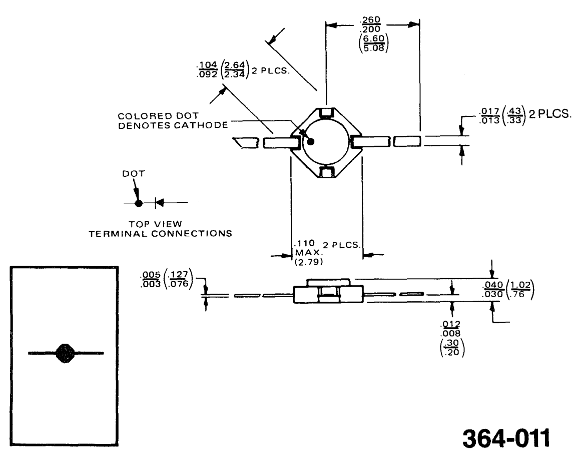
Note: Millimeters in parentheses.



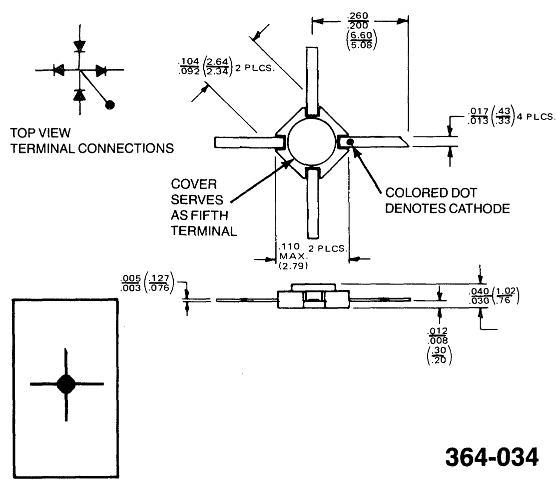
364-008



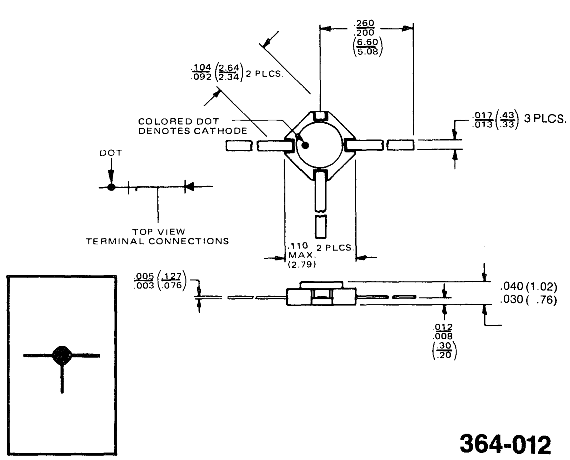
364-020



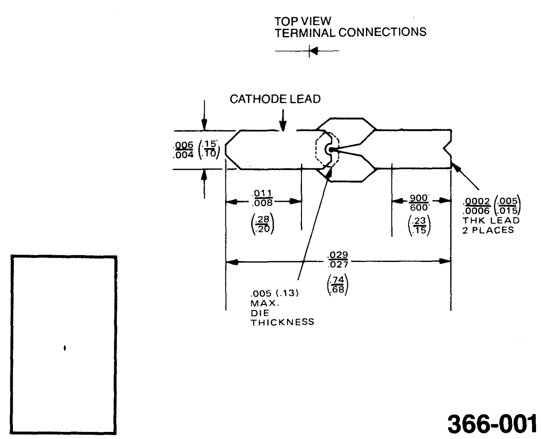
364-011



364-034

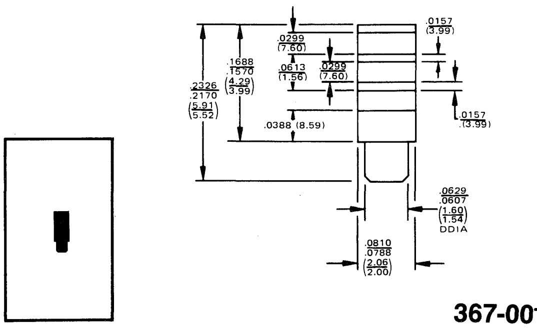


364-012

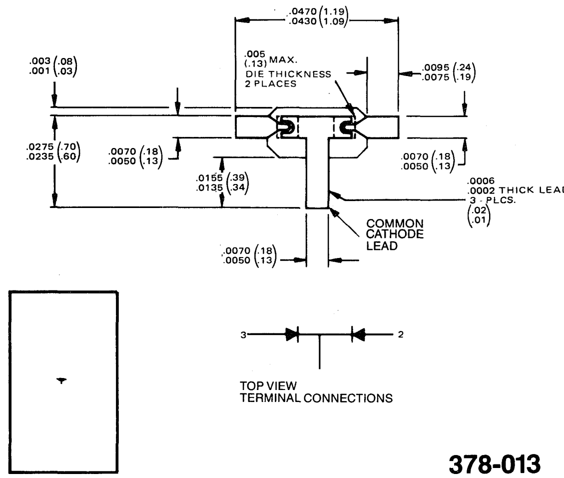


366-001

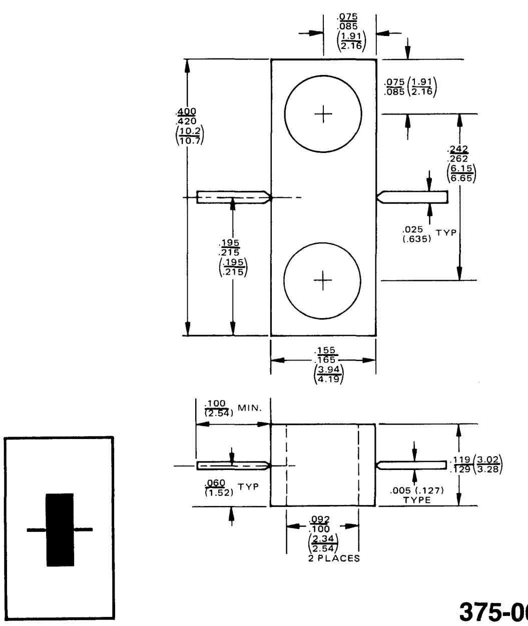
Note: Millimeters in parentheses.



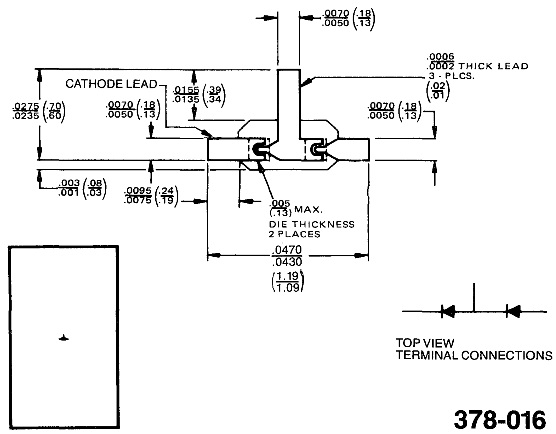
367-001



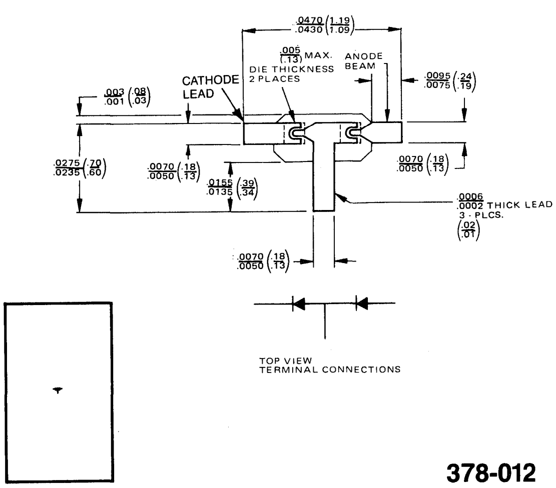
378-013



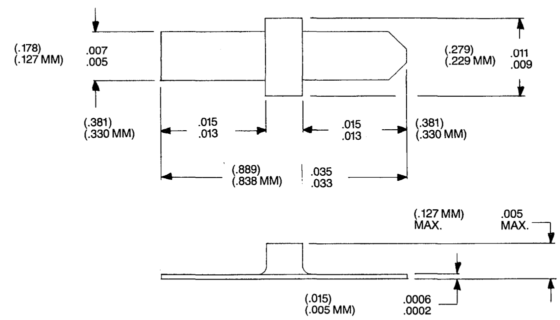
375-001



378-016



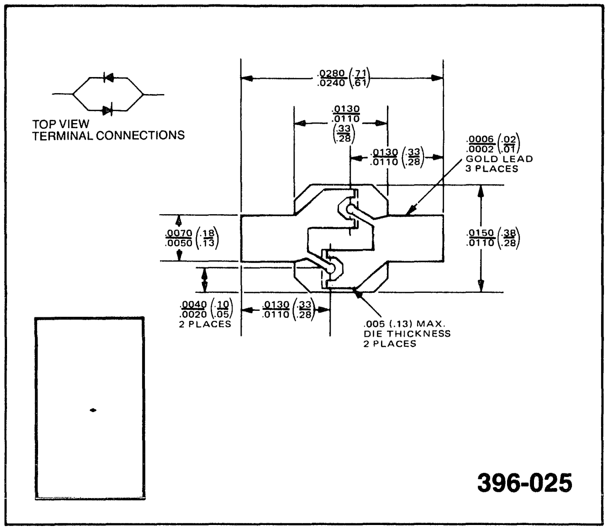
378-012



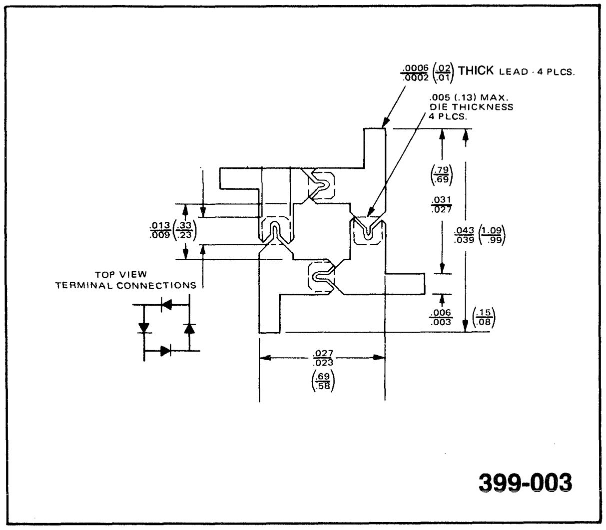
389-001

Note: Millimeters in parentheses.

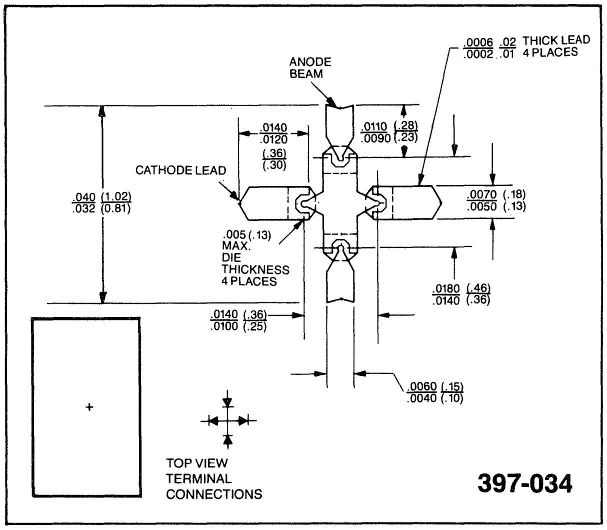
Outline Drawings



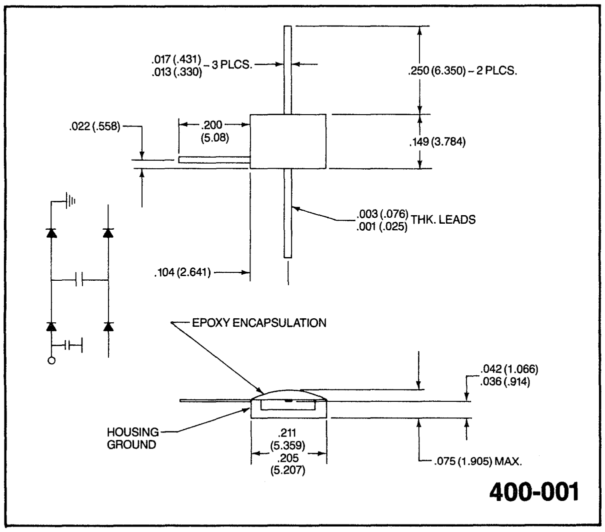
396-025



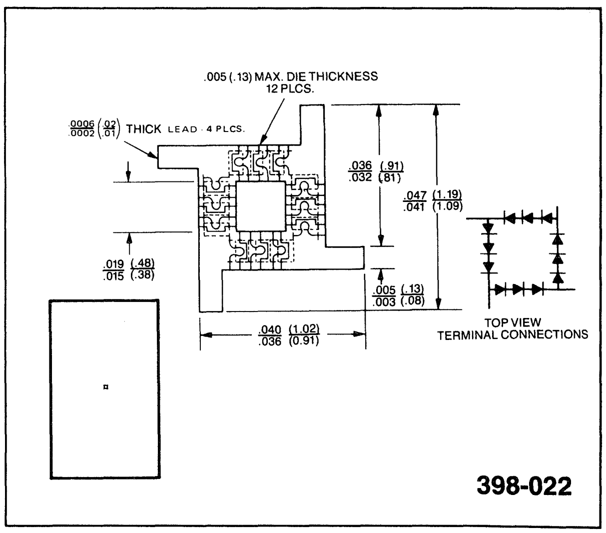
399-003



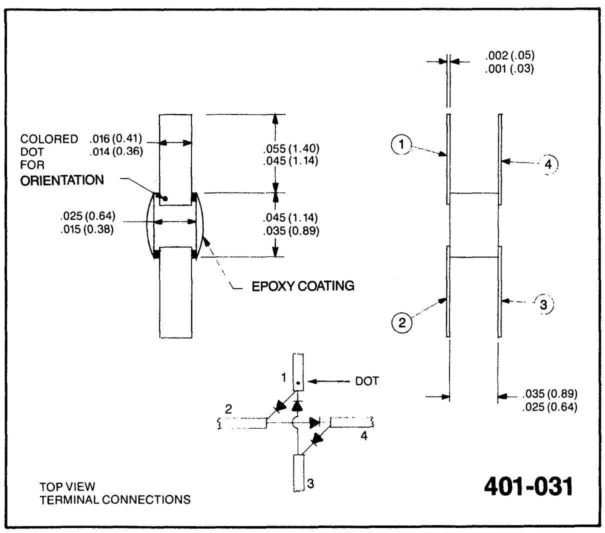
397-034



400-001

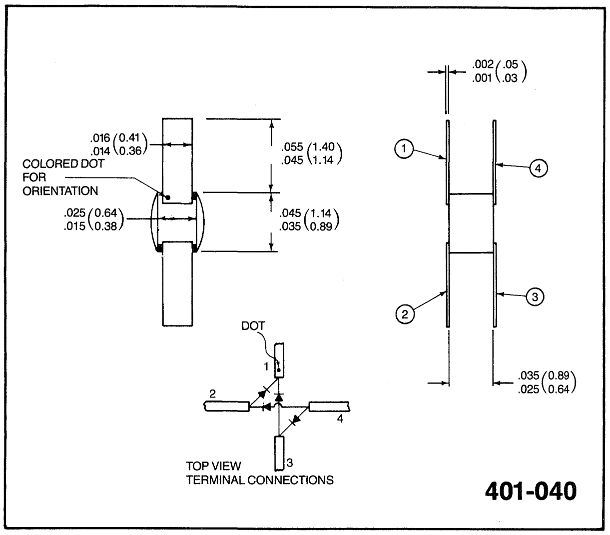


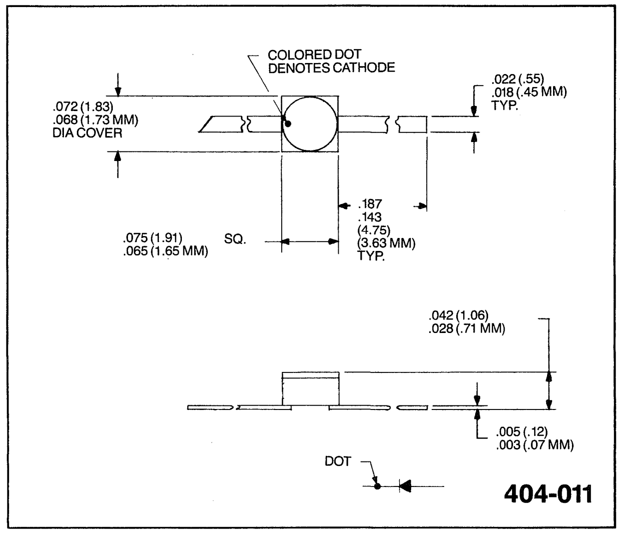
398-022

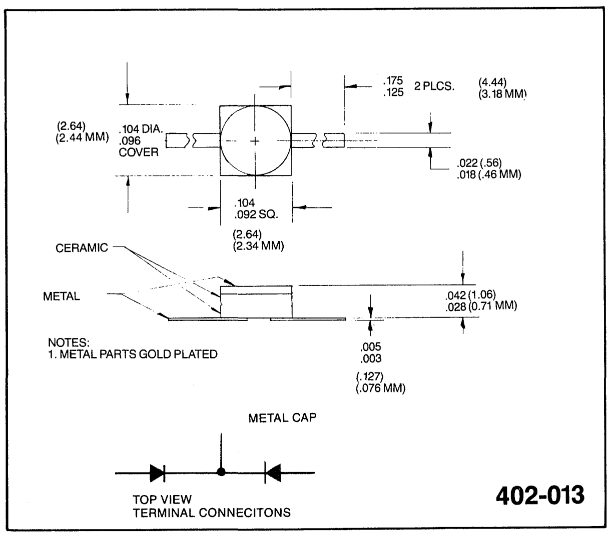


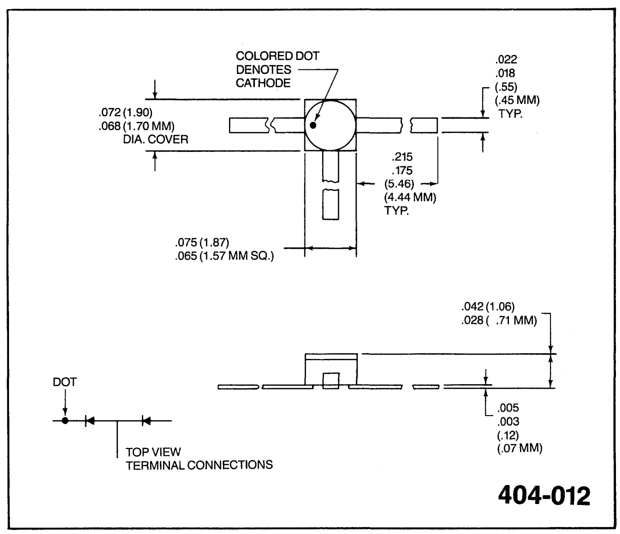
401-031

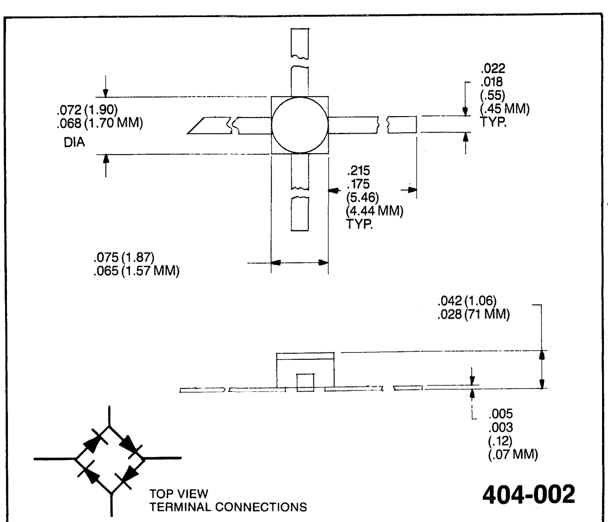
Note: Millimeters in parentheses.

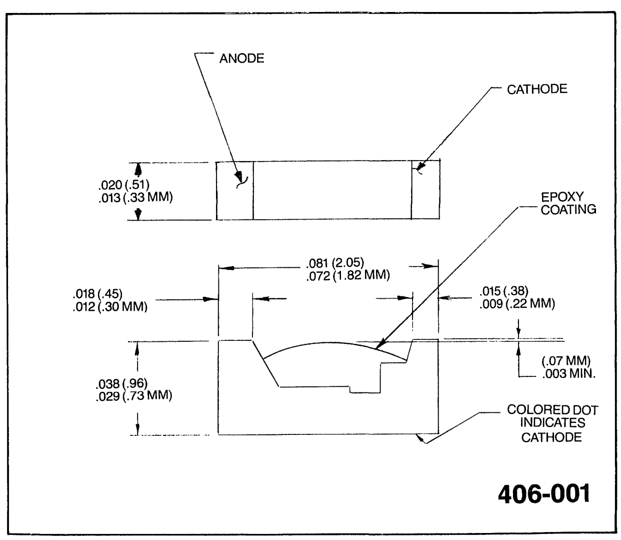






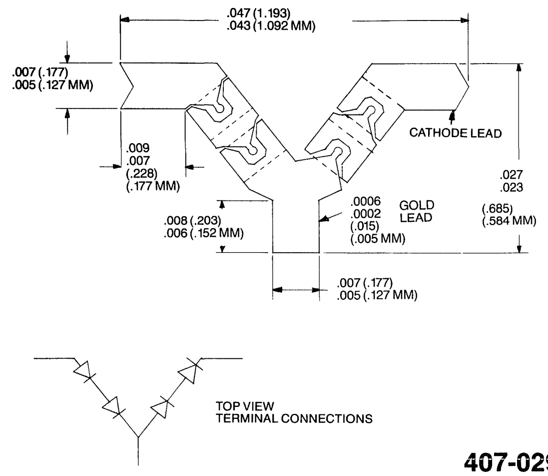




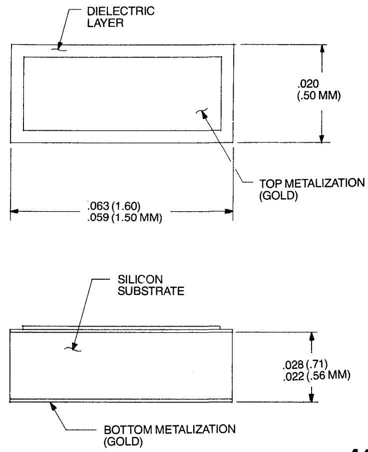


Note: Millimeters in parentheses.

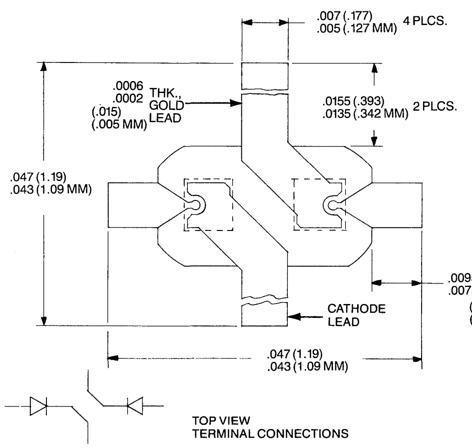
Outline Drawings



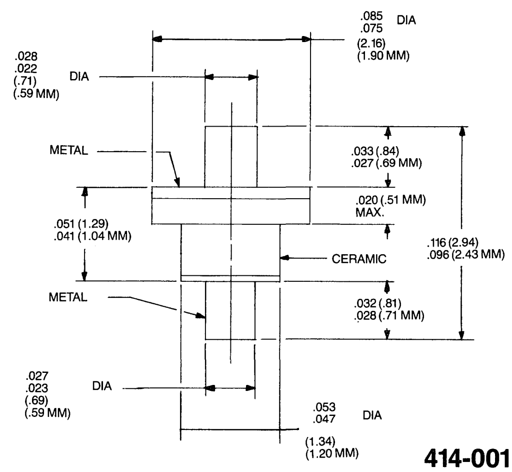
407-029



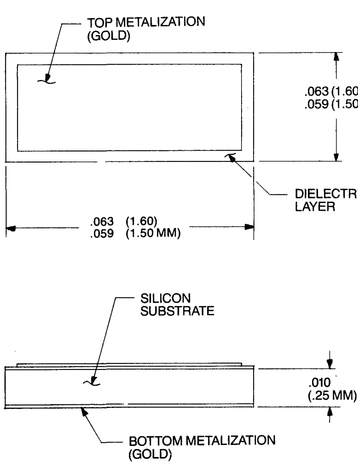
411-802



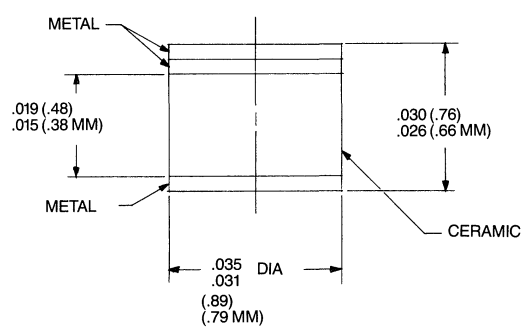
408-009



414-001

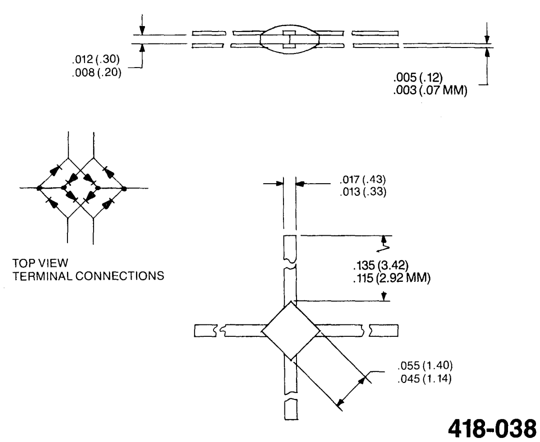


411-801

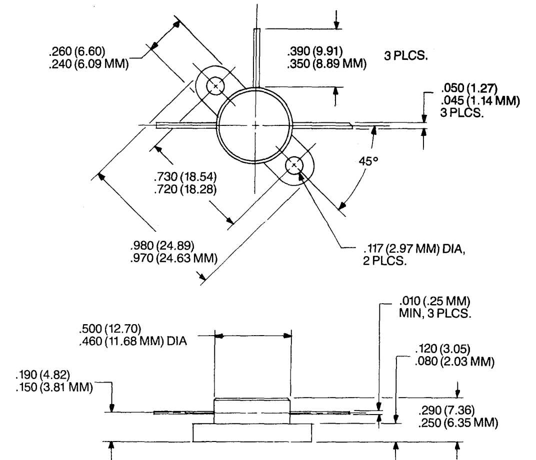


417-001

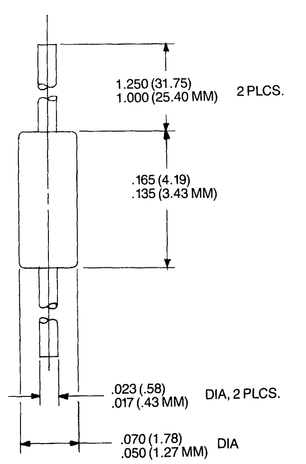
Note: Millimeters in parentheses.



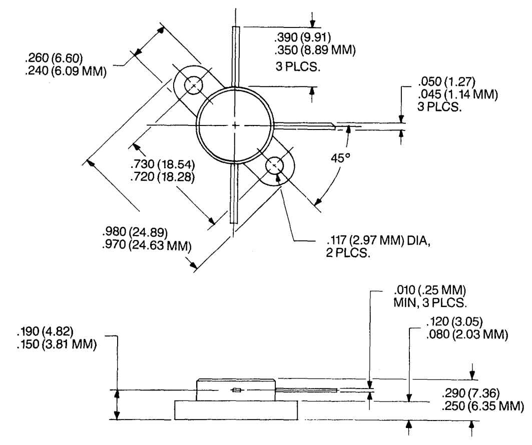
418-038



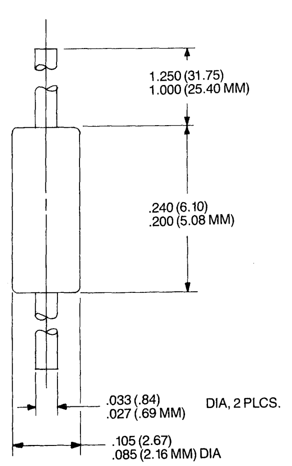
423-901



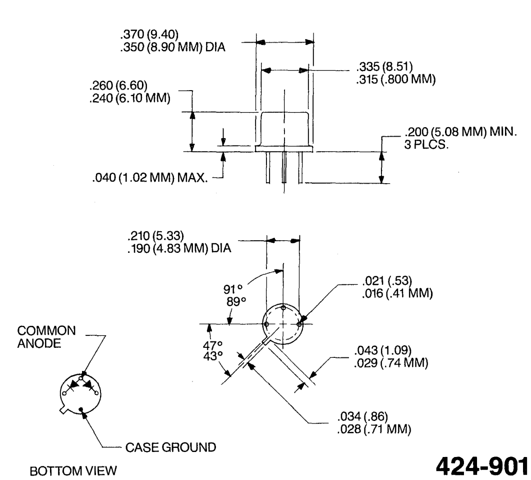
420-001



423-902



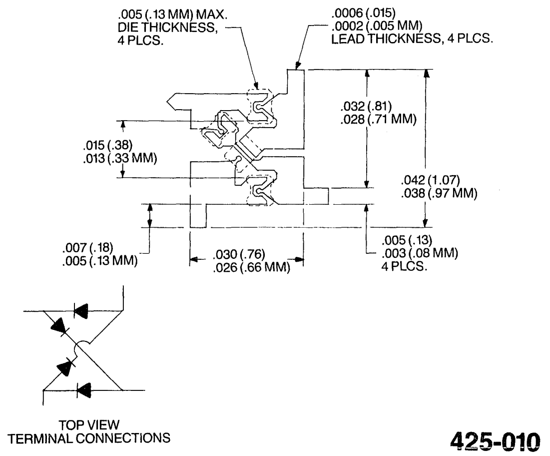
421-001



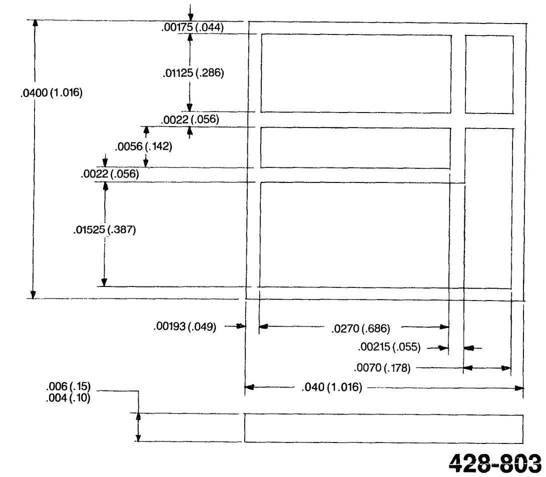
424-901

Note: Millimeters in parentheses.

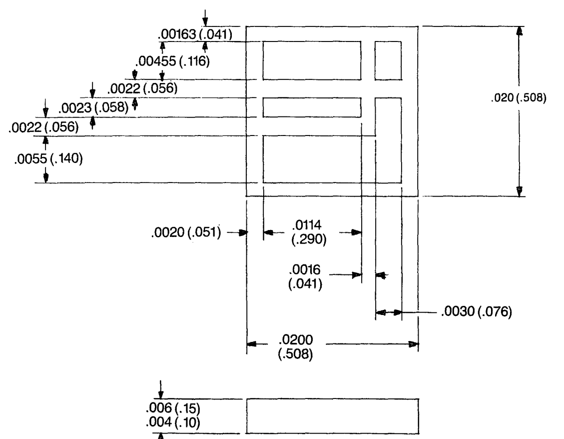
Outline Drawings



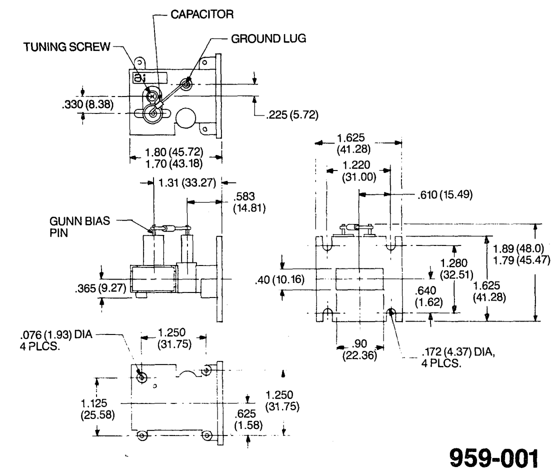
425-010



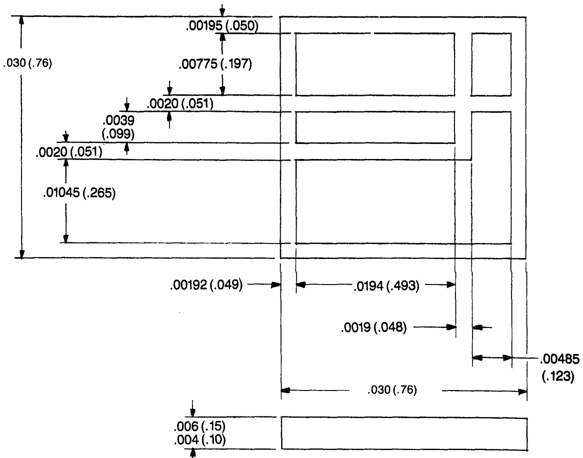
428-803



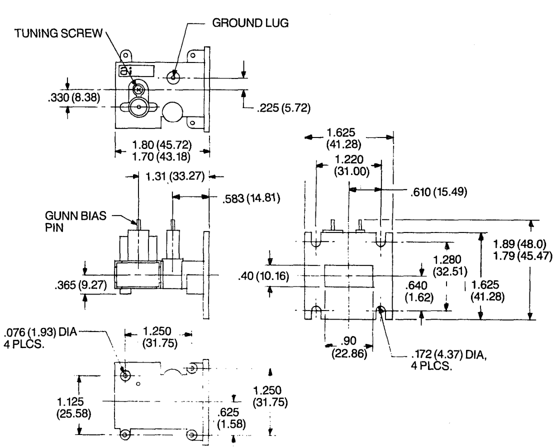
428-801



959-001

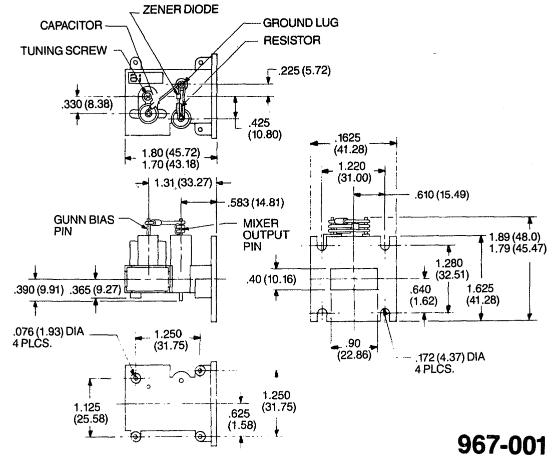


428-802

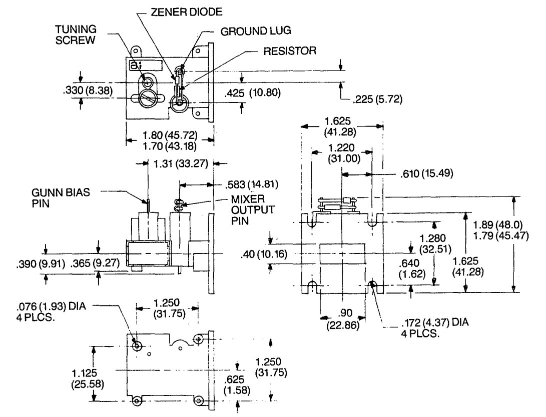


959-002

Note: Millimeters in parentheses.



967-001



967-002

Note: Millimeters in parentheses.

Package Silhouettes

The silhouettes on the following pages are actual size, and their corresponding package style numbers are provided merely as an aid for choosing the proper package for your needs. Alpha has unique manufacturing skills and new product capabilities, as well as complete facilities for fabrication of special package designs and for solving special mounting problems. Call the factory for further information.

Open Packages

Actual Size	Alpha Package
	176-001
	176-801
	176-002
	179-001
	173-001, 002
	184-001
	184-804

30MIL (OD) Ceramic — Low Parasitic

Actual Size	Alpha Package
	417-001
	304-001
	290-001

50MIL (OD) — Low Inductance

Actual Size	Alpha Package
	084-001
	082-001
	253-001
	067-001

50MIL (OD) Ceramic — Low Capacitance

Actual Size	Alpha Package
	247-001
	237-001
	350-001
	320-001
	414-001
	247-802
	247-805
	247-807

80MIL (OD) — Low Inductance

Actual Size	Alpha Package
	048-001
	248-001
	093-001
	092-001

80MIL (OD) — Low Capacitance

Actual Size	Alpha Package
	168-001
	119-001
	135-001
	023-001

80MIL (OD) — Low Capacitance (cont.)

	013-001
	207-001
	168-801
	168-802
	367-001

Lower Frequency — High Power Packages

Actual Size	Alpha Package
	240-001
	116-001
	017-001

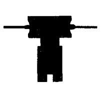
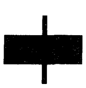
Screw-Thread Packages

Actual Size	Alpha Package
	296-001
	305-001
	315-001
	158-001
	188-001
	118-001
	117-001

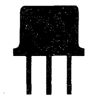
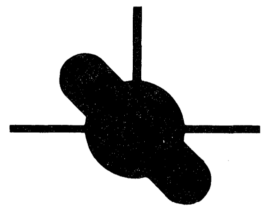
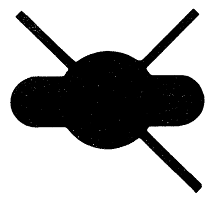
Glass Packages

Actual Size	Alpha Package
	420-001
	421-001
	075-001
	062-001
	099-001
	287-001

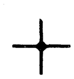
50 Ohm Broadband Packages

Actual Size	Alpha Package
	197-001
	190-001
	375-001

High Power Multi-Throw Packages

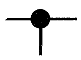
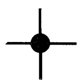
Actual Size	Alpha Package
	424-901
	423-901
	423-902

50MIL Square Ceramic

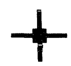
Actual Size	Alpha Package
	295-011
	295-012
	295-xxx
 (8 leads)	418-038

Package Silhouettes

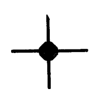
100MIL (OD) Ceramic

Actual Size	Alpha Package
	130-011
	131-012
	132-xxx
	313-002

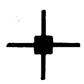
Hermetically Sealed — 70MIL Square

Actual Size	Alpha Package
	404-011
	404-012
	404-002

Hermetically Sealed — 110 MIL Diagonal

Actual Size	Alpha Package
	364-011
	364-012
	364-002

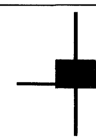
Hermetically Sealed — 100MIL Square

Actual Size	Alpha Package
	325-011
	325-012
	325-xxx

Fiberglass

Actual Size	Alpha Package
	337-xxx
	401-040

T Attenuator

Actual Size	Alpha Package
	400-001

Section 9
Index

• All devices in this catalog are listed alphanumerically in the following index, with their corresponding page number.

Section 10
Ordering Information, Domestic and International Sales Offices and Representatives

Ordering Information, Domestic and International Sales Offices and Representatives

Warranty/Ordering Information

How to Order

Orders may be placed with our local field sales representatives, listed later in this section, or with the Semiconductor Division's sales department at:

Alpha Industries—Semiconductor Division
20 Sylvan Road
Woburn, Massachusetts 01801
Telphone: (617) 935-5150
TWX: 710-393-1236
TELEX: 949436

Correct ordering information speeds delivery. When ordering, please specify type or model numbers and product name. For example, "Type XXX, Beam-Lead Schottky Barrier Diodes," or "Model XXX, Beam-Lead PIN Diodes." Be sure to include the prefix or suffix on type or model numbers to identify special versions of the product.

Terms and Conditions of Sales

The minimum order accepted by Alpha is $50.00 on OEM and distributor orders; all others, export and government, are $100.00 minimum. On all orders, payment is due net 30 days following date of shipment. Taxes are not included in Alpha's prices. Foreign payments and terms are arranged on an individual bases by Alpha's International Marketing Department.

Shipments

Shipments to destinations within the United States and overseas made directly from the factory are billed F.O.B. Worburn, Mass.

Warranty Provisions

Alpha products are warranted to be free of defects in materials or manufacture and to conform to the applicable published ratings and characteristics in effect at the time of shipment. Alpha's liability under such warranty is limited to replacing or repairing, at our option, any goods found to be defective in said respects, which are returned to us, transportation prepaid. In no event shall Alpha be liable for collateral or consequential damages. This warranty shall not apply to any products which have been subjected to misuse, improper installation, repair, alteration, neglect, accident, inundation, fire, or operation outside the published maximum ratings. Alpha shall have the right of final determination in regard to the cause and existence of any defect under this warranty.

Repairs or Replacements

In accordance with the conditions of the Warranty Statement, all defective units should be returned to the factory whether repairable or not, so that we may avoid a continuation of the defect in future production runs or in new product designs.

Service

Alpha welcomes the opportunity to work with you. Realizing that service is the keystone of any lasting and mutually rewarding business relationship, we will spare no effort to assure your complete satisfaction.

North American Sales Offices & Representatives

New England
Alpha Industries, Inc.
New England Sales
2 Courthouse Lane, Unit 4
Courthouse Square
Office Park II
Chelmsford, MA 01824
Phone: (617) 927-1820
Twx: 710-321-0020

Metro New York/
N. New Jersey
Trionic Associates
320 Northern Blvd.
Great Neck, L.I., NY 11020
Phone: (516) 466-2300
Twx: 510-223-0834

Fort Monmouth, NJ
Marketing Services
Associates, Inc.
Crystal Brook
Professional Building
Route 35
Eatontown, NJ 07724
Phone: (201) 389-1311
Fax: (201) 389-2229

Upstate New York
Ossmann Instruments
6666 Old Collamer Road
East Syracuse, NY 13057
Phone: (315) 437-7052
Twx: 710-541-1523

S. New Jersey/
E. Pennsylvania/Delaware
Omni Sales
1014 Bethlehem Pike
Erdenheim, PA 19118
Phone: (215) 233-4600
Twx: 510-661-9170

W. Pennsylvania/Ohio
Rixan Associates
5062 Wadsworth Road
Dayton, OH 45414
Phone: (513) 278-4216

Rixan Associates
P.O. Box 1384
Stow, OH 44224
Phone: (216) 686-2909

Maryland/Virginia
W. Virginia/Washington, DC
E. Tennessee
Burgin-Kreh Associates, Inc.
7000 Security Blvd., Suite 330
Baltimore, MD 21207
Phone: (301) 265-8500
Twx: 710-862-1450

Burgin-Kreh Associates, Inc.
P.O. Box 4455
8314 Timberlake Road
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Technology Marketing Corp.
599 Industrial Drive
Carmel, IN 46032
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Twx: 910-997-0194

Technology Marketing Corp.
3428 West Taylor Street
Fort Wayne, IN 46804
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Technology Marketing Corp.
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Overland Park, KS 66212
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Twx: 910-749-4077

Electri-Rep
2258 Schuetz Road, Suite 108
St. Louis, MO 63146
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Technical Marketing, Inc.
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Arizona, New Mexico,
& El Paso, TX
Semper Fi Sales, Inc.
7905 East Greenway Road,
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Twx: 910-951-0020

Colorado & Utah
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