1969 state devices

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application note index

AN 904 **The PIN Diode**

The PIN diode is essentially a high-frequency resistance element whose resistance value can be varied by a dc or low-frequency bias signal. This Note describes the important characteristics of the PIN diode and the relationship of these characteristics to its use as a high-frequency switching or attenuating element. Typical application circuits are presented. 16 pages.

AN 907 **The Hot Carrier Diode: Theory, Design And Application.**

The Hot Carrier or Schottky barrier diode is virtually an ideal ultra-high-frequency switching device. This Note contains an up-to-date discussion of the physics of its operation, and describes its electrical and physical characteristics. Comparison is made to the PN-junction and point-contact diodes. 14 pages.

AN 909 **Electrical Isolation Using The HP 4310**

In the HP 4310 Photon Coupled Isolator, a gallium arsenide electroluminescent diode is optically coupled to a silicon photodiode but electrically decoupled. Electrical isolation using this technique is described. The Note also gives the equivalent circuit of the device along with suggested applications and their typical circuits. 4 pages.

AN 910 **Optoelectronic Coupling For Coding, Multiplexing, And Channel Switching**

The stream of photons from a gallium arsenide electroluminescent diode carries enough energy to a silicon photodiode to enable operation of isolated electronic switches. Isolated switching, as with a relay, is thus possible and the Note gives design principles and typical circuits using the HP 4310 Photon Coupled Isolator. 2 pages.

AN 911 **Low Level DC Operation Using HP Photo-Choppers**

Threshold performance of chopper amplifiers can be extended to lower signal levels by using photochoppers. A brief discussion is given of the photochopper amplifier technique, showing various arrangements for applying negative feedback. Suggested circuits for driving the neon lamps are also described. 5 pages.

AN 912 **An Attenuator Design Using PIN Diodes**

This Note discusses the use of PIN diodes as variable RF resistance elements controlled by dc bias. Through the use of this mechanism a constant impedance R-type attenuator network is developed. Control of attenuation from 1 to 20 db is obtained through a variable dc bias. 4 pages.

AN 914 **Biasing And Driving Considerations For PIN Diode RF Switches And Modulators**

Discusses application of PIN diodes as RF switches and modulators from the standpoint of the video driving waveforms required, and the means available to generate these waveforms. Emphasis is given to methods of achieving very fast switching speeds or high modulation frequencies. 23 pages.

AN 915 **Threshold Detection And Demodulation Of Visible And Infrared Radiation With Pin Photodiodes**

Solid-state photodetectors, particularly PIN photodiodes, are compared for threshold signal applications with the more traditional multiplier phototubes. Relative functional merits are presented, and a family of spectral sensitivity curves for various types of photodetectors is given. Terminal circuit design principles and realizations are described. 5 pages.

AN 916 **HP GaAs Sources**

HP Gallium Arsenide EL (electroluminescent) diodes radiate in a narrow band at a wavelength of 9000 A° when forward biased. When properly utilized, the radiation from the EL diode can be switched on and off in less than 100 nanoseconds. AN 916 discusses how the characteristics of this EL diode may be applied to optical circuits and describes design principles for obtaining optimum performance. 2 pages.

AN 917 **HP PIN Photodiode**

HP silicon planar PIN photodiodes are ultrafast detectors of visible and near infrared radiation. The low dark current of the planar diodes enables detection of very low radiation levels. AN 917 discusses how the characteristics of the HP silicon planar photodiode apply in optical circuits and explains design principles for obtaining optimum performance. 2 pages.

AN 918 **Pulse And Waveform Generation With Step Recovery Diodes**

One major area of Step Recovery Diode applications is in pulse shaping and waveform generation. This note describes in detail what characteristics of the SRD are most critical to pulse applications, how these are controlled and specified, and how the SRD can be used in a variety of pulse shaping and waveform generating circuits. 26 pages.

AN 920 **Harmonic Generation Using Step Recovery Diodes And SRD Modules**

Harmonic frequency multiplication, and "comb" spectrum generation using step recovery diodes, are the topics of this note. It describes the fundamental theoretical considerations and practical design techniques which have been found useful in the design of switching reactance multipliers. It also illustrates many practical multiplier designs. Finally, the note summarizes some important design criteria concerning multiplier noise, bandwidth, and stability. 32 pages.

AN 922 **Application Of PIN Diodes**

How the PIN diode can be applied to a variety of RF control circuits is the subject of this note. Such applications as attenuating, leveling, amplitude and pulse modulating, switching, and phase shifting are discussed in detail. Also examined are some of the important properties of the PIN diode and how they affect its application.

AN 924 **Application Of The Dual Photocell**

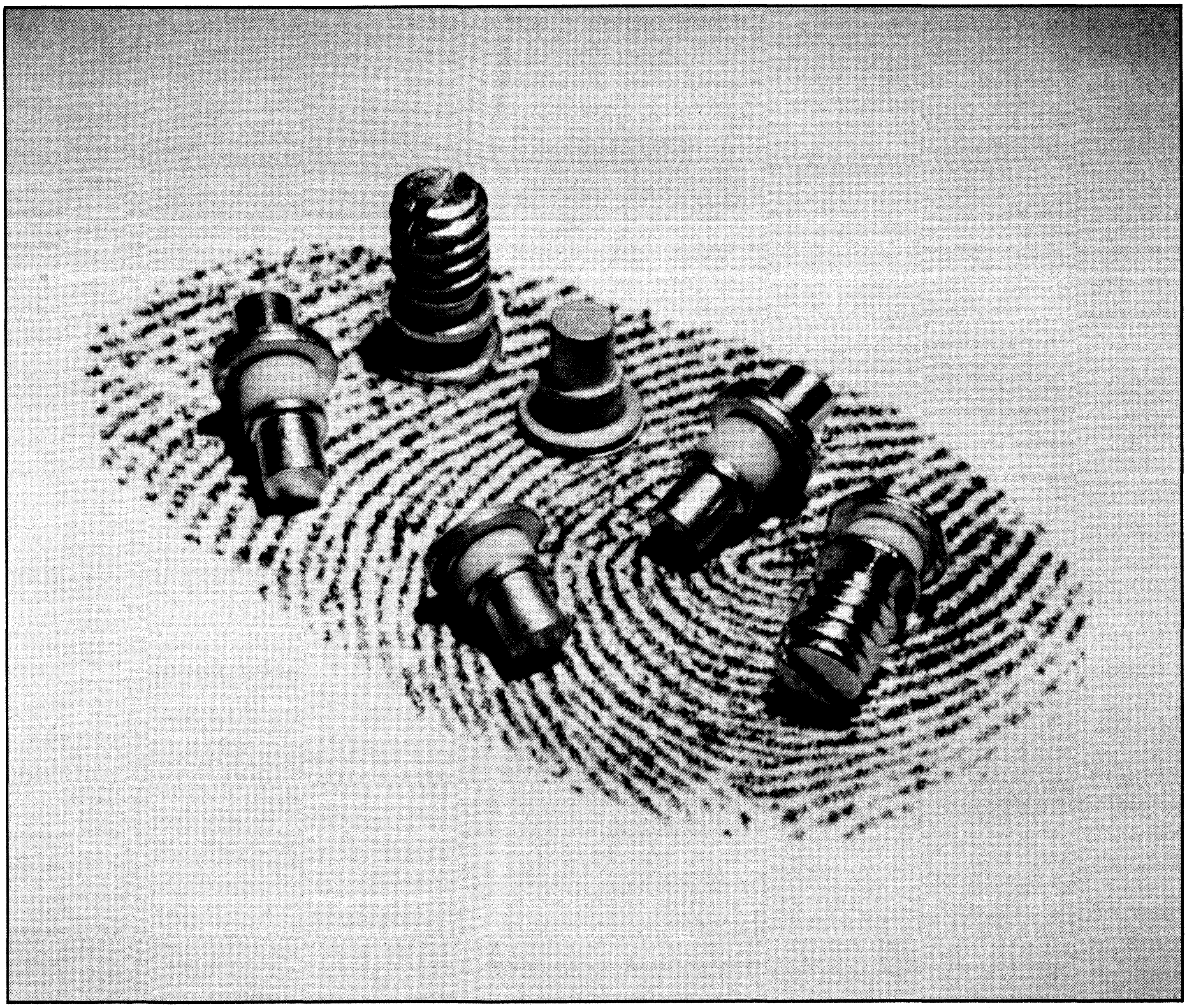
This note covers in considerable detail the application of dual photocells in low-noise choppers and analog multipliers. It also covers some other applications such as synchronous modulator-demodulator choppers; light beam position sensors; voltage tunable resistors; dual function controls in analog and switching circuits, and in stereo volume controls.

step recovery diodes

HEWLETT hp PACKARD

STEP RECOVERY DIODES FOR HARMONIC GENERATION

SRD-1



Description

HP step recovery diodes are constructed using advanced epitaxial, passivation, gettering, and dimension control techniques. Contact to the chip is made using the latest methods for low thermal resistance and minimum package inductance. The high resistivity, dimensionally tailored, intrinsic layer assures minimum transition time in conjunction with optimum reverse bias capacitance.

Applications

HP step recovery diodes are intended for use as low and high-order, single-stage harmonic generators requiring the ultimate in performance and reliability. These devices have the basic design capability to meet the general requirements of MIL-S-19500, in addition to the special reliability requirements of man-rated space systems.

The step recovery diode, when driven into forward conduction (overdrive), stores charge and appears as a low impedance. When the reverse drive current depletes the stored charge, the diode becomes a high impedance. During this high impedance or open circuit state, a voltage pulse is generated. This pulse occurs once for each period of the drive frequency. When this series of pulses is terminated in a resistive load, a comb spectrum is generated (see Figure 1). By terminating the pulses in a resonant load, the spectrum is optimized at the desired output frequency for harmonic generation.

Application Note 920 and HP Special Information Note No. 4 contain additional detailed information on step recovery diodes and the techniques required to design step recovery diode multipliers.

FEATURES

High order, single stage, harmonic generation for high efficiency.

Radiation resistant for use in nuclear environments.

Easily temperature stabilized allowing operation over broad temperature ranges.

These step recovery diodes are useful in high order multipliers for local oscillator service.

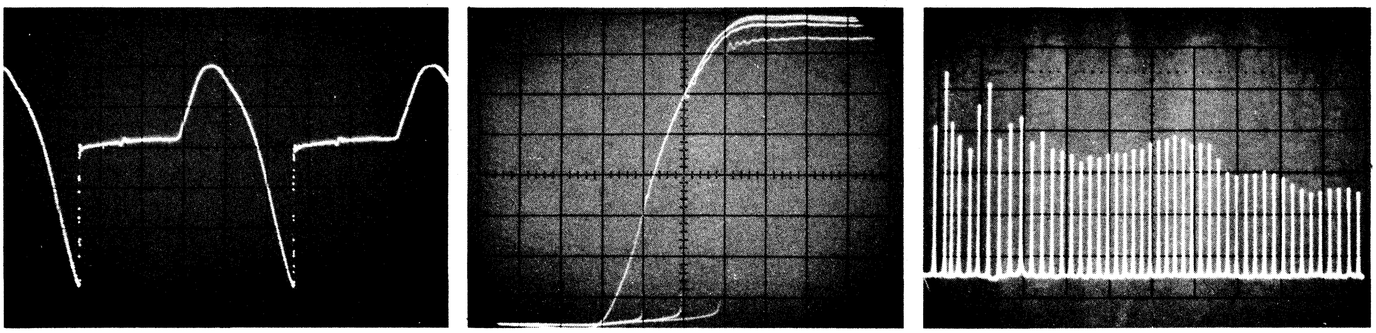
ABSOLUTE MAXIMUM RATINGS

T_{OPR}—Operating Temperature Range. . −65°C to +200°C

T_{STG}—Storage Temperature Range. . . . −65°C to +200°C

θ_{JC}—Thermal Resistance (Junction to Case) . See Table I

P_{DISS}—DC Power Dissipation Derating Characteristic . . . . $\frac{200°C - T_{CASE}}{\theta_{JC}}$



A B C

Figure 1. The sub-nanosecond transition of the Step Recovery Diode after a period of reverse conduction is seen in (A) where a 10 MHz sine wave has been applied across the diode and the current through the diode is monitored. This transition can be used to shape pulses to provide picosecond rise and fall times (B), or as a very rich source of high order harmonics (C).

STEP RECOVERY DIODE SPECIFICATIONS AT T_A = 25°C

Characteristics	C_O Max.	V_F Max. at I_F		V_{BR} Min.	t_t Max. at I_F		τ Min.	I_R Max. at V_R		θ_{JC}	PACKAGE OUTLINE
HP Type Number	pF	V	mA	V	ps	mA	ns	nA	V	°C/W	
5082-0134	10.0	1.0	300	35	400	10	125	50	30	75	31
5082-0114	10.0	1.0	300	35	400	10	125	50	30	300	11
5082-0133	10.0	1.0	200	35	500	10	90	50	30	75	31
5082-0113	10.0	1.0	200	35	500	10	90	50	30	300	11
5082-0241	8.0	1.0	600	65	500	10	100	10	30	60	31
5082-0240	8.0	1.0	450	65	500	10	100	10	30	60	31
5082-0181	8.0	1.0	350	65	500	10	100	10	30	300	11
†5082-0298	8.0	1.0	300	50	500	10	100	10	30	60	31
5082-0180	8.0	1.0	250	50*	500	10	100	10	30	300	11
†5082-0299	6.0	1.0	300	50	400	10	125	10	30	300	11
5082-0132	3.0	1.0	150	35	300	15	50	50	30	100	31
5082-0112	3.0	1.0	150	35	300	15	50	50	30	300	11
5082-0152	2.1	1.0	40	15	150	15	20	10	10	600	15
†5082-0130	2.1	1.0	40	15	200	15	20	10	10	600	15
5082-0243	2.0	1.0	150	35	150	15	30	10	10	100	31
5082-0242	2.0	1.0	100	35	200	15	30	10	10	100	31
5082-0251	1.6	1.0	40	15	150	15	20	10	10	250	31
5082-0151	1.6	1.0	40	15	150	15	20	10	10	600	15
†5082-0111	1.6	1.0	40	15	200	15	20	10	10	600	15
5082-0253	1.1	1.0	40	25	150	15	20	10	10	250	31
5082-0153	1.1	1.0	40	25	150	15	20	10	10	600	15
5082-0154	1.1	1.0	40	25	200	15	20	10	10	600	15
Test Condition	f = 1.0 MHz V_R = OV	I_F		I_R = 10 μA	Fig. 3		Fig. 2	V_R		Note 1	Note 2

* Specification was 65 volts.

† New types.

NOTE 1: θ_{JC} is an absolute maximum rating and is listed here for convenience.

NOTE 2. See mechanical specifications for details.

Design Optimized Step Recovery Diode

These devices have been design optimized for performance in specific frequency ranges for both high and low order multiplication. Double-ended lifetime, capacitance and breakdown voltage specifications assure uniformity and reproducibility. Transition time and thermal resistance are also specified to insure optimum performance of these economical ceramic packaged step recovery diodes.

ABSOLUTE MAXIMUM RATINGS

T_{OPR}—Operating Temperature Range. . −65°C to +200°C
T_{STG}—Storage Temperature Range. . . . −65°C to +200°C
(T_{OPR} and T_{STG} for the HP 5082-0380 is −65°C to +175°C)

ELECTRICAL SPECIFICATIONS AT T_A = 25°C

HP Type Number (Use Tested Equivalent HP Type No.)	Characteristics	Output Frequency Range	Output Power		Breakdown Voltage		Reverse Bias Capacitance		Effective Minority Carrier Lifetime		Transition Time	Thermal Resistance
	Symbol (units)	f_o (GHz)	P_{out} (W)	N	V_{BR} (volts)		C_{VR} (pF)		τ (ns)		t_t (ps)	θ_{JC} (°C/W)
	Package Outline	Nominal	Typical		Min.	Max.	Min.	Max.	Min.	Max.	Max.	Max.
5082-0360 (5082-0300)	40	1.5 - 2.5	5.0	4	80	110	3.5	6.5	150	400	650	20
5082-0365	31	2.5 - 4.5	4.0	3	50	80	2.5	4.1	80	240	300	25
5082-0370 (5082-0310)	41	4.5 - 8.0	2.5	3	40	60	1.9	3.1	50	150	200	30
5082-0375 (5082-0320)	41	8.0 - 12.4	1.0	2	25	40	0.8	1.6	20	60	120	50
5082-0380* (5082-0330)*	47	12.4 - 18.0	0.5	2	18	28	0.8	1.4	20	60	120	110
Test Conditions	Note 1	Note 2			I_R = 10 μA		V_R = 10 V, f = 1.0 MHz Note 4		Fig. 2		Fig. 3	Note 3

* These specifications are based on data taken on preproduction devices. Final specifications are subject to change without prior notice.

NOTE 1. See mechanical specifications for details.

NOTE 2. Typical output power is at a single frequency within the recommended output frequency range and is for a multiplication order of ×2 to ×4. Data is based on theory and laboratory work.

NOTE 3. Thermal resistance test procedures and conditions are described in the October 1967 HP Journal, pages 2-9.

NOTE 4. These values include package capacitance.

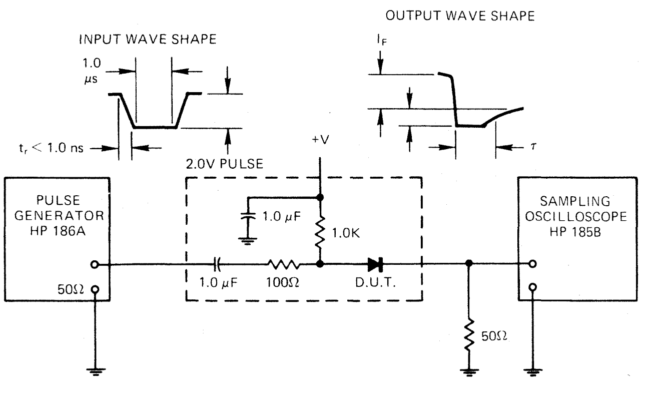


Figure. 2. Test circuit for measurement of the effective minority carrier lifetime. The value of the reverse current (I_R) is approximately 6 mA and the forward current (I_F) is 1.7 I_R. The lifetime (τ) is measured across the 50% points of the observed wave shape. The input pulse is provided by a pulse generator having a rise time of less than one nanosecond. The output pulse is amplified and observed on a sampling oscilloscope.

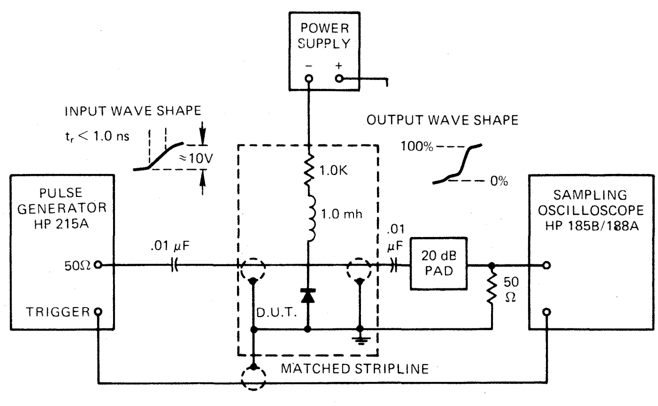


Figure 3. Test circuit for measurement of transition time. The strip line is matched to the impedance necessary to preserve the wave shape between the capacitance coupled points. The forward current is adjusted. The input pulse is provided by a pulse generator having a rise time of less than one nanosecond. The output pulse is attenuated and then observed on a sampling scope. The transition time is measured between the 20% and 80% points of the observed wave shape.

Functional Use-Tested Step Recovery Diodes

In addition to the conventional DC and transient parameters, these use-tested devices are given a final test in an actual multiplier. This use test assures a reproducible and uniform product and gives the designer a guarantee of microwave performance.

ABSOLUTE MAXIMUM RATINGS

Characteristics	Symbol	5082-0300	5082-0310	5082-0320	5082-0330*
Thermal Resistance (Junction to Case)	θ_{JC}	20°C/W	30°C/W	50°C/W	110°C/W
DC Power Dissipation Derating Characteristic	P_{DISS}		$\frac{200°C-T_{CASE}}{\theta_{JC}}$		$\frac{175°C-T_{CASE}}{\theta_{JC}}$
Operating Temperature Range	T_{OPR}		−65°C to +200°C		−65°C to +175°C
Storage Temperature Range	T_{STG}		−65°C to +200°C		−65°C to +175°C

ELECTRICAL SPECIFICATIONS AT T_A = 25°C

Functional Use Test Specifications

HP Type Number		Test Conditions		Specification
	f_{in}	f_{out}	P_{in}	P_{out}
	GHz	GHz	W	W
5082-0300	0.2	2.0	15.0	2.0
5082-0310	0.6	6.0	4.0	0.400
5082-0320	2.0	10.0	2.0	0.200
5082-0330*	2.0	16.0	1.5	0.020

DC, TRANSIENT, AND MECHANICAL SPECIFICATIONS

HP Type Number		5082-0300		5082-0310		5082-0320		5082-0330*			
Characteristics	Symbol	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Units	Test Conditions
Breakdown Voltage	V_{BR}	75	—	40	—	20	—	18	—	Volts	I_R = 10 µA
Reverse Bias Capacitance	C_{VR}	2.5	6.5	1.9	3.5	0.65	1.3	0.8	1.13	pF	V_R = 10 V, f = 1.0 MHz Note 4
Effective Minority Carrier Lifetime	τ	100	—	50	—	10	—	20	—	ns	Fig. 2
HP Package Outline	OD	40		41		41		47		Note 1	

* These specifications are based on data taken on preproduction devices. Final specifications are subject to change without prior notice.

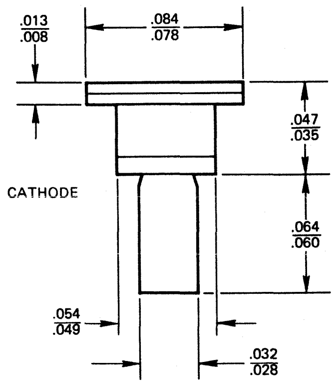
NOTE 1. See mechanical specifications for details.

MECHANICAL SPECIFICATIONS

Hewlett-Packard's step recovery diodes are available in a variety of packages. Special package configurations are available upon request. Contact your local HP Field Office for additional information.

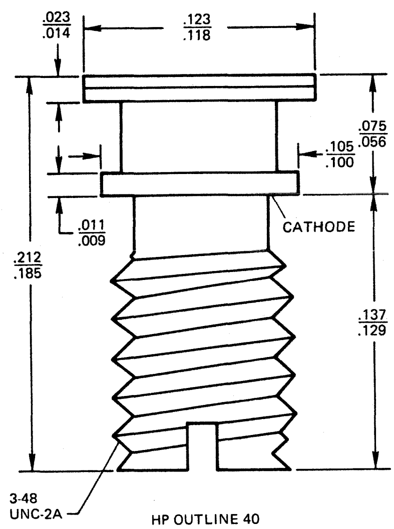
Glass package marking is by digital coding with a cathode band. Metal-ceramic package marking is by color-coded data on ceramic; clockwise when facing cathode, starting at open space.

The glass packages have a hermetic seal with gold-plated dumet leads. The metal ceramic packages are hermetically sealed. The anode studs and flanges are gold-plated Kovar. The cathode studs are gold-plated copper. The maximum soldering temperature for both the glass and metal-ceramic packages is 230°C ±5°C for 5 seconds.



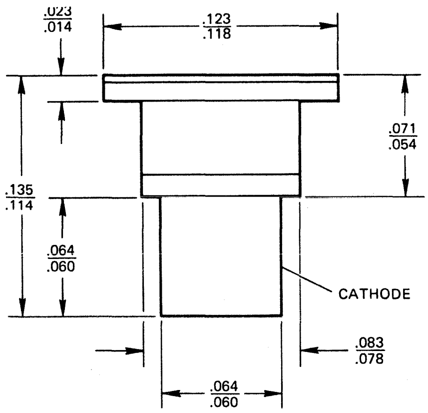
HP OUTLINE 47

$C_P \approx 0.5$ pF
$L_P \approx 0.2$ nH



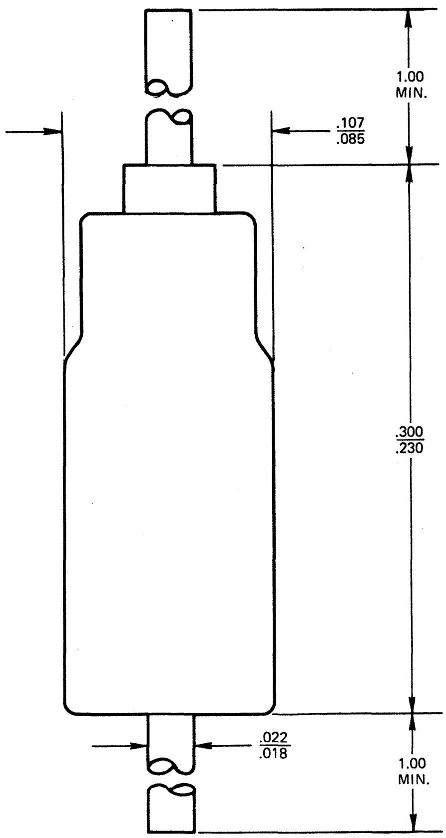
HP OUTLINE 40

$C_P \approx 0.2$ pF
$L_P \approx 0.4$ nH



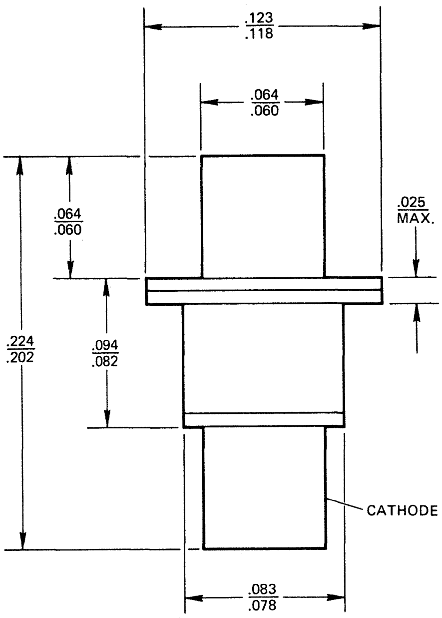
HP OUTLINE 41

$C_P \approx 0.3$ pF
$L_P \approx 0.4$ nH



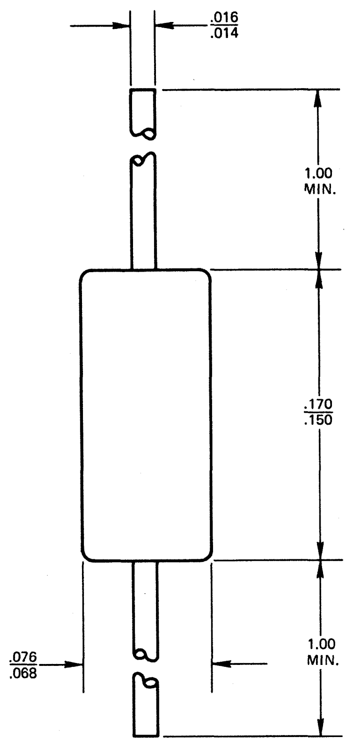
HP OUTLINE 11

$C_P \approx 0.15$ pF
$L_P \approx 4$ nH



HP OUTLINE 31

$C_P \approx 0.2$ pF
$L_P \approx 0.5$ nH



HP OUTLINE 15

$C_P \approx$
$L_P \approx 3$ nH

Reliability

HP step recovery diodes are suitable for high reliability space applications where maximum performance stability under the most adverse conditions is required. Maintenance of product reliability during manufacture has resulted in the use of HP diodes in major aerospace and national defense programs. Reliability and components engineers are invited to contact HPA's Quality and Reliability Assurance Department prior to writing purchase specifications for Hi-Rel components. With proper prescreening and conditioning, the step recovery diode is capable of meeting the following environmental conditions:

	MIL-STD 750 Reference	Conditions
Temperature, Storage	1031	See maximum ratings
Temperature, Operating	—	See maximum ratings
Solderability	2026	230°C as applicable
Temperature, Cycling	1051	5 cycles, see individual specification or rating
Thermal Shock	1056	5 cycles, 0 - 100°C
Moisture Resistance	1021	10 days, 90-98% RH
Shock	2016	5 blows, X, Y, Z at 1500 G
Vibration Fatigue	2046	32 hrs, X, Y, Z at 20 G min.
Vibration Variable Frequency	2056	Four 4-min. cycles, X, Y, Z, at 20 G min., 100 to 2000 Hz
Constant Acceleration	2006	X, Y, Z at 20,000 G
Terminal Strength	2036	Package dependent
Salt Atmosphere	1041	35°C fog for 24 hours

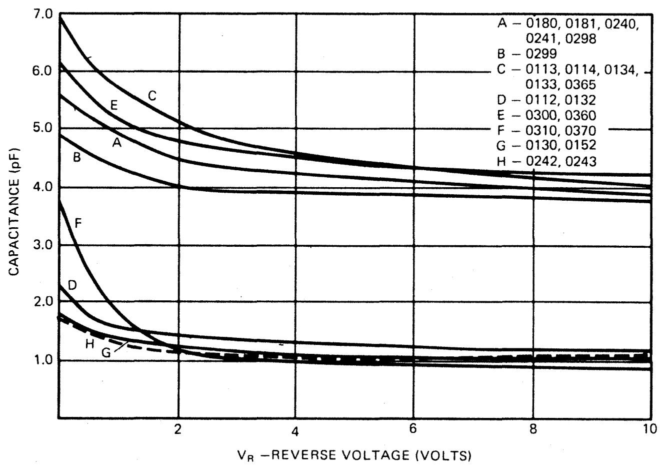


Figure 4. Typical Step Recovery Capacitance vs. Reverse Voltage Characteristics at $T_A = 25°C$, f = 1.0 MHz.

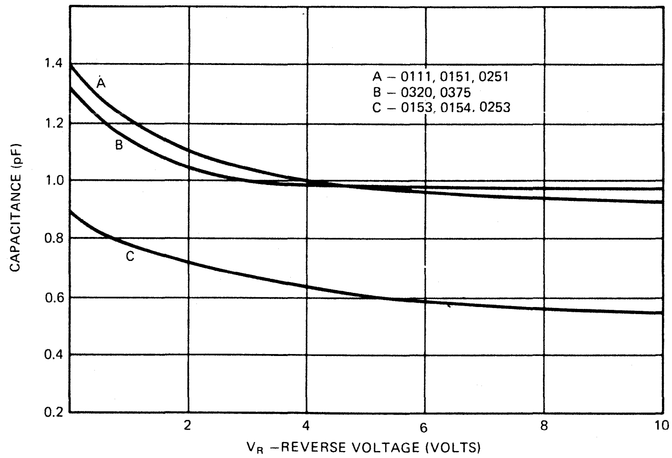


Figure 5. Typical Step Recovery Capacitance vs. Reverse Voltage Characteristics at $T_A = 25°C$, f = 1.0 MHz.

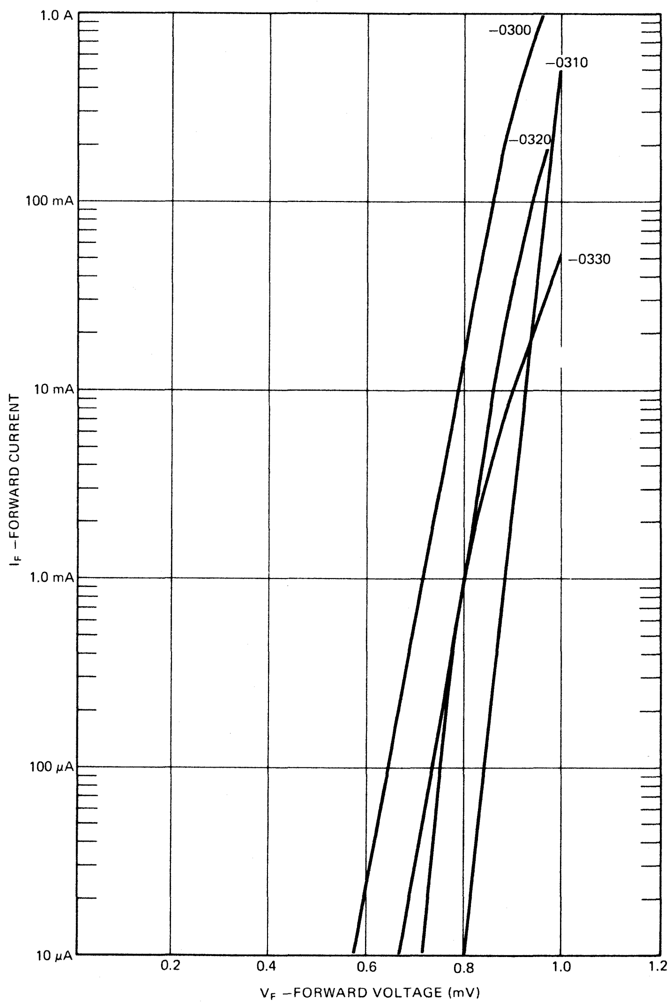


Figure 6. Typical Forward Current vs. Forward Voltage Characteristics of HP 5082-0300, 0310, 0320, and 0330 at $T_A = 25°C$.

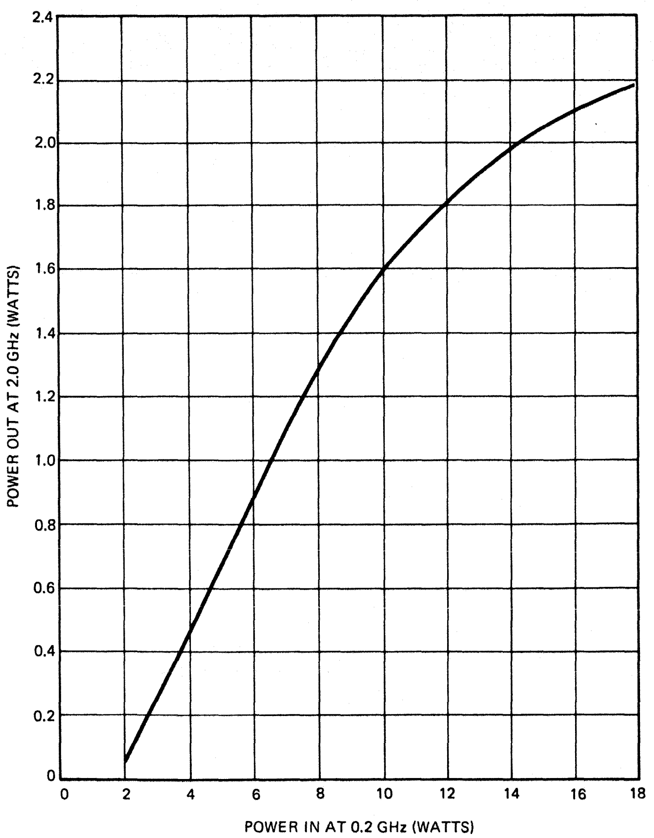


Figure 7. Typical Output Power vs. Input Power for HP 5082-0300 in a ×10 Multiplier at $T_A = 25°C$.

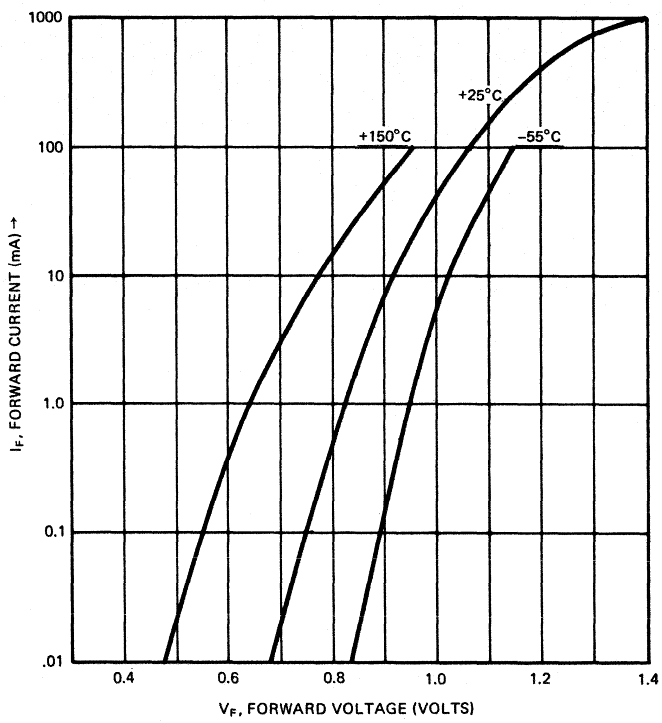


Figure 9. Typical Forward Current vs. Forward Voltage Characteristics of the HP 5082-0130, 0151, 2, 3, 4, and the 5082-0251, 2, 3, at $T_{CASE} = -55°C$, 25°C, and +150°C.

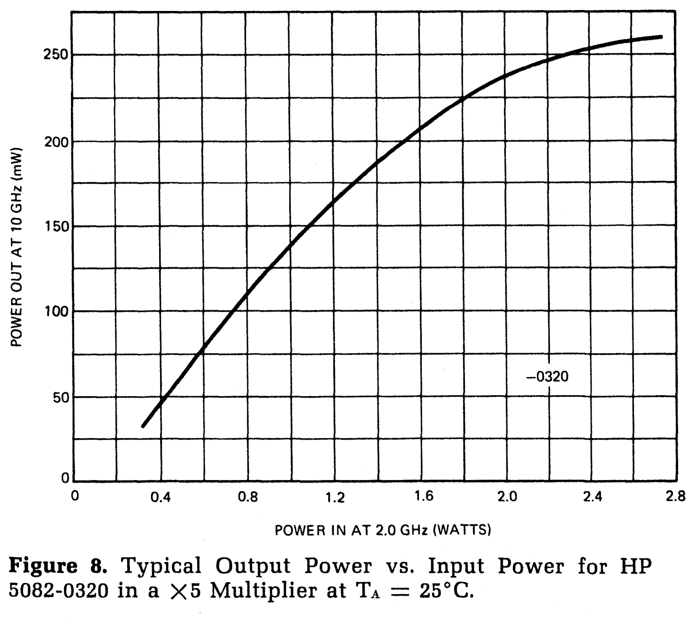


Figure 8. Typical Output Power vs. Input Power for HP 5082-0320 in a ×5 Multiplier at $T_A = 25°C$.

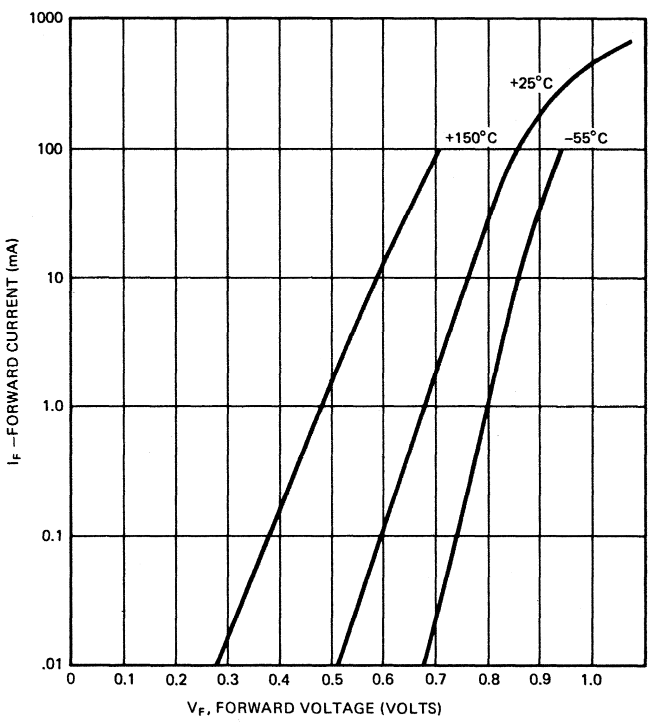


Figure 10. Typical Forward Current vs. Forward Voltage Characteristics of the HP 5082-0112, 3, 4, and 5082-0132, 3, 4 at $T_A = 55°C$, 25°C, and +150°C.

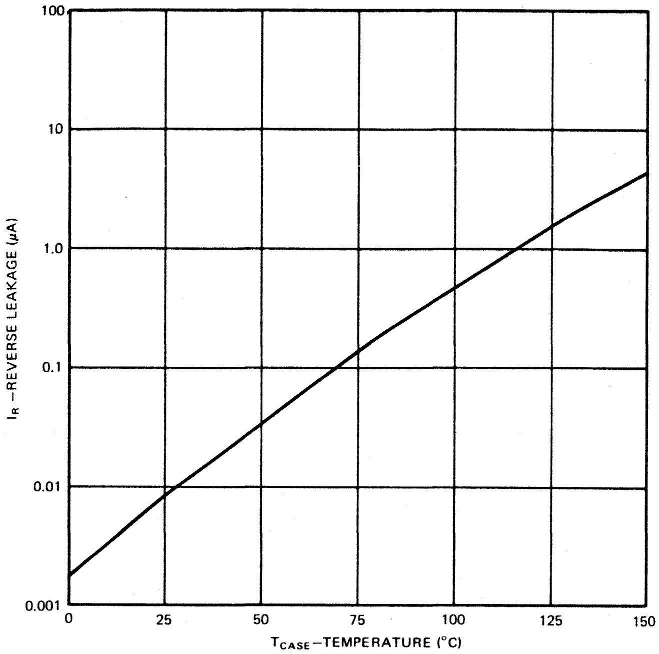


Figure 11. Typical Reverse Current vs. Case Temperature for the HP 5082-0112, 3, 4 and 5082-0132, 3, 4 at $V_R = -30$ volts.

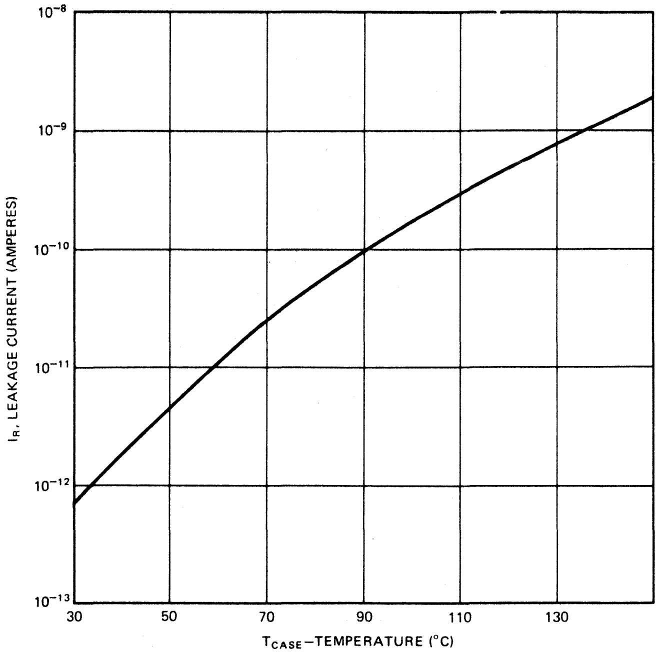


Figure 12. Typical Reverse Current vs. Case Temperature for the HP 5082-0130, 0151, 2, 3, 4 and the 5082-0251, 2, 3 at $V_R = -10$ volts.

HEWLETT hp PACKARD

STEP RECOVERY DIODES

PULSE SPECIFIED

SRD-2

FEATURES

Fully Time Domain Tested

Low Package Inductance

Surface Passivated

Radiation Resistant

Meets MIL-S-19500

Description

HP SRD's are epitaxial surface passivated silicon diodes with a precisely controlled abrupt junction profile. The required junction profile which determines the switching characteristics of the diode is controlled in manufacturing by new and advanced process techniques and is verified by complete time domain testing of the finished diode. The entire manufacturing and testing sequence is monitored by established quality control procedures to assure a high degree of product reliability and conformance to MIL-S-19500 specifications.

Applications

When forward biased the SRD will store charge and appear as a low impedance, typically less than 1 Ω. When the applied current is reversed, the SRD will remain a low impedance for a brief period of time until all the stored charge is removed, whereupon it will abruptly transition to a high impedance state, typically megohms. Transition speeds are in range of 85-250 picoseconds depending on the diode type. The delay times between the reversal of the drive current and transition to a high impedance are variable in the range of zero to 250 nanoseconds by the choice of forward and reverse drive current levels. Pulse amplitude can be as high as 50 volts.

The characteristics of the SRD make it a very useful component in a variety of extremely fast, high amplitude pulse and digital circuits. Some typical applications are:

Sharpening a slow (nanoseconds) rise time pulse to fast (picoseconds) rise time.

Providing a variable pulse delay up to 250 nanoseconds.

Reshape a sinusoidal waveform in the range of 10-500 MHz to a square waveform with rise time as fast as 100 picoseconds.

Reshape a sinusoidal waveform to a train of high amplitude picosecond wide impulses having a precisely controlled repetition rate.

Reducing transistor logic gate delays due to base charge storage.

Reshape variable amplitude pulses to equal area pulses.

Very wide band (typically 100 MHz) pulse counting FM discriminators.

These and other applications are described in detail in HP Application Note 918.

Absolute Maximum Ratings

Characteristic	Symbol	5082-0200	5082-0201	5082-0202
Thermal Resistance (Junction to Case)	θ_{JC}	50°C/W	100°C/W	300°C/W
DC Power Dissipation Derating Characteristic	P_{DISS}		$\frac{200°C - T_{CASE}}{\theta_{JC}}$	
Operating Temperature Range	T_{OPR}		−65°C to +200°C	
Storage Temperature Range	T_{STG}		−65°C to +200°C	

Electrical Specifications at $T_A = 25°C$

Characteristic	Symbol	Units	5082-0200 Min.	5082-0200 Max.	Test Conditions	5082-0201 Min.	5082-0201 Max.	Test Conditions	5082-0202 Min.	5082-0202 Max.	Test Conditions
Breakdown Voltage	V_{BR}	Volts	35	60	$I_R = -10\ \mu A$	35	50	$I_R = -10\ \mu A$	40	60	$I_R = -10\ \mu A$
Capacitance	C_{VR}	pF	1.9	4.0	$V_R = -10$ V; f = 1.0 MHz	0.7	1.6	$V_R = -10$ V; f = 1.0 MHz	2.5	6.0	$V_R = -10$ V; f = 1.0 MHz
Series Resistance	R_s	Ohms	—	0.5	$I_F = 400$ mA; f = 1.0 kHz	—	0.8	$I_F = 400$ mA; f = 1.0 kHz	—	0.4	$I_F = 400$ mA; f = 1.0 kHz
Leakage Current	I_R	nA	—	10	$V_R = -10$ V	—	10	$V_R = -10$V	—	50	$V_R = -30$ V
Transition Rise Time	t_{r1}	ps	—	125	$Q_s = 500$ pC Fig. 3	—	85	$Q_s = 200$ pC Fig. 3	—	250	$Q_s = 2000$ pC Fig. 3
Transition Rise Time	t_{r2}	ps	—	165	$Q_s = 2000$ pC Fig. 3	—	170	$Q_s = 1000$ pC Fig. 3	—	300	$Q_s = 10{,}000$ pC Fig. 3
Ramping	R_{A1}	%	—	10	$Q_s = 500$ pC Fig. 5	—	17	$Q_s = 200$ pC Fig. 5	—	10	$Q_s = 2000$ pC Fig. 5
Ramping	R_{A2}	%	—	15	$Q_s = 2000$ pC Fig. 5	—	20	$Q_s = 1000$ pC Fig. 5	—	13	$Q_s = 10{,}000$ pC Fig. 5
Rounding	R_{o1}	%	—	12	$Q_s = 500$ pC Fig. 4	—	5	$Q_s = 200$ pC Fig. 4	NOTE 1		
Rounding	R_{o2}	%	—	18	$Q_s = 2000$ pC Fig. 4	—	17	$Q_s = 1000$ pC Fig. 4	NOTE 1		
Forward Current	I_{FQ1}	mA	2.5	7.5	$Q_s = 500$ pC	1.5	4.5	$Q_s = 200$ pC	11	33	$Q_s = 2000$ pC
Forward Current	I_{FQ2}	mA	20	60	$Q_s = 2000$ pC	14	42	$Q_s = 1000$ pC	110	330	$Q_s = 10{,}000$ pC
Package Outline	—		41			31			11		

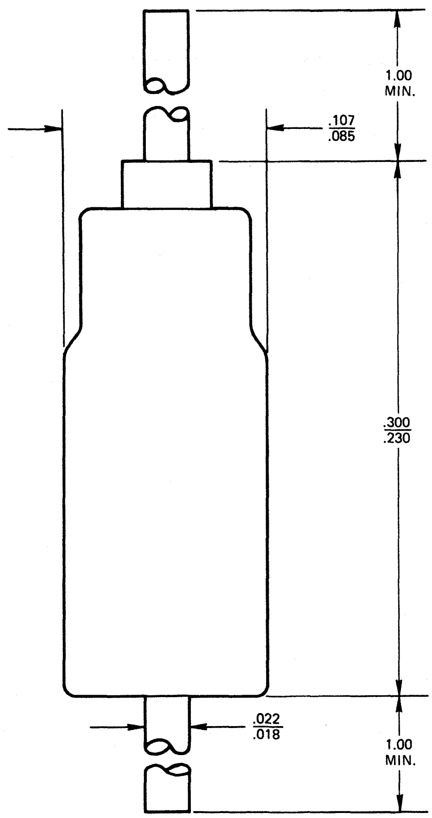
Note 1—Rounding is not specified for the HP 5082-0202 because of waveform overshoot due to package inductance.

Mechanical Specifications

The HP Outline 11 package is a hermetically sealed unit with a glass body and gold-plated dumet wire leads. It conforms to the JEDEC DO-7 outline. Typical package capacitance and inductance is 0.15 pF and 4 nH respectively. Marking is by digital coding with a cathode band.

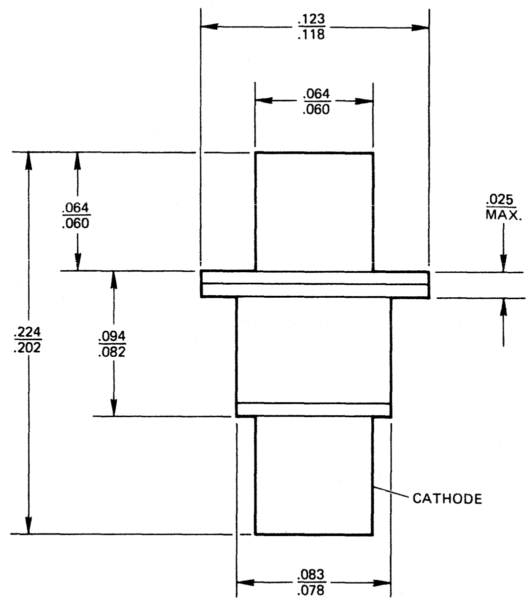
The HP Outline 31 package has a metal-ceramic hermetic seal. The cathode stud is gold-plated copper. The anode stud is gold-plated kovar. The HP Outline 31 typical package capacitance and inductance is 0.2 pF and 0.5 nH respectively. Marking is by color-coded dots on ceramic; clockwise when facing cathode, starting at open space.

All dimensions in inches



HP OUTLINE 11

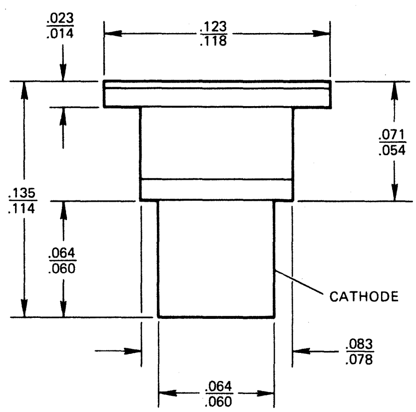
$C_P \approx 0.15$ pF
$L_P \approx 4$ nH



HP OUTLINE 31

$C_P \approx 0.2$ pF
$L_P \approx 0.5$ nH

The HP Outline 41 package has a metal-ceramic hermetic seal. The cathode stud is gold-plated copper. The anode flange is gold-plated kovar. Typical package capacitance and inductance of the Outline 41 is 0.3 pF and 0.4 nH, respectively. Marking is by color-coded dots on the ceramic body; clockwise when facing cathode starting at open space.



HP OUTLINE 41

$C_P \approx 0.3$ pF
$L_P \approx 0.4$ nH

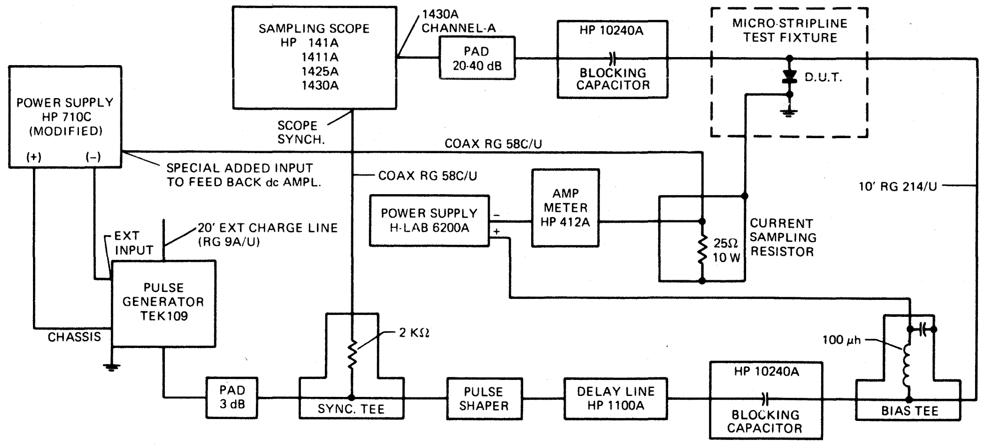


Figure 1. Test Setup Block Diagram

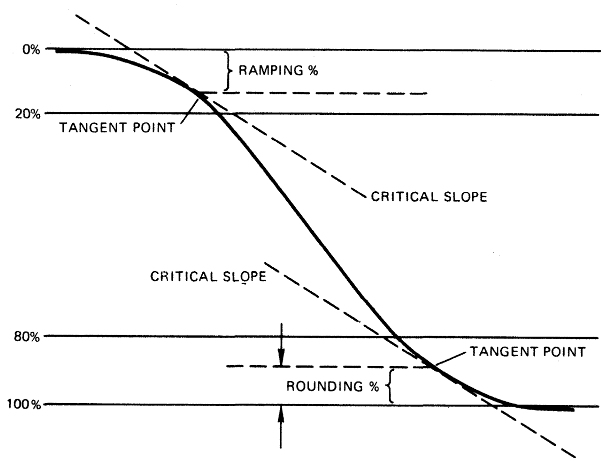


Figure 2. Waveform Definitions

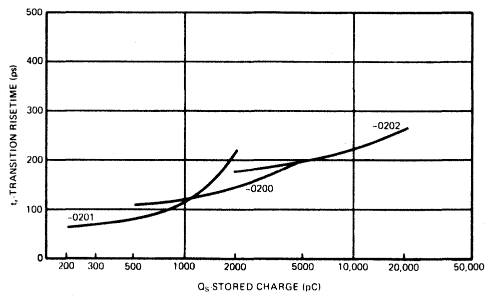


Figure 3. Typical 20%-80% Transition Rise Times Versus Stored Charge at $T_A = 25°C$

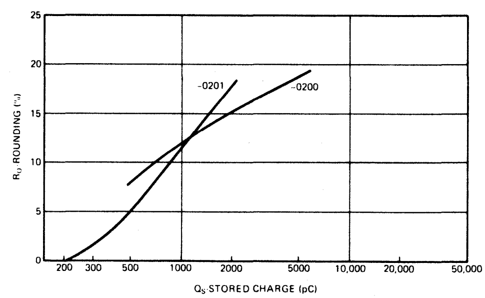


Figure 4. Typical Rounding Versus Stored Charge at $T_A = 25°C$. The 5082-0202 Rounding is not measurable because of waveform overshoot due to package inductance.

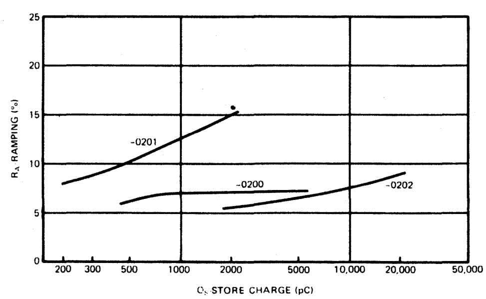


Figure 5. Typical Ramping Versus Stored Charge at $T_A = 25°C$

Transition Rise Time (t_r) is defined as the time between the 20% and 80% amplitude points of the overall step amplitude, measured in a 25-ohm circuit.

Ramping is stated as a percent of the overall step amplitude. The amplitude of the ramp is defined as the part of the overall step amplitude that lies **before** the first tangent of the waveform and the "critical" slope line.

Rounding is also stated as a percent of the overall step amplitude. Its amplitude is defined as the part of the overall step that lies **after** the second tangent point of the waveform and the "critical" slope line.

The "critical" slope in both of the above definitions is defined to be the slope of a line whose time separation between the 20% and 80% points is 3 times the rise time specification for the particular diode at the specified test conditions.

hot carrier diodes

SCHOTTKY BARRIER DIODE

HEWLETT hp PACKARD

HOT CARRIER DIODES

HP
2301
series
2356, 2370
2396

Picosecond Switching
Majority Carrier Conduction
No Charge Storage
Low Flicker (1/f) Noise
Low Leakage and High Conductance
Low Forward Threshold Voltage
High Pulse Power Capability
Low Mixer Intermodulation Products
Low Mixer Noise

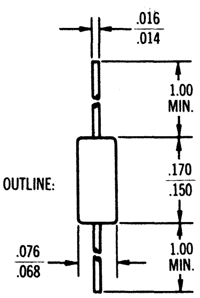


Figure 1a

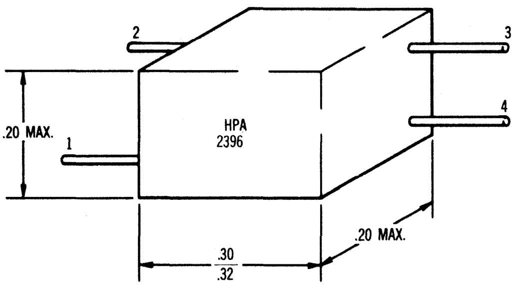


Figure 2a

LEAD	COLOR
1	BROWN
2	RED
3	ORANGE
4	YELLOW

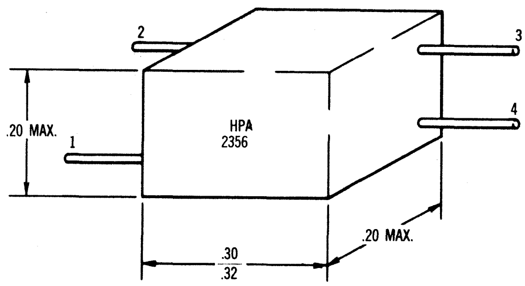


Figure 3a

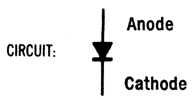


Figure 1b

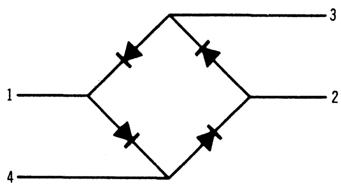


Figure 2b

All dimensions in inches

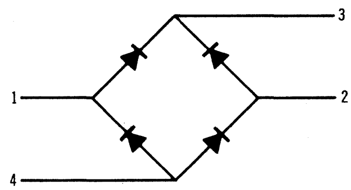


Figure 3b

DESCRIPTION

The HP 2300 series of Hot Carrier Diodes employ a metal-silicon Schottky barrier junction and utilize electrons for majority carrier conduction. The Hot Carrier Diode's performance conforms closely with theory and can be described as closely approximating the ideal diode. HP Application Note 907 contains additional detailed information.

APPLICATIONS

The HP 2300 series of Hot Carrier Diodes is intended for use in applications requiring the ultimate in performance and reliability. Extensive testing has shown that these devices exhibit the design capability necessary to meet the special reliability requirements of man-rated space systems in addition to the general requirements of MIL-S-19500.

In pulse operations the diode is ideal for clamping sampling gates, pulse shaping and general purpose usage requiring fractional picosecond switching times.

In the RF area the Hot Carrier Diode makes an excellent low noise mixer, high sensitivity small signal detector, large signal detector (power monitor) with broad dynamic range, limiter, discriminator and balanced modulator from low frequencies well into the microwave range.

ELECTRICAL SPECIFICATIONS AT $T_A = 25°C$

Single Diodes

Characteristics	Symbol	HP 2305		HP 2301		HP 2302		HP 2303		Units	Test Conditions
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
Breakdown Voltage	V_{BR}	30	—	30	—	30	—	20	—	V	$I_R = 10\ \mu A$
Reverse Current	I_R	—	300	—	300	—	300	—	500	nA	$V_R = 15\ V$
Forward Current	I_{F_1}	1.0	—	1.0	—	1.0	—	1.0	—	mA	$V_{F_1} = 0.4\ V$ max. (Note 1)
Forward Current	I_{F_2}	75	—	50	—	35	—	35	—	mA	$V_{F_2} = 1.0\ V$ max. (Note 1)
Capacitance	C_O	—	1.0	—	1.0	—	1.0	—	1.2	pF	$V_R = 0\ V$; $f = 1.0\ MHz$
Effective Minority Carrier Lifetime	τ	—	100	—	100	—	100	—	100	ps	Figure 8

Note 1: The test condition and specification are interchanged to make the tabulation easier to read. The actual test condition is forward current; the actual specification is forward voltage. The forward current is limited to prevent thermal runaway.

Matched Pairs and Quads

HP Type Number	HP 2306	HP 2308	HP 2370	HP 2396	HP 2356
Description	Matched pair of HPA 2301, unencapsulated and unconnected.	Matched pair of HPA 2303, unencapsulated and unconnected.	Matched Quad, unencapsulated and unconnected.	Matched Ring Quad, Epoxy encapsulated.	Matched Bridge Quad, Epoxy encapsulated.
Outline	Fig. 1a	Fig. 1a	Fig. 1a	Fig. 2a	Fig. 3a
Circuit	Fig. 1b	Fig. 1b	Fig. 1b	Fig. 2b	Fig. 3b

Characteristics	Symbol	HP 2306		HP 2308		HP 2370		HP 2396		HP 2356		Units	Test Conditions
		Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.		
Breakdown Voltage	V_{BR}	30	—	20	—	20	—	*	—	*	—	V	$I_R = 10\ \mu A$
Reverse Current	I_R	—	300	—	500	—	500	—	*	—	*	nA	$V_R = 15\ V$
Forward Current	I_{F_1}	1.0	—	1.0	—	1.0	—	1.0	—	1.0	—	mA	$V_{F_1} = 0.4\ V$ max. (Note 1)
Forward Current	I_{F_2}	50	—	35	—	35	—	35	—	35	—	mA	$V_{F_2} = 1.0\ V$ max. (Note 1)
Forward Voltage Match**	ΔV_F	—	20	—	20	—	20	—	20	—	20	mV	$I_F = 0.75$ to $20\ mA$
Capacitance	C_O	—	1.0	—	1.2	—	1.0	—	*	—	*	pF	$V_R = 0$, $f = 1.0\ MHz$
Capacitance Match**	ΔC_O	—	0.2	—	0.2	—	0.2	—	0.2	—	0.2	pF	$V_R = 0$, $f = 1.0\ MHz$
Effective Minority Carrier Lifetime	τ	—	100	—	100	—	100	—	*	—	*	ps	Figure 8

Note 1: The test condition and specification are interchanged to make the tabulation easier to read. The actual test condition is forward current; the actual specification is forward voltage. The forward current is limited to prevent thermal runaway.

* Breakdown voltage, reverse current, capacitance, and effective minority carrier lifetime cannot be readily verified after assembly and encapsulation because of the shunting effect of the other diodes. The encapsulated quads have the same parameter values as the HP 2370 unencapsulated quad prior to assembly and encapsulation.

** Quads and pairs having additional and/or tighter matching are available upon request. Please contact the local HP field sales office.

ABSOLUTE MAXIMUM RATINGS

T_{OPR}—Operating Temperature Range...... − 60°C to + 125°C
T_{STG}—Storage Temperature Range.......... − 60°C to + 125°C
P_{DISS}—DC Power Dissipation ($T_A = 25°C$)..................125 mW
U—Burnout (3 pulses with a 10 ns maximum pulse width; 20% allowable V_{BR} degradation; $T_A = 25°C$).....................................5 ergs

PACKAGE

The HP Outline 15 package has a glass hermetic seal with dumet leads. The leads on the Outline 15 package should be restricted so that the bend starts at least 1/16 inch from the glass body. With this restriction OD-15 package will meet MIL-STD-750, Method 2036, Conditions A and E (4 lbs. tension for 30 minutes). The maximum soldering temperature is 230°C ± 5°C for 5 seconds.

Outline 15 package inductance and capacitance is typically 0.2 pF and 3 nH respectively.

Marking is by digital coding with a cathode band.

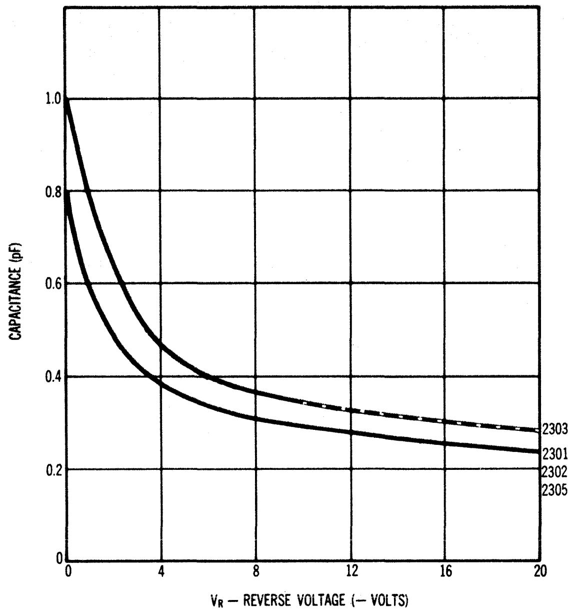


Figure 4. HP 2300 series typical capacitance vs. reverse voltage at $T_A = 25°C$.

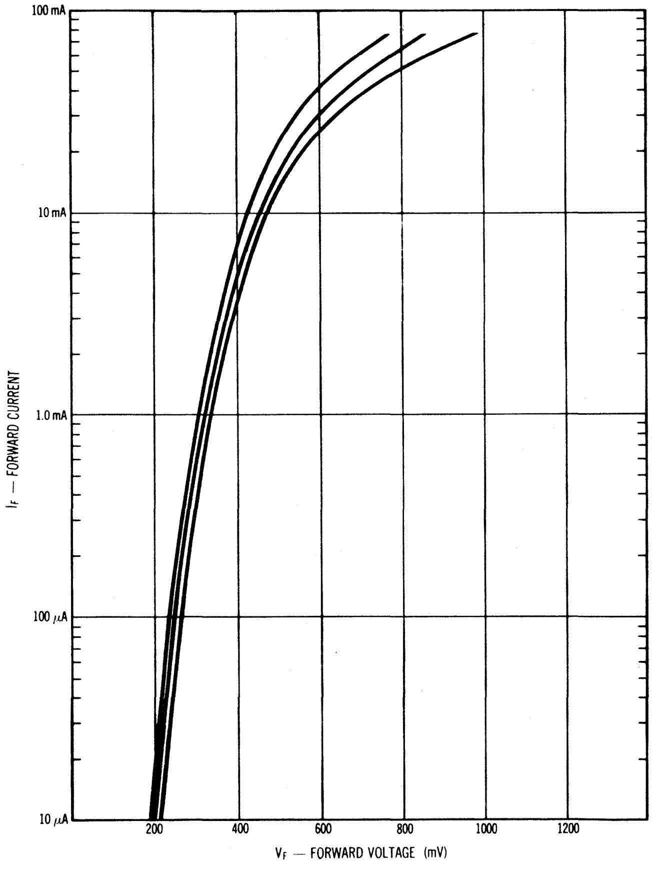


Figure 5a. HP 2301 typical minimum, median, and maximum forward current vs. forward voltage at $T_A = 25°C$.

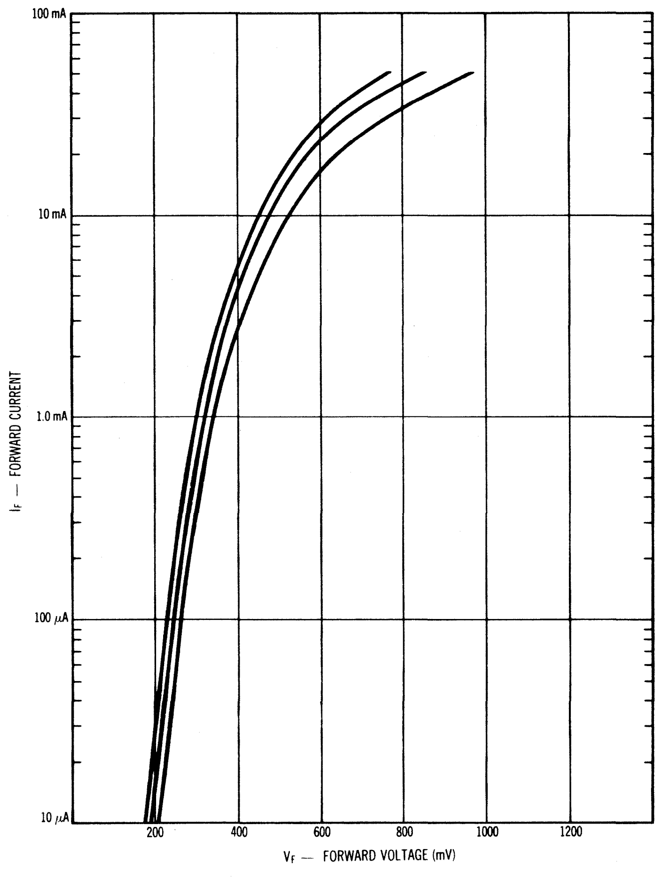


Figure 5b. HP 2302 typical minimum, median, and maximum forward current vs. forward voltage at $T_A = 25°C$.

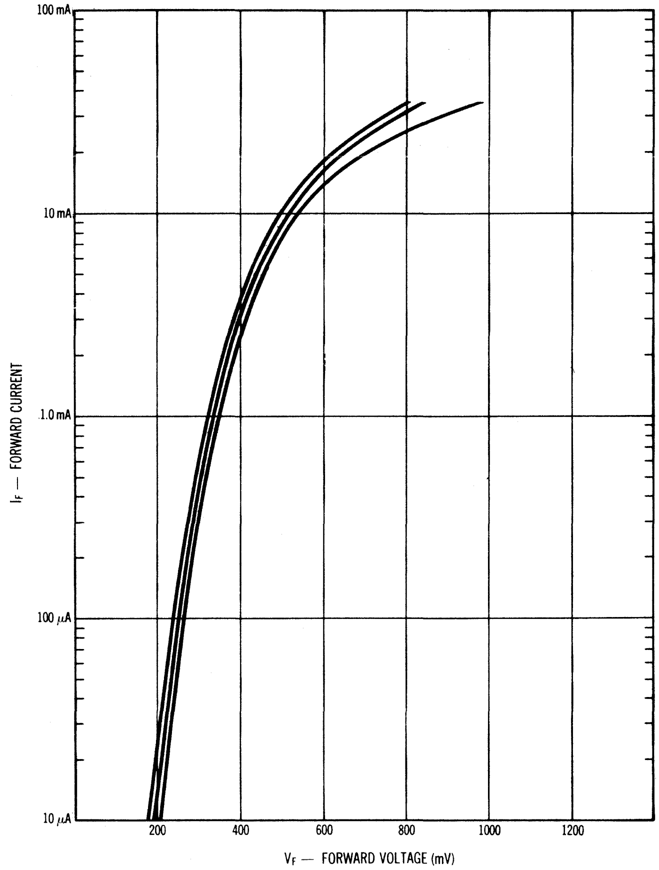


Figure 5c. HP 2303 typical minimum, median, and maximum forward current vs. forward voltage at $T_A = 25°C$.

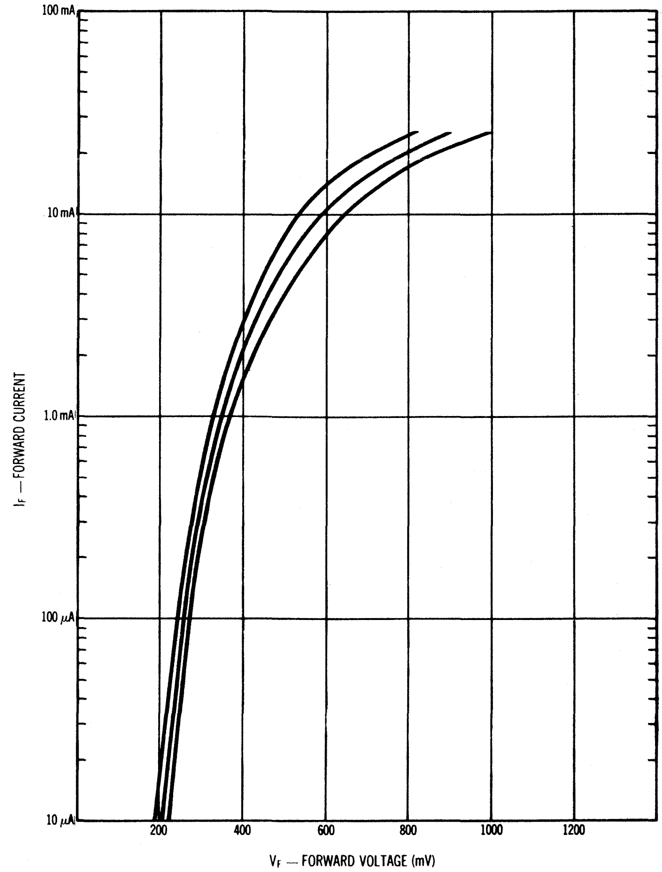


Figure 5d. HP 2305 typical minimum, median, and maximum forward current vs. forward voltage at $T_A = 25°C$.

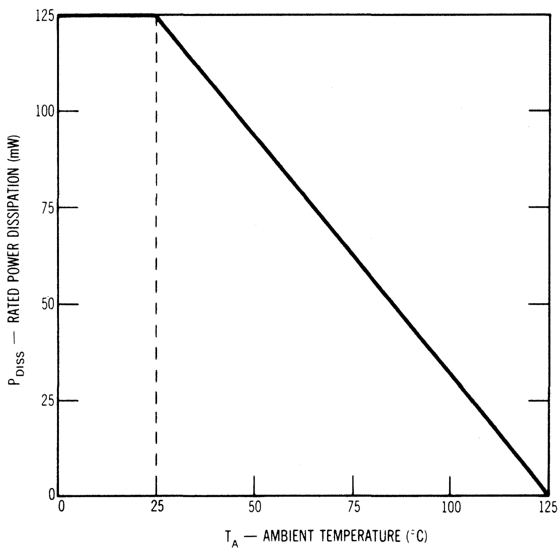


Figure 6. HP 2301 series dc power dissipation characteristics.

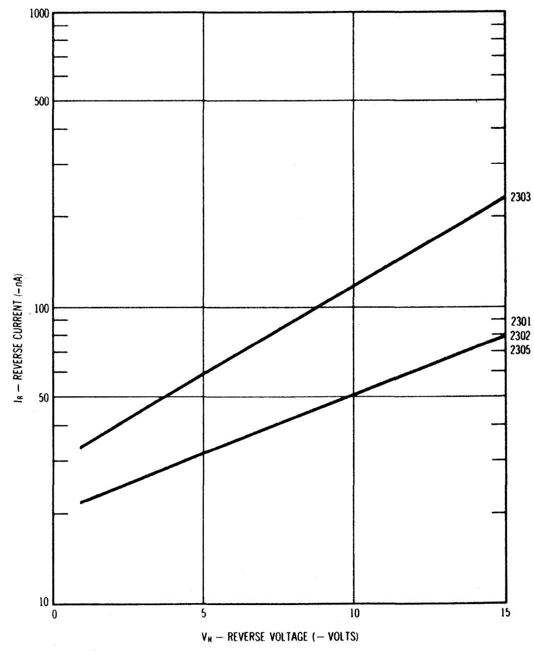


Figure 7. HP 2300 series typical reverse current vs. reverse voltage at $T_A = 25°C$.

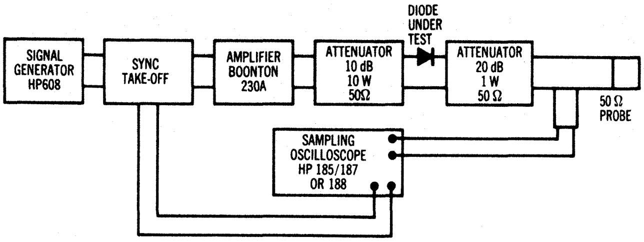


Figure 8a. Test setup.

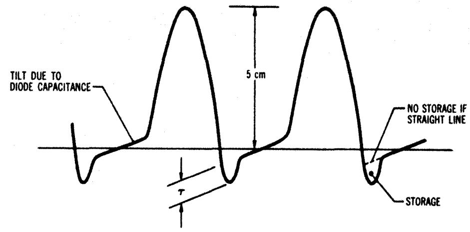


Figure 8b. Resulting oscilloscope display.

Figure 8. Effective minority carrier lifetime measurement.

The signal generator and power amplifier are adjusted to 54 MHz and the output level at 10 V RMS as read on the power amplifier meter. The sampling oscilloscope is adjusted so that the peak deflection corresponding to forward current is 5 cm or 20 mA, where 20 mV/cm = 4.0 mA/cm. Under these conditions, minority carrier lifetime is related to the amplitude designated as "τ" such that 1 cm corresponds to 500 ps. This scale will be linear to about 1.5 cm.

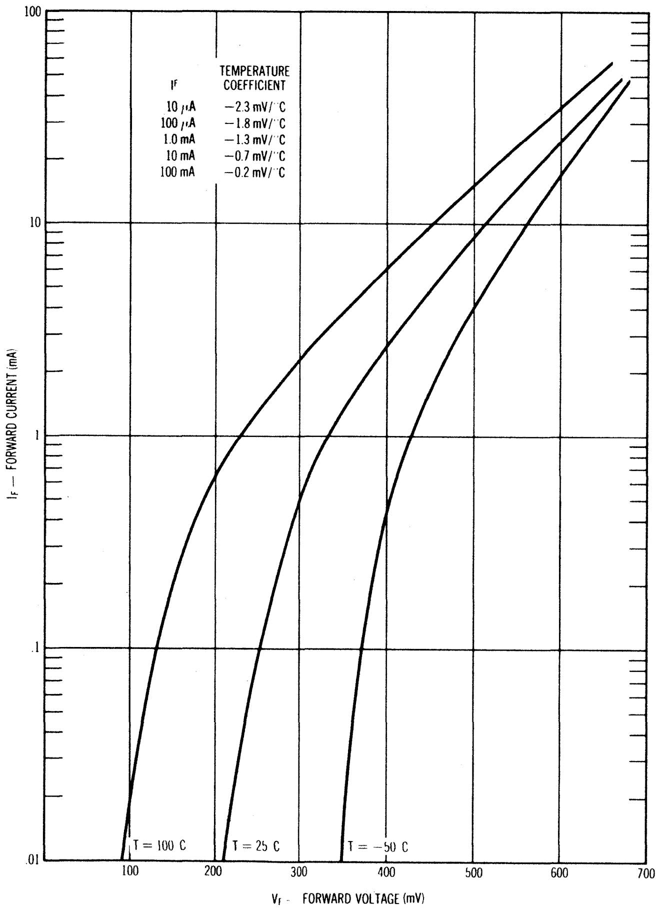


Figure 9. I-V curve showing typical temperature variation for HP 2300 series Hot Carrier Diodes.

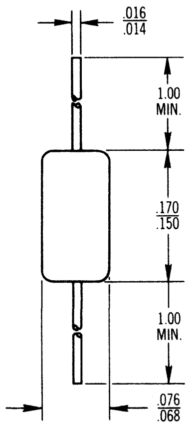
HEWLETT hp PACKARD

HOT CARRIER DIODES

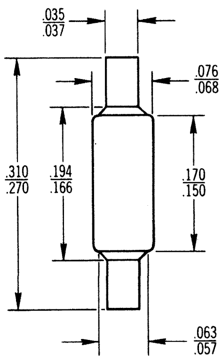
HP 2350, 2400 2500, 2600 series

Microwave Mixers and Detectors

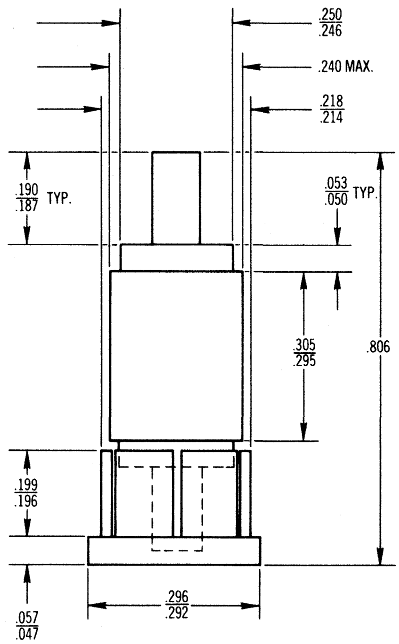
Low and Stable Noise Figure
Uniform and Repeatable RF Characteristics
Microminiature Size
High Burnout Resistance
Large Dynamic Range at High LO Powers
Low IF and Video Impedance
Low 1/f Noise



HP Outline 15



HP Outline 19



HP Outline 20

DESCRIPTION

Hot Carrier Diodes employ a metal-silicon Schottky barrier junction and utilize electrons for majority carrier conduction. The Hot Carrier Diode's performance conforms closely with theory and can be described as closely approximating the ideal diode. HP Application Note 907 contains additional detailed information.

APPLICATIONS

HP's Hot Carrier Mixer and Detector Diodes are intended for use in applications requiring the ultimate in performance and reliability. Extensive testing has shown that these devices exhibit the design capability necessary to meet the general requirements of MIL-S-19500, in addition to the special reliability requirements of man-rated space systems.

As mixers they offer low and stable noise figure as well as high pulse burnout resistance. Their uniform and repeatable RF characteristics allow the designer a great deal of latitude in specifying his RF circuitry.

The diodes are also intended for use as small signal square law detectors, and in large signal power monitor applications.

TEST CONDITIONS

HP HOT CARRIER MIXER DIODE SPECIFICATIONS AT $T_A = 25°C$

Test Frequency†		2.0 GHz			3.0 GHz			8.0 GHz		
Package Outline		15	19	20	15	19	20	15	19	20
$NF_O = 6.0$ dB	Single	2400	2406	2403	2565	2561	2563	-	-	-
	Pair*	2401	2407	2404	2566	2562	2564	-	-	-
	Quad*	-	-	-	-	-	-	-	-	-
$NF_O = 6.5$ dB	Single	2365	2415	2366	2550	2556	2553	2601	2611	2621
	Pair*	2418	2416	2417	2551	2557	2554	2606	2616	2626
	Quad*	-	-	-	2552	2558	2555	-	-	-
$NF_O = 7.0$ dB	Single	2350	2413	2353	2520	2526	2523	2602	2612	2622
	Pair*	2351	2414	2354	2521	2527	2524	2607	2617	2627
	Quad*	2374	-	-	2522	-	-	-	-	-
$NF_O = 7.5$ dB	Single	-	-	-	-	-	-	2603	2613	2623
	Pair*	-	-	-	-	-	-	2608	2618	2628
	Quad*	-	-	-	-	-	-	-	-	-
VSWR		1.3			1.5			1.5		
Z_{IF} (ohms)		150-250			100-250			125-250		

* Noise Figure Match ΔNF_O 0.3 dB max.
IF Impedance Match ΔZ_{IF} 25 ohms max.

† Test Conditions: The noise figure is measured at the specified test frequency and is a single sideband receiver noise figure using a 30 MHz, 1.5 dB Noise Figure IF amplifier. L.O. power is 1.0 mW.

MECHANICAL SPECIFICATIONS

The HP Outline 15 package has a glass hermetic seal with dumet leads. The leads on the Outline 15 package should be restricted so that the bend starts at least 1/16 inch from the glass body. With this restriction, Outline 15 package will meet MIL-STD-750, Method 2036, Conditions A and E (4 lbs. tension for 30 minutes). The maximum soldering temperature is 230°C ± 5°C for 5 seconds. Outline 15 package inductance and capacitance is typically 2 nH and 0.07 pF, respectively.

The HP Outline 19 package is an Outline 15 package which has gold-plated brass ferrules, soft-soldered onto the ends. This package is intended for replaceable mounting in spring clips or in a conventional miniature connector center conductor such as the OSM 217 adapter or equivalent.

The HP Outline 20 package is the Outline 15 glass package mounted such that it is a direct mechanical replacement for the 1N21WE or 1N23WE-type cartridge case.

Marking on all packages is by digital coding with a cathode band.

TYPICAL PERFORMANCE CHARACTERISTICS

HP Type	Junction Capacitance C_{JO} pF	Series Resistance R_S ohms	NF_O Temperature Coefficient + dB/°C
2400	0.5 - 0.9	7 - 11	0.004
2565	0.3 - 0.7	3 - 6	0.004
2601	0.2 - 0.6	4 - 7	0.004

ABSOLUTE MAXIMUM RATINGS

	Units	2300 2400	2500	2600
Operating Temperature Range	°C	− 60 to + 125	− 60 to + 125	− 60 to + 125
Storage Temperature Range	°C	− 60 to + 125	− 60 to + 125	− 60 to + 125
CW Power Dissipation at $T_A = 25°C$	mW	200	200	125
Peak Power Dissipation (1 nsec pulse, 0.001 DF at $T_A = 25°C$)	Watt	15	4	0.8
Pulse Burnout (3 10-nsec pulses for 1 dB increase in NF_O)	ergs	25	15	5

RELIABILITY

Hewlett-Packard Hot Carrier Diodes are suitable for high reliability space applications where maximum performance stability under the most adverse conditions is required. Maintenance of product reliability during manufacture has resulted in the use of these diodes in major aerospace and national defense programs.

ENVIRONMENTAL CHARACTERISTICS

	MIL-STD-750 Reference	Conditions
Temperature, Storage	1031	See maximum ratings
Temperature, Operating	—	See maximum ratings
Solderability	2026	230°C as applicable
Temperature, Cycling	1051	5 cycles, — 65° to + 125°C
Thermal Shock	1056	5 cycles, 0-100°C
Moisture Resistance	1021	10 days, 90-98% RH
Shock	2016	5 blows, X_1, Y_1, Y_2, at 1500 G
Vibration Fatigue	2046	32 hrs, X, Y, Z at 20 G min.
Vibration Variable Frequency	2056	4, 4-min. cycles, X, Y, Z, at 20 G min., 100 to 2000 Hz
Constant Acceleration	2006	X_1, Y_1, Y_2 at 20,000 G
Terminal Strength	2036	Package dependent
Salt Atmosphere	1041	35°C fog for 24 hours

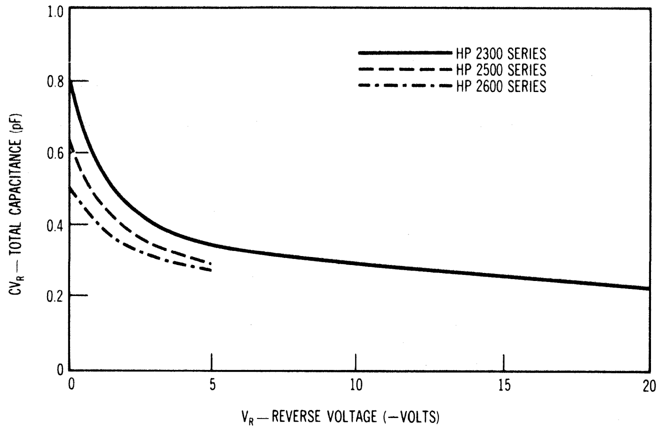


Figure 1. Typical Capacitance vs. Reverse Bias Voltage Characteristics at $T_A = 25°C$.

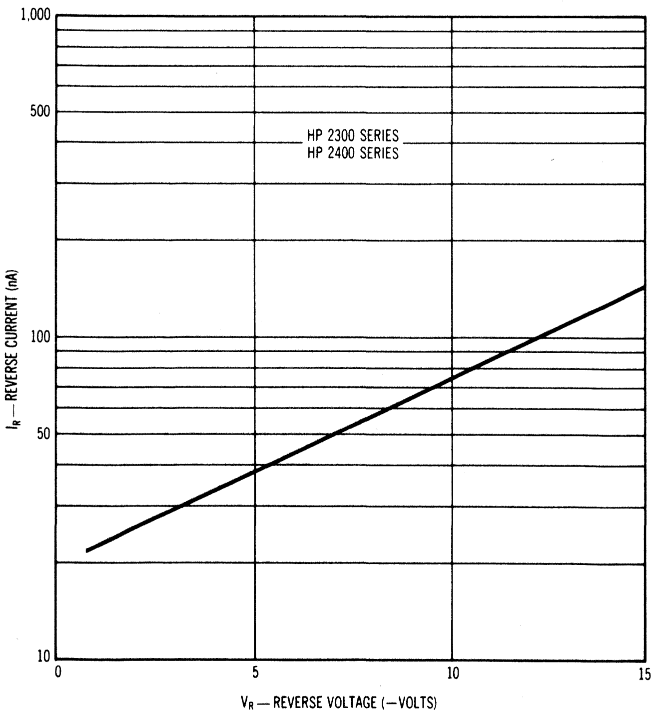


Figure 2. Typical HP 2300 and HP 2400 Series Reverse Current vs. Reverse Voltage Characteristics at $T_A = 25°C$.

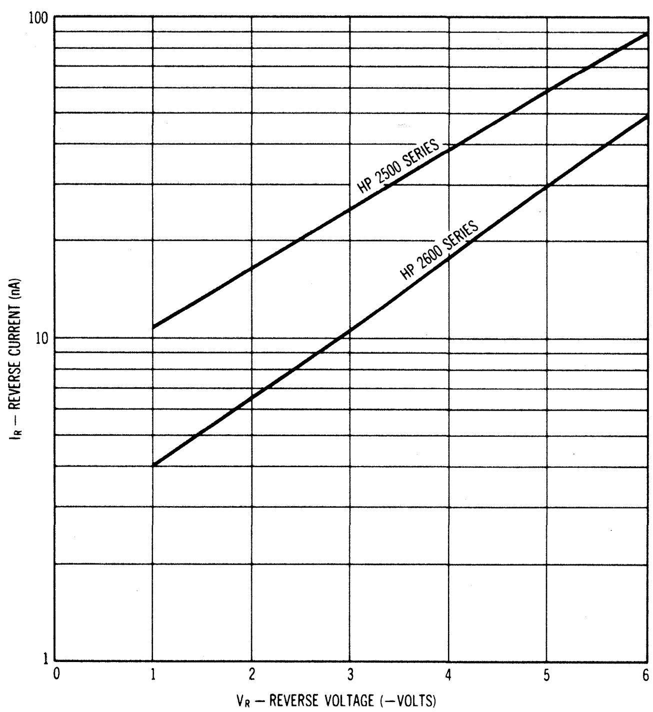


Figure 3. Typical HP 2500 and HP 2600 Series Reverse Current vs. Reverse Voltage Characteristics at $T_A = 25°C$.

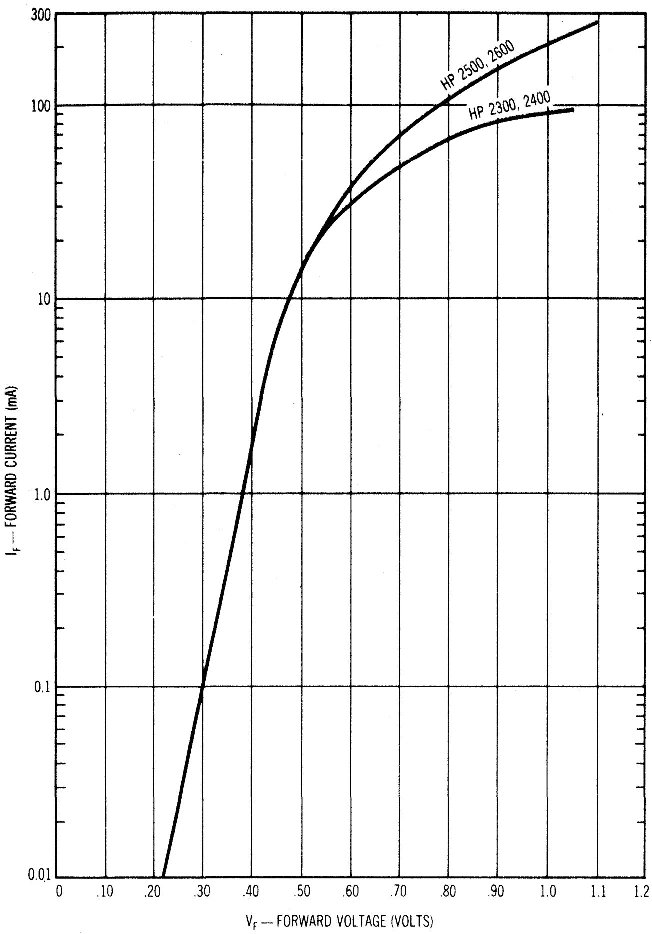


Figure 4. Typical Forward Current vs. Forward Voltage Characteristics at $T_A = 25°C$.

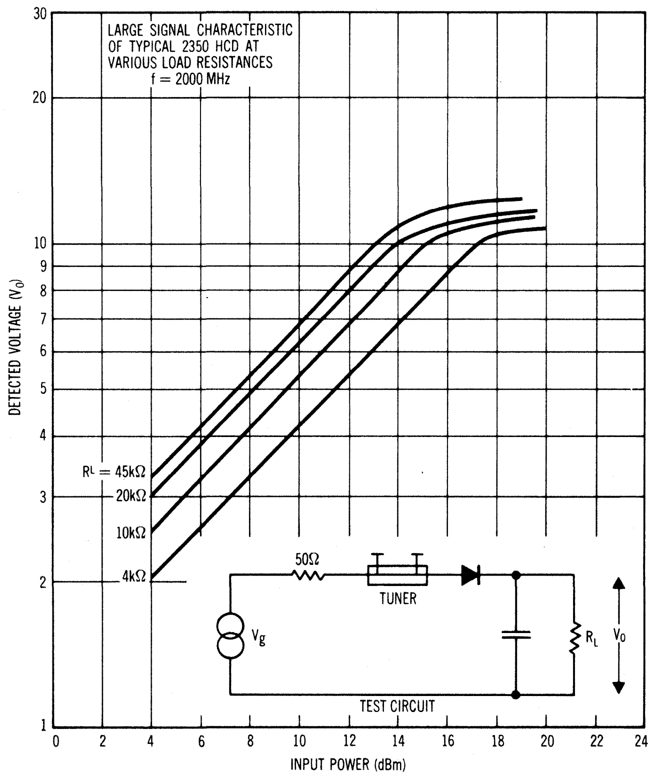


Figure 5. Typical HP 2350 Large Signal Detector Characteristics at $T_A = 25°C$.

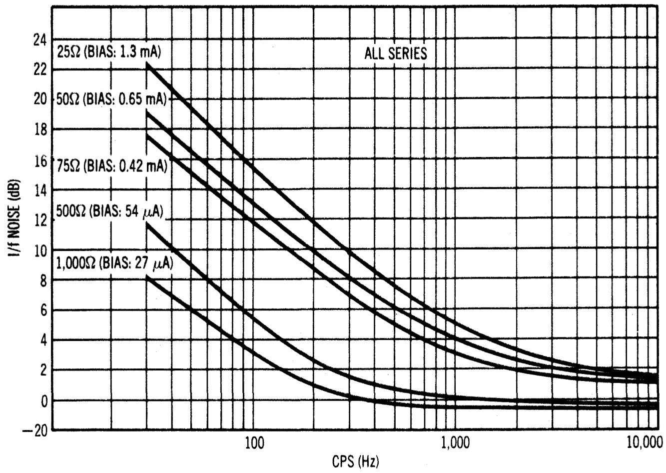


Figure 6. Typical Hot Carrier Diode Flicker (I/f) Noise Characteristics at $T_A = 25°C$.

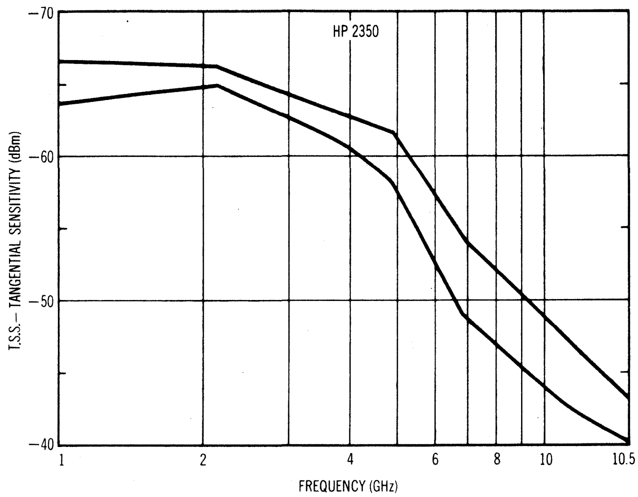


Figure 7. Minimum and Maximum Tangential Sensitivity of 50 Typical HP 2350 Hot Carrier Diodes.

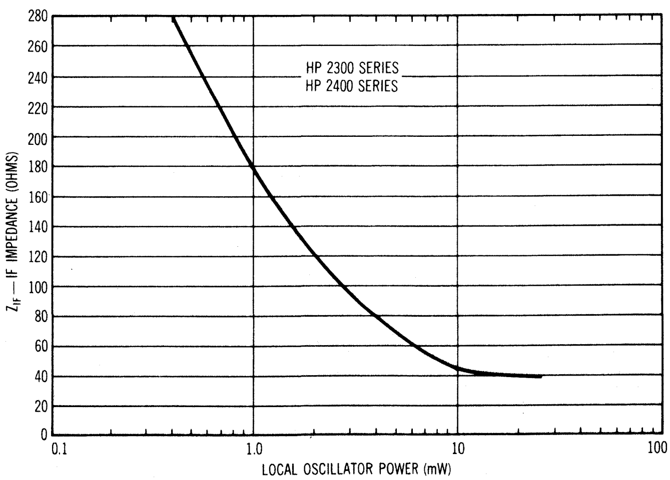


Figure 8. Typical HP 2300 and HP 2400 Series IF Impedance vs. Local Oscillator Power with f_{LO} = 2.0 GHz and f_{IF} = 30 MHz.

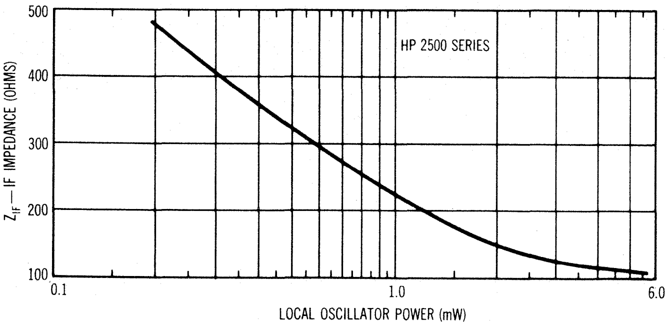


Figure 9. Typical HP 2500 Series IF Impedance vs. Local Oscillator Power at $f_{LO} = 3.0$ GHz and $f_{IF} = 30$ MHz.

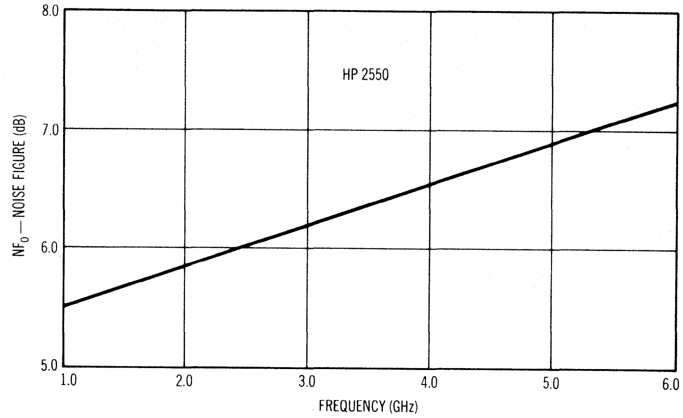


Figure 12. Typical HP 2550 Noise Figure vs. Frequency with $P_{LO} = 1.0$ mW, $f_{IF} = 30$ MHz, and $NF_{IF} = 1.5$ dB.

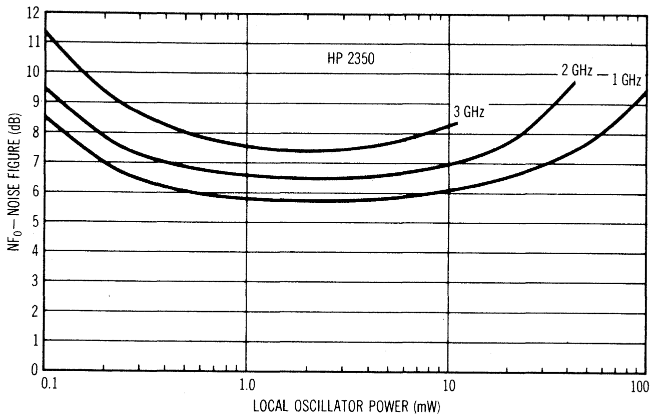


Figure 10. Typical HP 2350 Noise Figure vs. Local Oscillator Power at 1.0, 2.0, and 3.0 GHz with $f_{IF} = 30$ MHz and $NF_{IF} = 1.5$ dB.

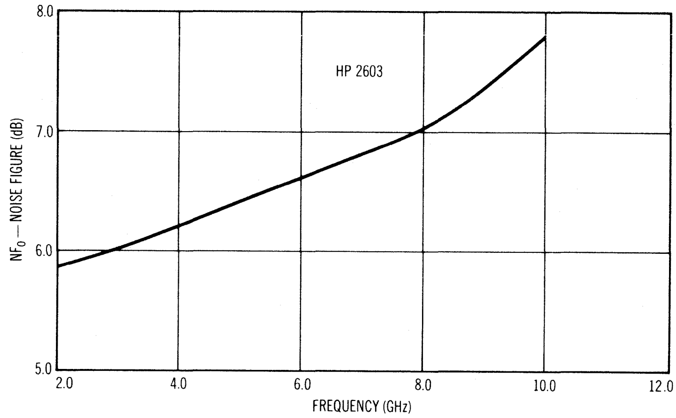


Figure 13. Typical HP 2603 Noise Figure vs. Frequency with $P_{LO} = 1.0$ mW, $f_{IF} = 30$ MHz, and $NF_{IF} = 1.5$ dB.

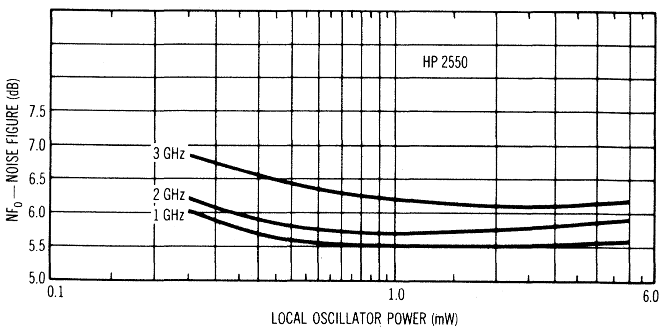


Figure 11. Typical HP 2550 Noise Figure vs. Local Oscillator Power at 1.0, 2.0, and 3.0 GHz with $f_{IF} = 30$ MHz and $NF_{IF} = 1.5$ dB.

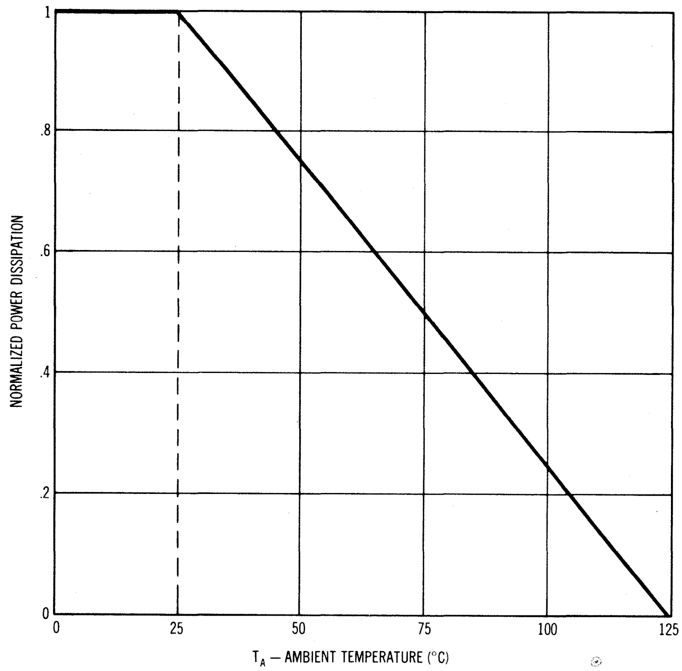


Figure 14. Power Derating Characteristics.

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HOT CARRIER DIODES

HP
2510
series

S-Band Mixer and Detector Diodes

6.0 dB noise figure at 3.0 GHz
Extremely low flicker noise
Hermetically sealed metal-ceramic package
Thermo-compression bonded ribbon lead
Low package inductance and capacitance

DESCRIPTION

The construction of the HP 2510 Hot Carrier Diode Series features a metal silicon epitaxial chip mounted in a miniature, hermetically sealed, metal-ceramic package. The anode contact is a thermocompression bonded ribbon lead, making this device suitable for use in environments requiring reliable performance during high shock and vibration.

APPLICATIONS

The HP 2510 Series Hot Carrier Diodes are designed for use in SHF mixers and detectors. The extremely low flicker (l/f) noise characteristic of this diode makes it particularly suitable for "Zero-IF" or Doppler mixer applications, phase detectors, and as sensors in phase lock loops.

Low package inductance and capacitance make this device especially useful in broadband mixer and detector applications. The package design is ideally suited for use in stripline or coaxial mixer designs.

ABSOLUTE MAXIMUM RATINGS

P_{DISS}—CW Power Dissipation ....200 mW
T_{STG}—Storage Temperature Range .... − 60°C to + 125°C
T_{OPR}—Operating Temperature Range .... − 60°C to + 125°C

ELECTRICAL SPECIFICATIONS AT T_A = 25°C

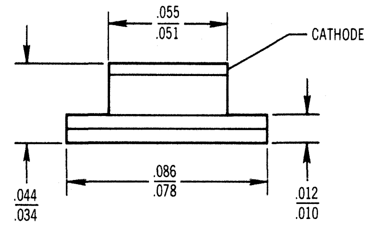
Single Sideband Noise Figure*		HP Type Number
6.0 dB	Single	2511
	Pair†	2516
6.5 dB	Single	2512
	Pair†	2517

VSWR = 1.5 max. and Z_{IF}** = 100-250 Ω for all types.

* The noise figure is specified at 3.0 GHz and is a single sideband receiver noise figure using a 1.5 dB IF amplifier. Local oscillator power is 1.0 mW.

** The IF impedance is measured at 30 MHz with the diode mounted in a coaxial test fixture and biased with 1.0 mW local oscillator power.

† Noise Figure Match: ΔNF_O = 0.3 dB max.
IF Impedance Match: ΔZ_{IF} = 25 ohms max.



Outline 38
Dimensions in Inches

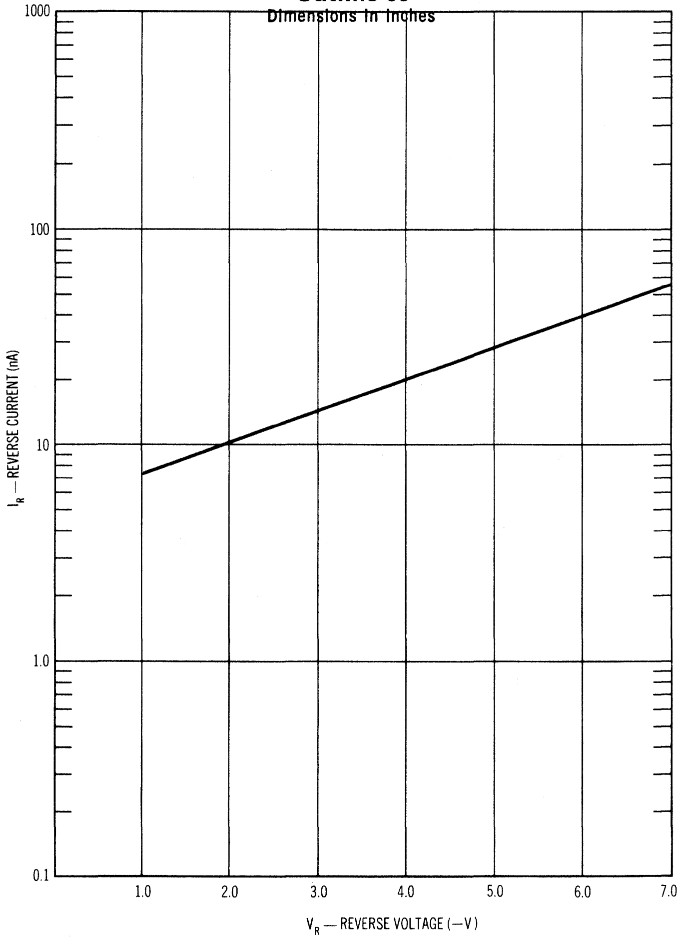


Figure 2. HP 2510 Series Typical Reverse Current versus Reverse Voltage at T_A = 25°C.

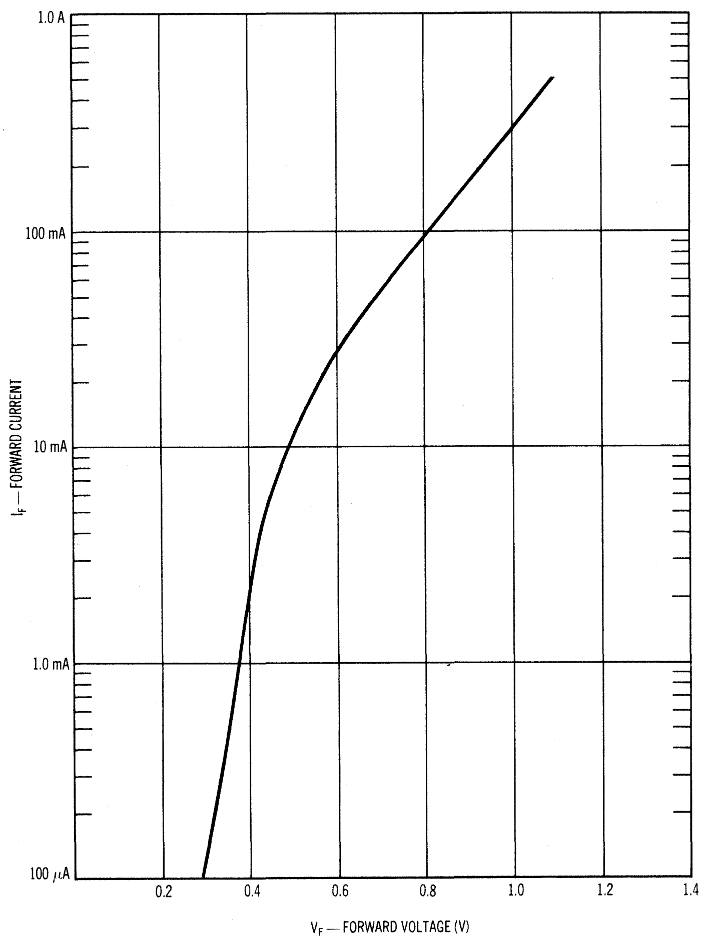


Figure 1. HP 2510 Series Typical Forward Current versus Forward Voltage at T_A = 25°C.

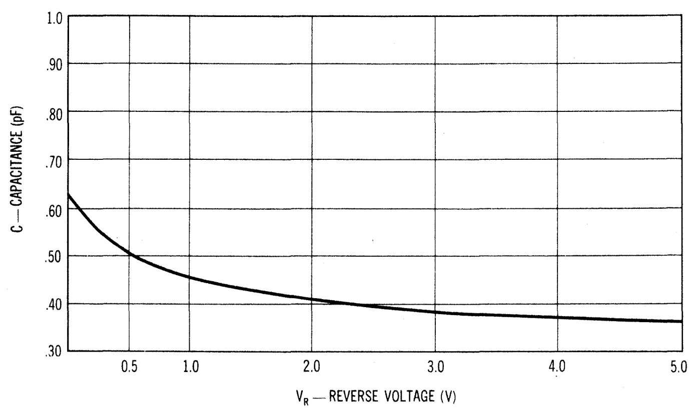


Figure 3. HP 2510 Series Typical Capacitance versus Reverse Bias Voltage at T_A = 25°C.

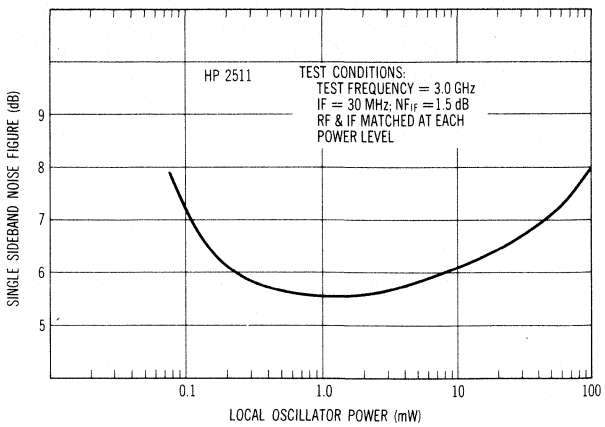


Figure 4. HP 2511 Typical Single Sideband Noise Figure versus Local Oscillator Power.

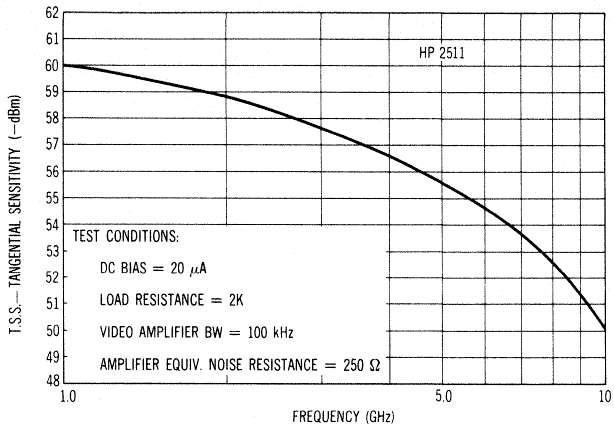


Figure 5. HP 2511 Typical Tangential Signal Sensitivity versus Frequency.

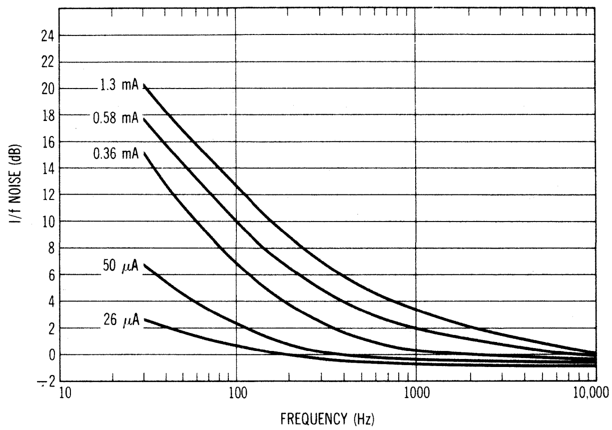


Figure 6. HP 2510 Series Typical I/f Noise versus Frequency.

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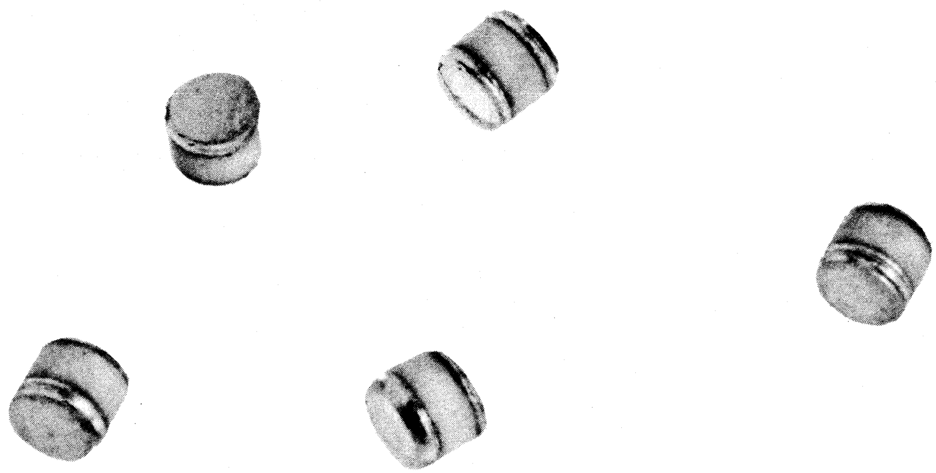
Hot Carrier Diodes

HP 5082-2700 series

X-Band Mixer and Detector Diodes



6.0 dB NF_o at X-band with 1.0 mW L.O. Power

−53 dBm T.S.S. at X-band

Low Parasitic, Symmetrical Microminiature Package

Planar Passivated Construction with Thermo-compression Bond

−60°C to +150°C Storage and Operating Temperature Range

0.13 pF Typical Zero Bias Chip Capacitance

HP 5082-2700 series hot carrier diodes are constructed using a metal semiconductor Schottky barrier junction. Advanced epitaxial techniques and precise process control insure uniformity and repeatability of this planar, . . .

surface-passivated microwave semiconductor. The chip is mounted in a symmetrical, microminiature, hermetically sealed, ceramic package. Anode contact is made by a thermocompression bonded gold-plated ribbon. This construction allows the device to be used in environments requiring reliable performance during high shock and vibration.

APPLICATIONS

Low package inductance and capacitance, typically 0.3 nH and 0.1 pF respectively, make this device especially useful in broadband mixer and small signal detector applications at frequencies above and below X-band. Typical T.S.S. at 10 GHz is −53 dBm with a 40 μA bias current and using an A.E.L. Model 153A Video Amplifier with 5 MHz bandwidth. The microminiature, symmetrical package meets the design engineer's needs for forward or reverse pairs in balanced mixer configurations and is ideally suited for stripline, coaxial, or waveguide mixer designs.

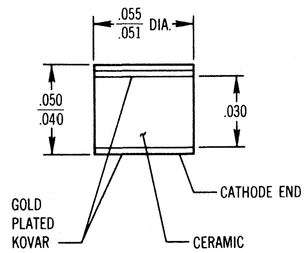
ABSOLUTE MAXIMUM RATINGS

P_{DISS} (1)—CW Power Dissipation ....100 mW
T_{OPR} (2)—Operating Temperature Range −60°C to +150°C
T_{STG}—Storage Temperature Range ....−60°C to +150°C
(1) At a case temperature of 25°C.
(2) Derates to zero power dissipation at 150°C.

ELECTRICAL SPECIFICATIONS AT T_A = 25°C

Single Sideband Noise Figure*		HP Type Number
6.0 dB	Single	5082-2701
	Pair†	-2706
6.5 dB	Single	-2702
	Pair†	-2707
7.0 dB	Single	-2703
	Pair†	-2708

VSWR = 1.5 max. and Z_{IF}** = 250-400 Ω for all types.



Dimensions in inches

Outline 44

* The noise figure is specified at 9.375 GHz and is a single sideband receiver Noise Figure using a 1.5 dB IF amplifier. Local oscillator power is 1.0 mW.
** The IF Impedance is measured at 30 MHz with the diode mounted in a waveguide test fixture and biased with 1.0 mW local oscillator power.
† Noise Figure Match: ΔNF_O = 0.3 dB max.
IF Impedance Match: ΔZ_{IF} = 25 ohms max.

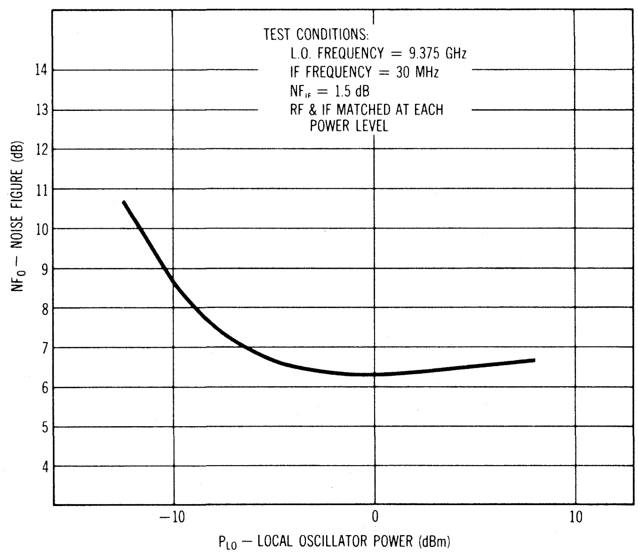


Figure 1. HP 5082-2702 typical noise figure versus local oscillator power.

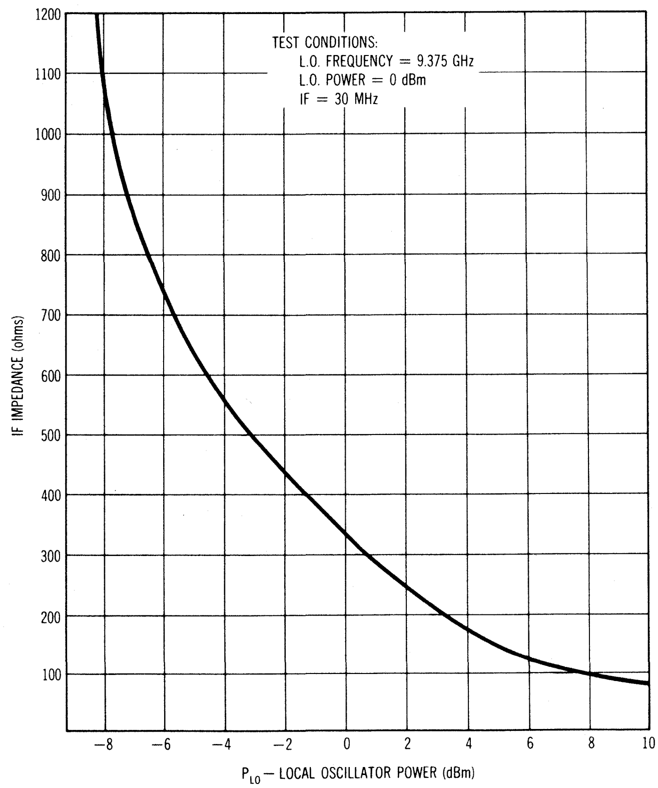


Figure 2. HP 5082-2700 series typical IF impedance versus local oscillator power.

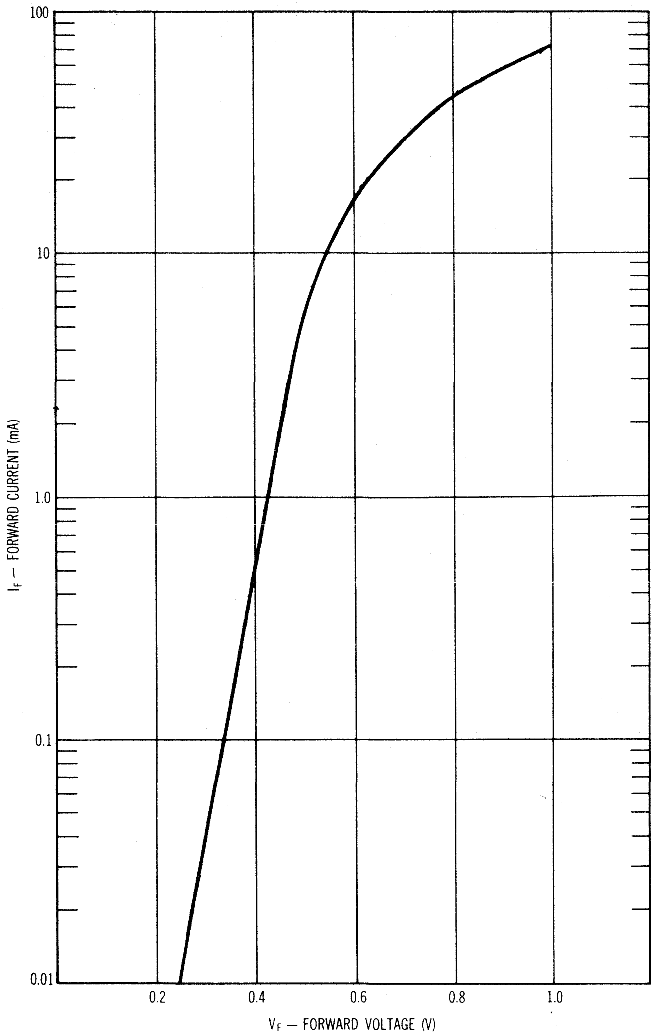


Figure 3. HP 5082-2700 series typical forward current versus forward voltage at $T_A = 25°C$.

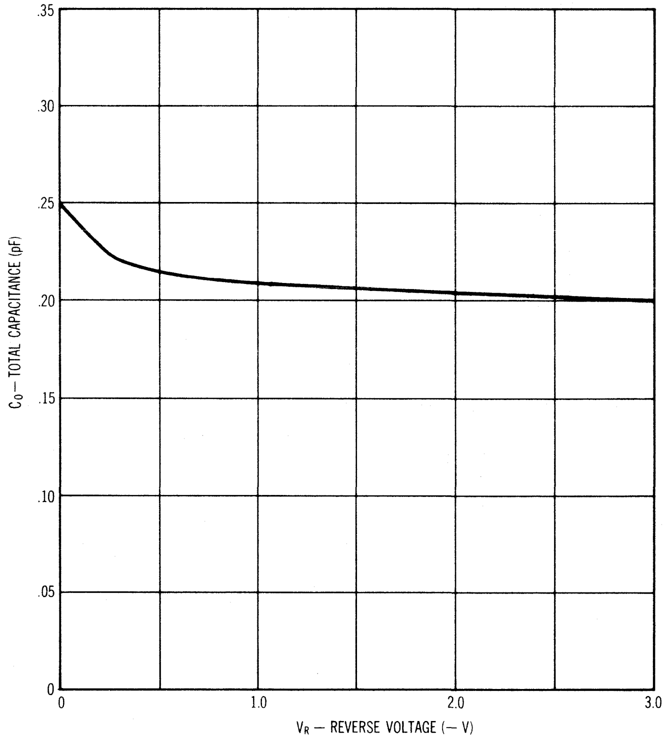


Figure 4. HP 5082-2700 series typical reverse bias capacitance at $T_A = 25°C$.

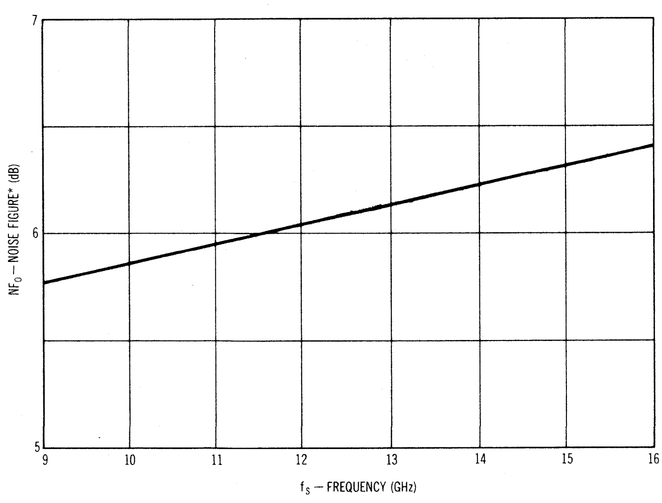


Figure 5. HP 5082-2701 typical single sideband noise figure versus frequency with IF = 30 MHz, $NF_{IF} = 1.5$ dB and $P_{LO} = 1.0$ mW.

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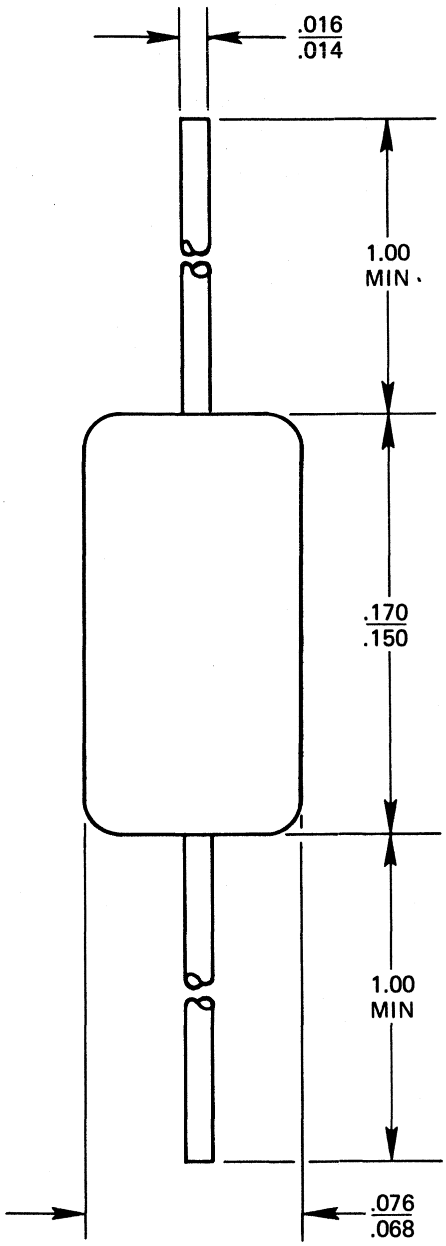
HOT CARRIER DIODES

HP 5082-2800 SERIES

HCD-1



Features

- New Low Price
- 70-Volt Breakdown Voltage
- 410 mV Turn-on Voltage
- Low Stored Charge
- Subnanosecond Reverse Recovery and Turn-on Time
- Low Leakage Current
- 200°C Operating and Storage Temperature
- Withstands 20,000 G Shock

Description

The HP 5082-2800 device is the first of a series of epitaxial, planar passivated diodes whose construction utilizes a unique combination of both a conventional PN junction and a Schottky barrier. This manufacturing process (patent applied for) results in a device with the high breakdown and temperature characteristics of silicon; the turn-on voltage of germanium; and the speed of a Schottky barrier, majority carrier device.

Applications

The HP 5082-2800 is priced to replace conventional PN junction diodes in both RF and digital applications. It is useful in digital circuits requiring a low turn-on voltage and subnanosecond switching times such as DTL gates, pulse steering circuits, and other low-level applications. It is also well suited for use in very fast high-voltage sampling gates where the high PIV capability allows wide dynamic range. The low turn-on gives low offsets, and the extremely low storage minimizes output offsets due to diode stored charge flow in the storage capacitor. Its 95% rectification efficiency at UHF and high burnout capabilities make this device an efficient and reliable detector, especially at high RF levels. Low UHF losses and high PIV also suggest its use as a very wide dynamic range UHF mixer and modulator which can be driven at high L.O. levels. In addition to its clear technical advantages in the above applications, the low price of the HP 5082-2800 suggests its use in many less critical applications for purely economic reasons.

ELECTRICAL SPECIFICATIONS AT $T_A = 25°C$

Specification	Symbol	Min.	Max.	Units	Test Condition
Breakdown Voltage	V_{BR}	70	—	Volts	$I_R = 10\ \mu A$
Forward Voltage	V_{F1}	—	0.41	Volts	$I_{F1} = 1.0$ mA
Forward Voltage	V_{F2}	—	1.0	Volts	$I_{F2} = 15$ mA
Reverse Leakage	I_R	—	200	nA	$V_R = 50$ V
Capacitance	$C_{T(O)}$	—	2.0	pF	$V_R = 0$ V, f = 1.0 MHz
Effective Minority Carrier Lifetime	τ	—	100	ps	$I_F = 5.0$ mA

Unencapsulated and unconnected matched pairs and quads are also available with ΔV_F of 20 mV from 0.5 to 5.0 mA forward current and ΔC_O match of 0.3 pF. The matched pair is the HP 5082-2804. The matched quad is the HP 5082-2805.

ABSOLUTE MAXIMUM RATINGS

P_{DISS}	Power Dissipation @ $T_A = 25°C$	250 mW (Note 1)
T_A	Operating Temperature Range	−65°C to +200°C
T_{STG}	Storage Temperature Range	−65°C to +200°C

Note 1. As measured using an infinite heat sink.

Mechanical Specifications

The HP Outline 15 package has a glass hermetic seal with dumet leads. The leads on the Outline 15 package should be restricted so that the bend starts at least 1/16 inch (1.6 mm) from the glass body. With this restriction, Outline 15 package will meet MIL-STD-750, Method 2036, Conditions A and E [4 lb (1,8 kg)] tension for 30 minutes. The maximum soldering temperature is 230°C ±5°C for five seconds.

Outline 15 package inductance and capacitance is typically 0.2 pF and 3 nH, respectively.

Marking is by digital coding with a cathode band.

Reliability

The HP 5082-2800 diode is suitable for high reliability space applications where maximum performance under the most adverse conditions is required. Maintenance of product reliability during manufacture has resulted in the use of HP diodes in major aerospace and national defense programs.

ENVIRONMENTAL CAPABILITIES

	MIL-STD-750 Reference	Conditions
Temperature, Storage	1031	−65°C to +200°C
Temperature, Operating		−65°C to +200°C
Solderability	2026	230°C as applicable
Temperature, Cycling	1051	5 cycles, −65°C to +200°C
Thermal Shock	1056	5 cycles, 0-100°C
Moisture Resistance	1021	10 days, 90-98% RH
Shock	2016	5 blows, X_1, Y_1, Y_2 at 1500 G
Vibration Fatigue	2046	32 hrs, X_1, Y_1, Z_1 at 20 G min.
Vibration Variable Frequency	2056	Four 4-min. cycles, X, Y, Z at 20 G min., 100 to 2000 Hz
Constant Acceleration	2006	X_1, Y_1, Y_2, at 20,000 G
Terminal Strength	2036	See mechanical specifications
Salt Atmosphere	1041	35°C fog for 24 hours

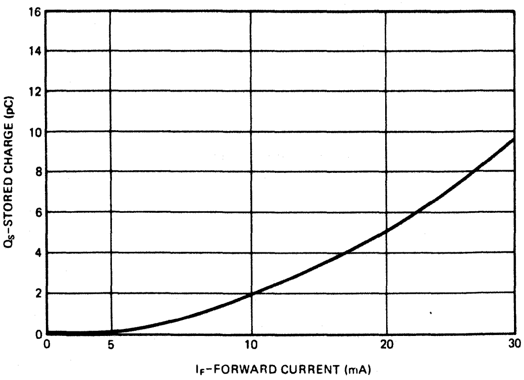


Figure 1. HP 5082-2800 typical stored charge (Q_s) vs. forward current (I_F) @ $T_A = 25°C$.

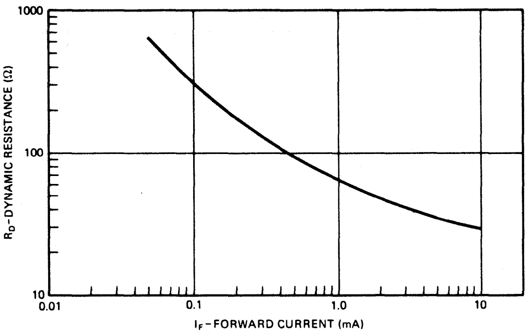


Figure 2. Typical dynamic resistance (R_D) vs. forward current (I_F) at $T_A = 25°C$.

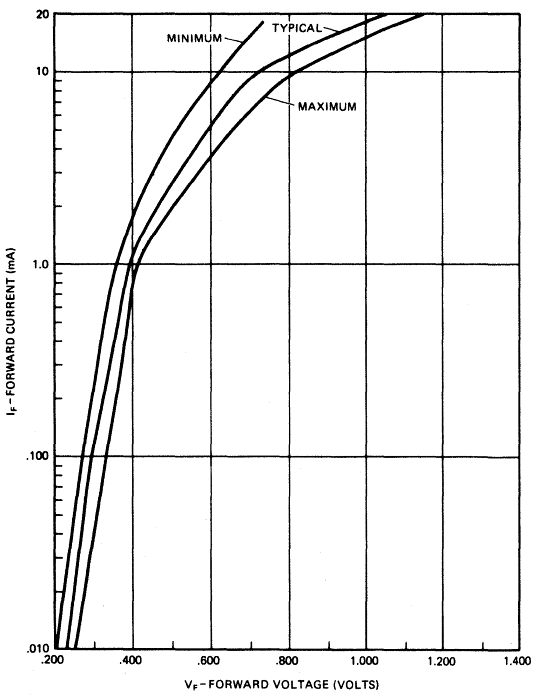


Figure 3. Typical variation of forward voltage (V_F) vs. forward current (I_F) at $T_A = 25°C$.

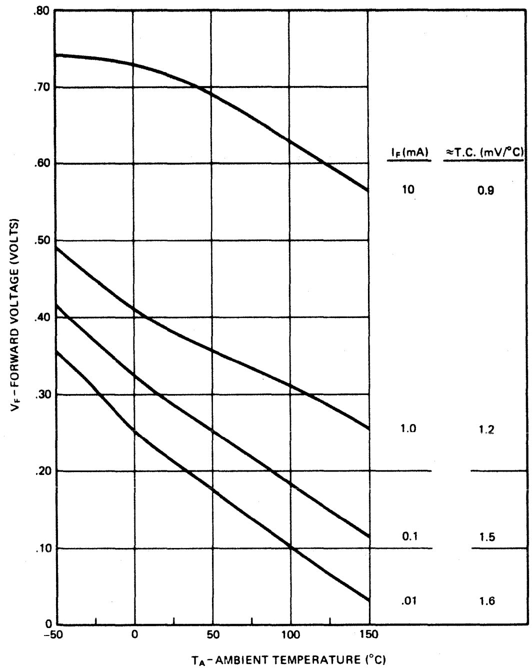


Figure 4. Typical variation of forward voltage (V_F) vs. temperature (T_A) at various values of forward current (I_F).

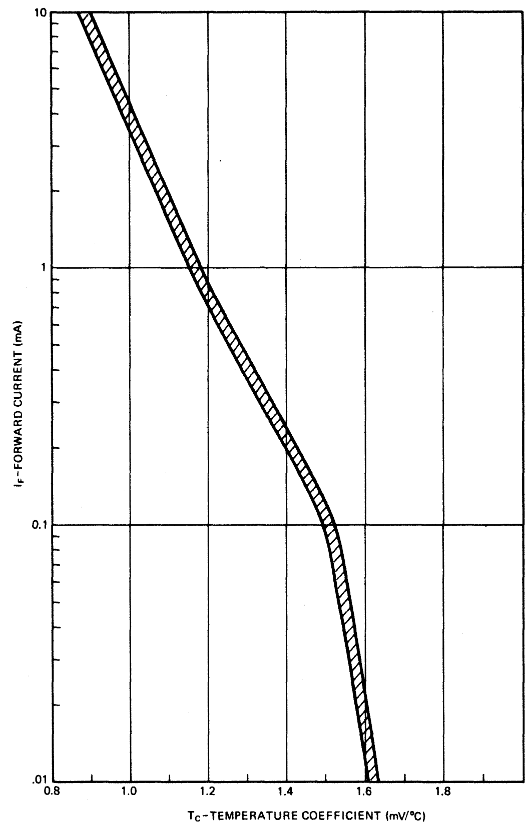


Figure 5. Typical temperature coefficient (T_C) vs. forward current (I_F).

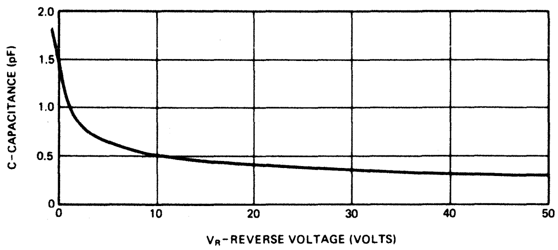


Figure 6. Typical capacitance (C) vs. reverse voltage (V_R) at $T_A = 25°C$.

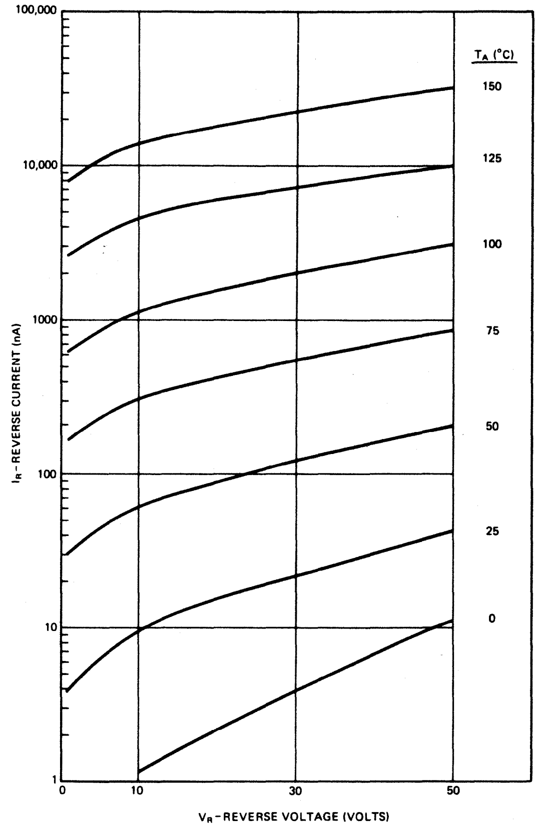


Figure 8. Typical variation of reverse current (I_R) vs. reverse voltage (V_R) at various temperatures.

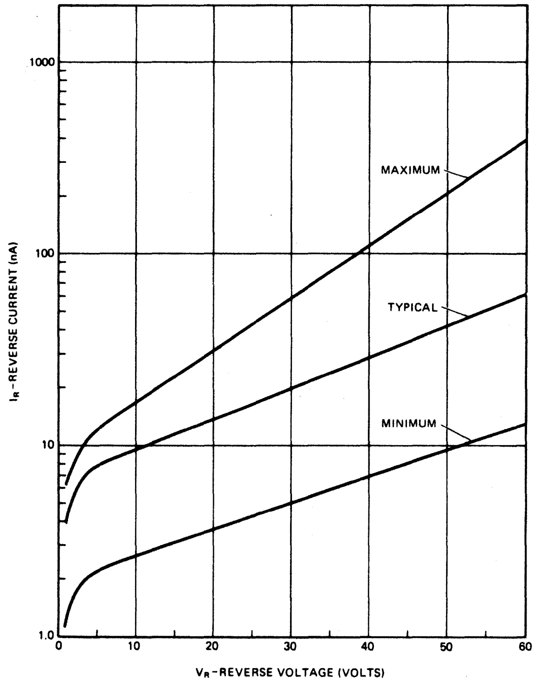


Figure 7. Typical variation of reverse current (I_R) vs. reverse voltage (V_R) at $T_A = 25°C$.

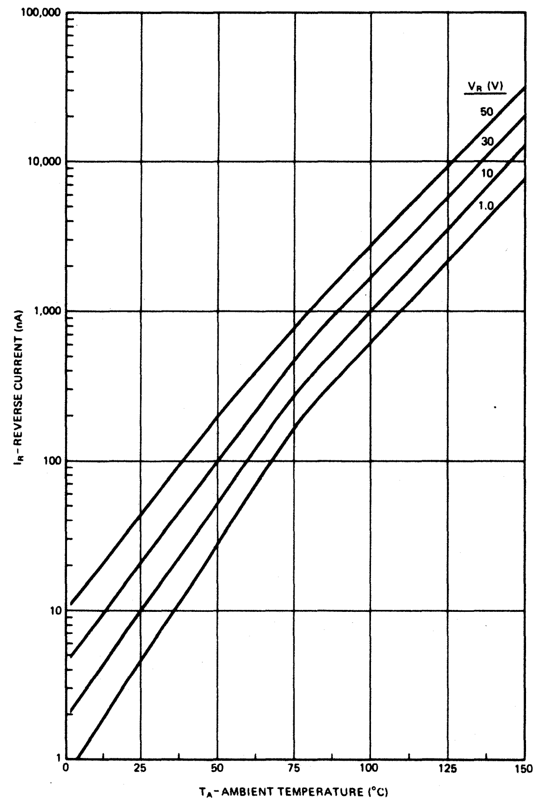


Figure 9. Typical variation of reverse current (I_R) vs. temperature (T_A) at various values of reverse voltage (V_R).

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HOT CARRIER DIODES

HP 2900, 2912 2970, 2996 2997

Low Cost
No-Charge Storage
Pulse Burnout Resistant
Ultrafast Switching
Low 1/f Noise

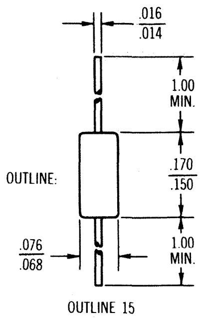


Figure 1a

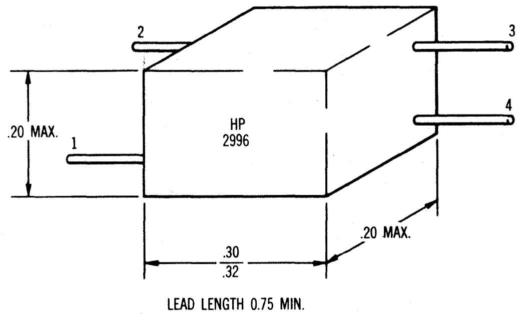


Figure 2a

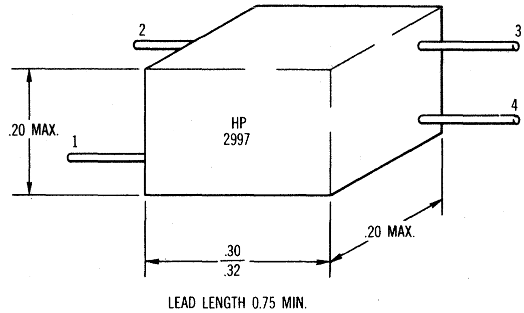


Figure 3a

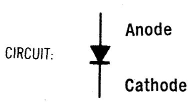


Figure 1b

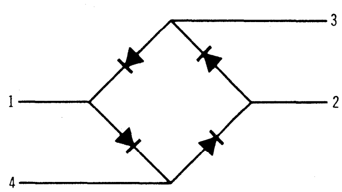


Figure 2b

All dimensions in inches

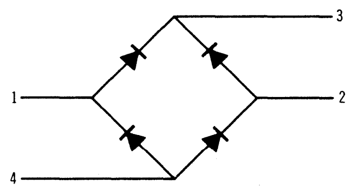


Figure 3b

DESCRIPTION

The HP 2900 series of Hot Carrier Diodes employ a metal-silicon Schottky barrier junction and utilize electrons for majority carrier conduction. The Hot Carrier Diode's performance conforms closely with theory and can be described as closely approximating the ideal diode. HP Application Note 907 contains additional detailed information.

APPLICATIONS

The HP 2900 series of Hot Carrier Diodes is priced for use in commercial applications.

In pulse operations the diode is ideal for clamping, sampling gates, pulse shaping, and general purpose usage requiring fractional picosecond switching times.

In the RF area the Hot Carrier Diode makes an excellent low noise mixer, high sensitivity, small signal detector, large signal detector (power monitor), limiter, discriminator, and balanced modulator from low frequencies through the UHF range.

The HP 2300 series Hot Carrier Diode—rather than the 2900 series—should be considered for military and space applications requiring high reliability performance.

MATCHED PAIRS AND QUADS

HP Type Number	HP 2900	HP 2912	HP 2970	HP 2996	HP 2997
Description	Single Diode	Matched pair of HPA 2900, unencapsulated and unconnected.	Matched Quad, unencapsulated and unconnected.	Matched Ring Quad, Epoxy encapsulated.	Matched Bridge Quad, Epoxy encapsulated.
Outline	Fig. 1a	Fig. 1a	Fig. 1a	Fig. 2a	Fig. 3a
Circuit	Fig. 1b	Fig. 1b	Fig. 1b	Fig. 2b	Fig. 3b

		HP 2900		HP 2912		HP 2970		HP 2996		HP 2997			
Characteristics	**Symbol**	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.	Max.	**Units**	**Test Conditions**
Breakdown Voltage	V_{BR}	10	—	10	—	10	—	*	—	*	—	V	$I_R = 10\ \mu A$
Reverse Current	I_R	—	100	—	100	—	100	—	*	—	*	nA	$V_R = 5.0$ V
Forward Voltage	V_{F_1}	—	0.4	—	0.4	—	0.4	—	0.4	—	0.4	V	$I_{F_1} = 1.0$ mA
Forward Voltage	V_{F_2}	—	1.0	—	1.0	—	1.0	—	1.0	—	1.0	V	$I_{F_2} = 20$ mA
Forward Voltage Match	ΔV_F	—	—	—	30	—	30	—	30	—	30	mV	$I_F = 1.0$ to 10 mA
Capacitance	C_O	—	1.2	—	1.2	—	1.2	—	*	—	*	pF	$V_R = 0$ V, f = 1.0 MHz
Effective Minority Carrier Lifetime	τ	—	120	—	120	—	120	—	*	—	*	ps	Figure 8

* Breakdown voltage, reverse current, capacitance, and effective minority carrier lifetime cannot be readily verified after assembly and encapsulation because of the shunting effect of the other diodes. The encapsulated quads have the same parameter values as the HP 2970 unencapsulated quad prior to assembly and encapsulation.

Consult the HP 2300 series data sheet or contact the local HP field sales office for quads and pairs having additional and/or tighter matching.

ABSOLUTE MAXIMUM RATINGS

T_{OPR}—Operating Temperature Range...... – 60°C to + 100°C
T_{STG}—Storage Temperature Range.......... – 60°C to + 100°C
P_{DISS}—Power Dissipation ($T_A = 25$°C) .... 50 mW
U—Burnout (3 pulses with a 10 ns maximum pulse width; 20% allowable V_{BR} degradation; $T_A = 25$°C) .... 5 ergs

PACKAGE

The HP Outline 15 package has a glass hermetic seal with dumet leads. The leads on the Outline 15 package should be restricted so that the bend starts at least 1/16 inch from the glass body. With this restriction OD-15 package will meet MIL-STD-750, Method 2036, Conditions A and E (4 lbs. tension for 30 minutes). The maximum soldering temperature is 230°C ± 5°C for 5 seconds.

Outline 15 package inductance and capacitance is typically 0.2 pF and 3 nH respectively.

Marking is by digital coding with a cathode band.

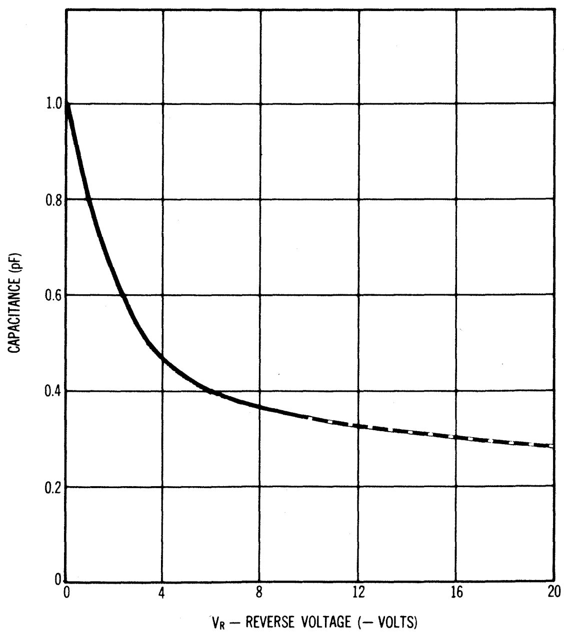


Figure 4. Typical HP 2900 capacitance vs. reverse voltage characteristics at $T_A = 25$°C.

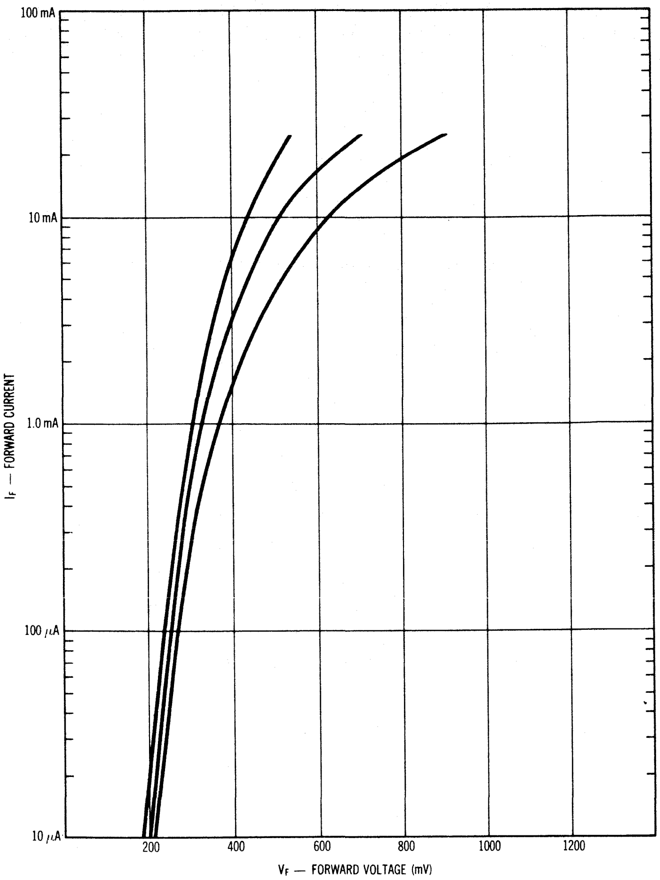


Figure 5. Typical HP 2900 minimum, median and maximum forward current vs. forward voltage characteristics.

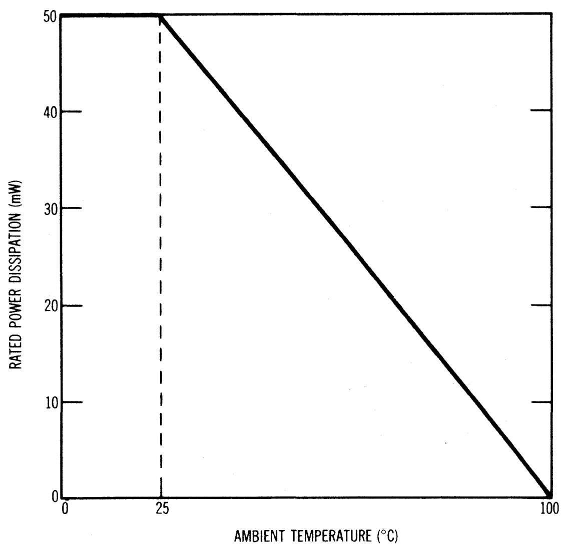


Figure 6. HP 2900 power dissipation characteristics.

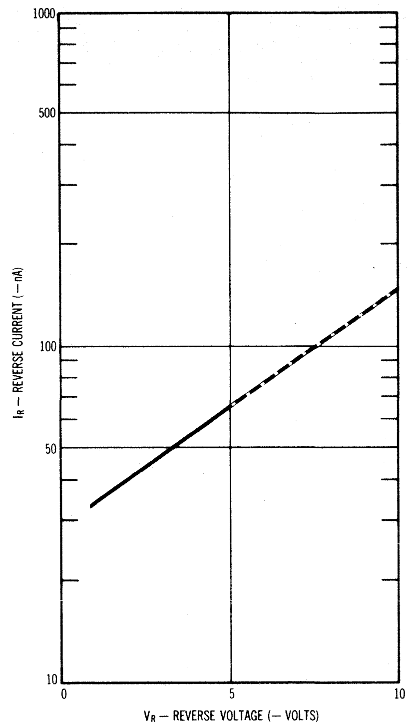


Figure 7. Typical HP 2900 reverse current variation vs. reverse voltage at $T_A = 25°C$.

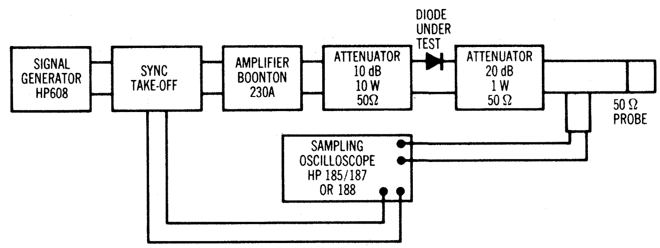


Figure 8a. Test setup.

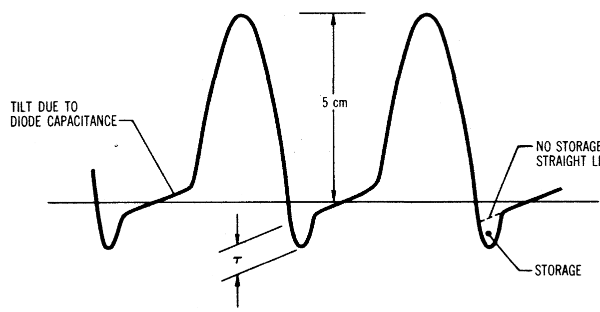


Figure 8b. Resulting oscilloscope display.

Figure 8. Effective minority carrier lifetime measurement.

The signal generator and power amplifier are adjusted to 54 MHz and the output level at 10 V RMS as read on the power amplifier meter. The sampling oscilloscope is adjusted so that the peak deflection corresponding to forward current is 5 cm or 20 mA, where 20 mV/cm = 4.0 mA/cm. Under these conditions, minority carrier lifetime is related to the amplitude designated as "τ" such that 1 cm corresponds to 500 ps. This scale will be linear to about 1.5 cm.

pin diodes

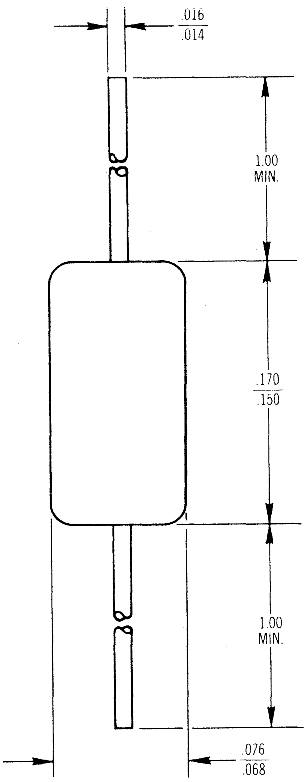
HEWLETT PACKARD

PIN DIODES

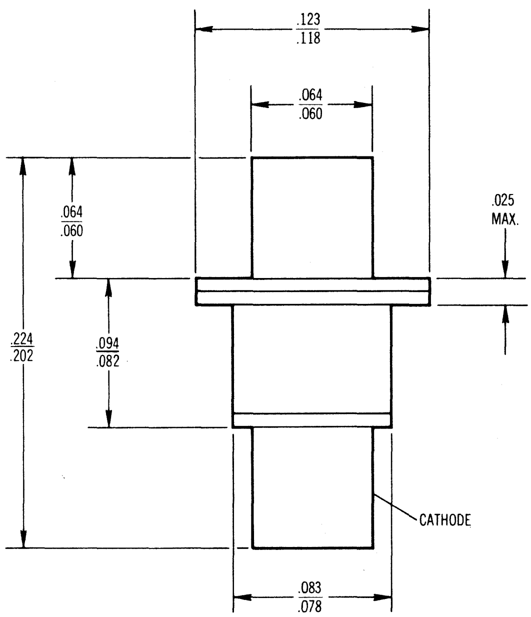
HP 5082-3000 series

Signal Conditioning and Control Devices

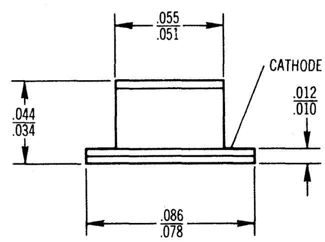
Low Reverse Bias Capacitance for High Isolation
Low Residual Series Resistance for Low Insertion Loss



(Outline 15)



(Outline 31)



(Outline 38)

Dimensions in inches

DESCRIPTION

The HP 5082-3000 Series PIN Diodes are planar passivated silicon devices manufactured using modern processing techniques to provide optimum characteristics for signal conditioning and control applications.

APPLICATIONS

HP PIN diodes are intended for use in signal conditioning and control applications at frequencies well into the microwave region. By varying the dc bias current, the dynamic resistance may be varied from less than 1.0 ohm to 10,000 ohms. These devices provide turn-on and turn-off times of tens of nanoseconds, and are especially useful where the lowest possible residual series resistance and junction capacitance are required for high ON to OFF switching ratios. Additional information on PIN diodes is contained in HP Application Notes 904 and 912. Applications information on biasing and switching PIN diodes is available in HP Application Note 914.

ABSOLUTE MAXIMUM RATINGS

T_{OPR}—Operating Temperature Range....– 65°C to + 150°C
T_{STG}—Storage Temperature Range........– 65°C to + 150°C
P_{DISS}—DC Power Dissipation at T_C = 25°C

HP 5082-3001, 5082-3002, 5082-3039..................0.250 W
HP 5082-3101, 5082-3102 ....1.0 W
HP 5082-3201, 5082-3202 ....3.0 W

PACKAGES

The HP Outline 15 package has a glass hermetic seal with dumet leads. The leads on the Outline 15 package should be restricted so that the bend starts at least 1/16 inch (1,6 mm) from the glass body. With this restriction, Outline 15 package will meet MIL-STD-750, Method 2036, Conditions A and E (4 lbs. [1,8 kg.] tension for 30 minutes). The maximum soldering temperature is 230°C ± 5° for 5 seconds. Typical package inductance and capacitance is 2 nH and 0.07 pF, respectively. Marking is by digital coding with a cathode band.

The HP Outline 31 package has a metal-ceramic hermetic seal. The anode stud is gold-plated copper. The cathode stud is gold-plated Kovar. The maximum soldering temperature is 230°C ± 5°C for 5 seconds. Typical package inductance and capacitance is 1.0 nH and 0.2 pF, respectively. Marking is by color-coded dots on ceramic; clockwise when facing anode, starting at open space.

The HP Outline 38 package: The anode and cathode are gold-plated Kovar. The maximum soldering temperature is 230°C ± 5°C for 5 seconds. Typical package inductance and capacitance is 0.4 nH and 0.2 pF. The package is not marked.

ELECTRICAL SPECIFICATIONS AT T_A = 25°C

Characteristic		Breakdown Voltage (min.)	Total Capacitance (max.)	Residual Series Resistance (max.)	Effective Minority Carrier Lifetime (min.)
HP Type Number	Package Outline	V_{BR} (volts)	C_{VR} (pF)	R_S (ohms)	τ (ns)
5082-3001	15	150	0.30	1.5	100
5082-3002	15	200	0.25	1.5	100
5082-3039	15	100	0.40	2.0	75
5082-3101	38	150	0.32	1.5	100
5082-3102	38	200	0.30	1.5	100
5082-3201	31	150	0.35	1.5	100
5082-3202	31	200	0.32	1.5	100
Test Condition		I_R = 10 μA	V_R = 50 V	I_F = 100 mA	I_F = 50 mA

ENVIRONMENTAL CHARACTERISTICS

	MIL-STD-750 Reference	Conditions
Temperature, Storage	1031	See Maximum Ratings
Temperature, Operating	—	See Maximum Ratings
Solderability	2026	230°C as applicable
Temperature, Cycling	1051	5 cycles, – 65 to + 125°C
Thermal Shock	1056	5 cycles, 0 to + 100°C
Moisture Resistance	1021	10 days, 90-98% RH
Shock	2016	5 blows, X_1, Y_1, Y_2 @ 1500 G
Vibration Fatigue	2046	32 hrs. X, Y, Z, @ 1500 G
Vibration Variable Frequency	2056	Four 4-min cycles, X, Y, Z, @ 20 G Min., 100 to 2000 Hz
Constant Acceleration	2006	X_1, Y_1, Y_2 @ 20,000 G
Terminal Strength	2036	Package Dependent
Salt Atmosphere	1041	35°C fog for 24 hours

Typical Operating Characteristics

EQUIVALENT CIRCUIT

At frequencies over 10 MHz PIN diodes may be used as electrically controlled resistors. A plot of the typical relationship between control current and resistance is given in Figure 1.

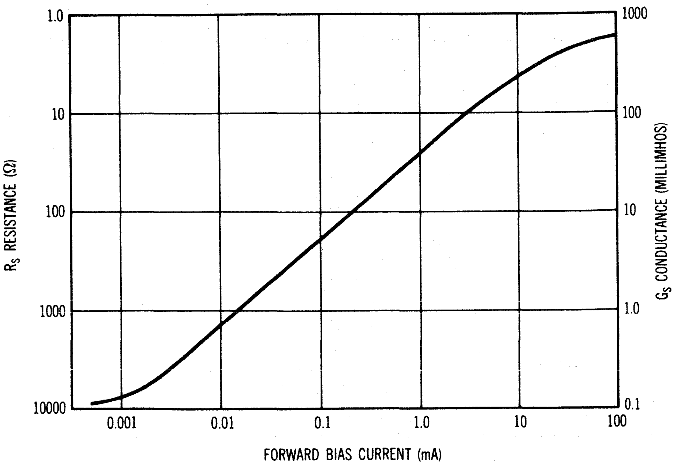


Figure 1. Typical RF Conductance (Resistance) vs. Forward dc Current.

In the range from 10 μA to 10 mA, $R_i = 26 I^{-.87}$. At higher currents, the parasitic series resistance limit is reached, and so resistance will approach some value less than 1.0 ohm. At zero and reverse bias a limit of about 10,000 ohms is asymptotically approached. Associated with this resistance are the reactive elements of the diode. These reactance elements exhibit significantly different characteristics at low frequencies (below 1 GHz) than at microwave frequencies. The junction capacitance is bias dependent at low frequencies. Typically at 1 MHz C_J varies from 0.7 pF at zero bias to 0.05 pF at minus 50 volts. At microwave frequencies C_J is essentially independent of bias. The microwave equivalent circuit of Figure 2 will be valid for frequencies above 1 GHz.

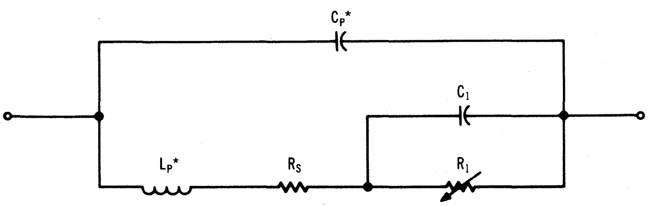


Figure 2. Typical PIN Diode Microwave Equivalent Circuit.

* Actual values for L_P and C_P are affected by external mounting and connections.

ATTENUATION

The variation of r-f resistance with bias current (as in Figure 1) is convenient for calculating circuit performance regardless of input and/or output impedance level. Figures 3 and 4 offer the designer of 50 Ω impedance level circuits a still more convenient design tool. Attenuation α is given in dB for a single series PIN diode as functions of frequency and bias current. Figure 3 is for fixed frequencies. Figure 4 is for fixed dc bias current. For power levels expressed in dBm:

$$P_{out} = P_{in} - \alpha \text{ (from Figure 3 or 4)}$$

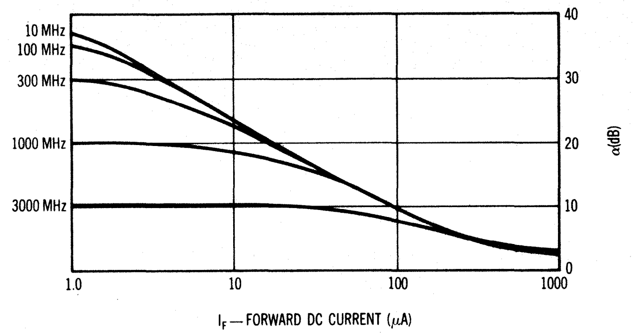


Figure 3. Attenuation Factor vs. Forward dc Current, 50 Ω system—Fixed Frequency.

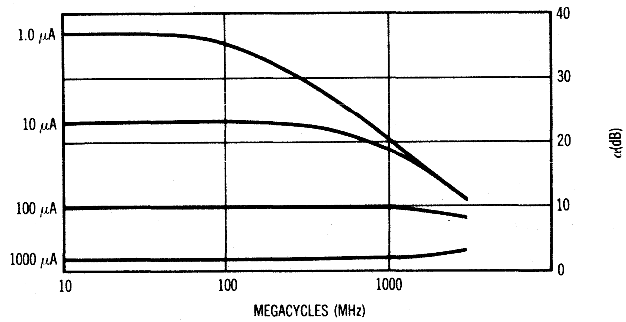


Figure 4. Attenuation Factor vs. Frequency, 50 Ω system—Fixed Forward dc Current.

HARMONIC DISTORTION

Harmonics are generated by the PIN diodes. Harmonic output levels depend upon signal level, bias level, and frequency, and can be expressed by:

$$i_{harmonic} = k_h \, (i_{fundamental})^2$$

where k_h = a value obtained from Figure 5

$i_{harmonic}$ = harmonic current in mA

$i_{fundamental}$ = fundamental current in mA

This relationship is valid so long as $(i_{fundamental})^2 < \frac{I_c}{10}$

where I_c is the forward dc current in mA.

Values for k_h are given by Figure 5 as functions of frequency and dc bias current.

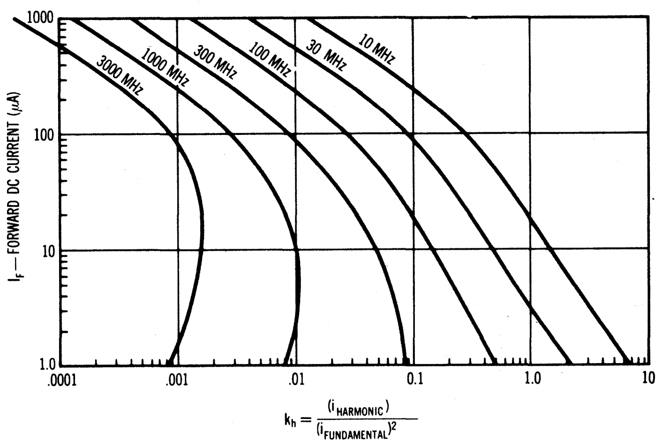


Figure 5. Relationship Between Harmonic Current and Fundamental Current as a Function of Forward dc Current and Fundamental Frequency.

Harmonics generated by an attenuator consisting of a single series PIN diode can also be expressed in terms of input and output power levels, bias current, and frequency. These factors are related through the attenuation factor α and a harmonic generation factor η as formulated below:

$P_h = \eta + 2\,P_f$ Valid for $P_g < +20$ dBm and at fixed frequency and forward dc current.

$P_f = P_g - \alpha$

where P_g = power available from 50 Ω source (dBm)

P_f = fundamental frequency power (dBm) to 50 Ω load

P_h = harmonic frequency (dBm) to 50 Ω load

Values of η in dB are given for a single series PIN diode in a 50 Ω system in Figures 6 and 7. Figure 6 is for fixed frequencies, while Figure 7 is for fixed dc bias currents.

Variations of P_g, P_f and P_h versus frequency and dc bias current can be calculated from values of α and η shown in Figures 4, 5, 6, and 7 and inserted in the above formulas. A 50 Ω system is assumed.

For $P_g > 20$ dBm, α changes very little, but η decreases substantially so that if the values given for η are used for $P_g > +20$ dBm, the harmonic generation computed will be greater than would be measured at these higher power levels.

Following is an example of the use of the formulas:

Suppose $P_g = -10$ dBm and it is desired that
$P_f - P_h > 40$ dB at 100 MHz

What range of dc current and attenuation can be used?

$$P_f = P_g - \alpha$$
$$P_h = \eta + 2\,P_f = \eta + 2\,P_g - 2\,\alpha$$
$$P_f - P_h = (-P_g + \alpha - \eta) > 40$$

Since $P_g = -10$ dBm then $\alpha - \eta > 30$ dB at 100 MHz for $P_f - P_h > 40$ dB

At 100 MHz from curves of α and η vs. dc current

for I =	10	100	200
$\alpha =$	+23	10	6
$\eta =$	−4	−18	−25
$\alpha - \eta =$	27	28	31

Thus the dc current must be > 200 μA, and if the 6 dB attenuation does not give a high enough spread, the only alternative is to reduce P_g to permit use of lower dc current and hence higher attenuation.

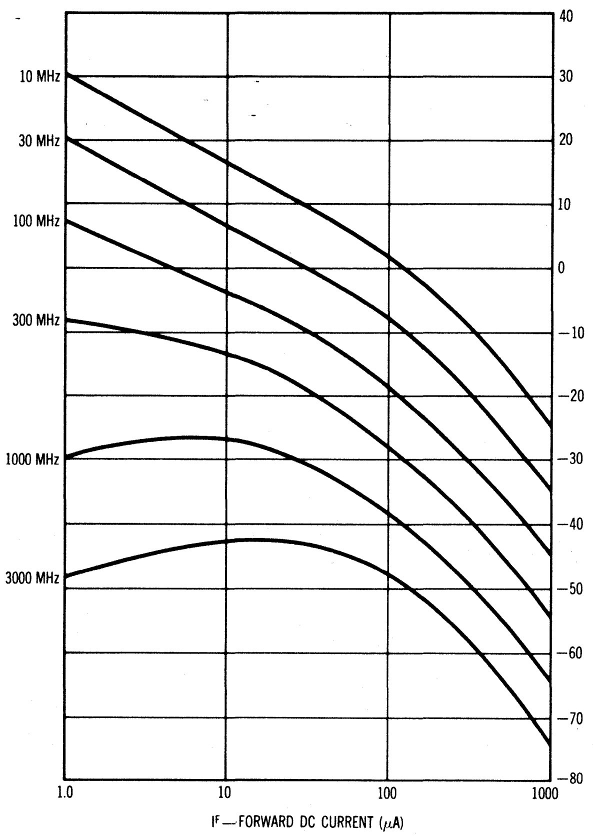


Figure 6. Harmonic Generation Factor vs. Forward dc Current 50 Ω system—Fixed Frequency.

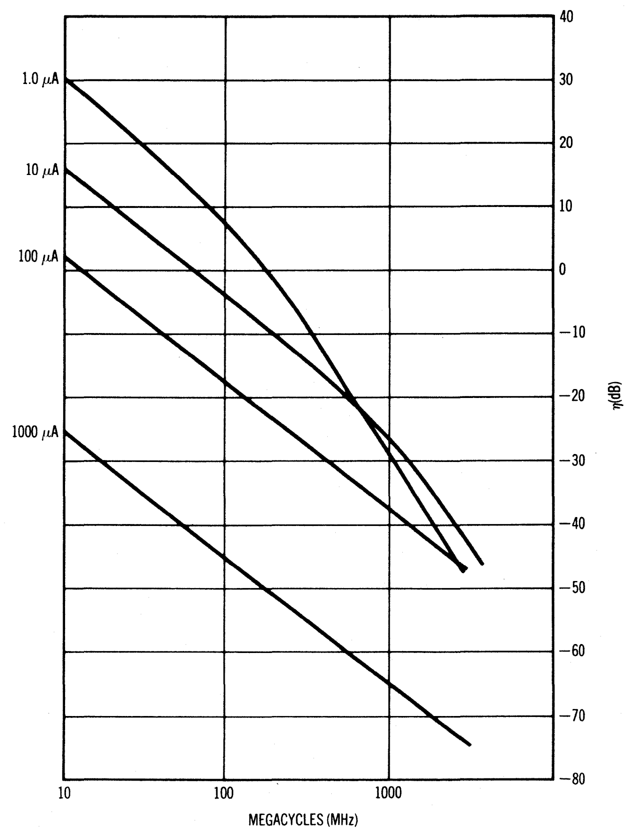


Figure 7. Harmonic Generation Factor vs. Frequency 50 Ω system—Fixed Forward dc Current.

SWITCHING SPEED

Switching speed is measured in the circuit shown in Figure 8. This circuit is not optimized for fastest possible switching but does yield information regarding the switching properties of the diodes. Typically, the switching times for this circuit are:

	Zero Bias	**20 V Rev. Bias**
T_{ON} (nsec)	≈ 100	≈ 100
T_{OFF} (nsec)	≈ 800	≈ 250

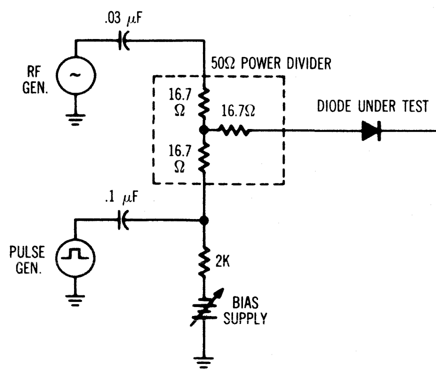


Figure 8. Switching Speed Test Circuit.

At intermediate values of bias, the OFF-time decreases as the bias increases while the ON-time increases to nearly twice its zero-bias value, then decreases until at approximately 20 volts it is again at its zero bias value. Faster switching can be achieved (particularly switching from high forward current to low reverse bias voltage) by driving the diode with a high pulse amplitude and a high reverse bias. High pulse and bias amplitudes may not always be available, but improved performance can be obtained by the use of a more sophisticated drive circuit. In general, such a circuit would include a low-pass filter for introducing the pulse and bias, and a high-pass filter to transmit the RF envelope while preventing the drive pulse from reaching the load. (See Figure 9.)

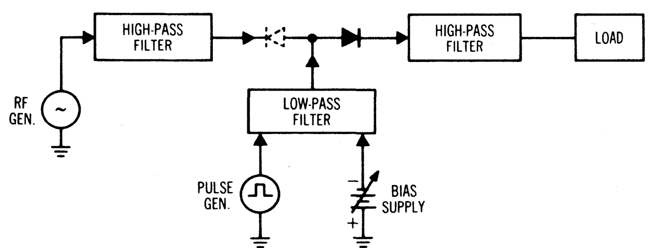


Figure 9. Block Diagram of Switching Circuit.

The selection of circuit element values is governed by consideration of diode properties as well as performance requirements. These considerations may be summarized as follows:

1. The switching source should present a high impedance to the RF signal.
2. By increasing the turn-on drive pulse, T_{ON} and insertion loss may be reduced at the expense of increased T_{OFF}.
3. Application of reverse bias improves isolation and decreases T_{OFF}, but requires a higher drive pulse amplitude.
4. Drive pulse amplitude may be limited by the tolerable levels of disturbance it produces in the load.
5. Circuit elements for the high-pass filters are selected according to filter formulas to transmit the RF, but if the frequency is low, it may be necessary to compromise T_{ON} and T_{OFF} to prevent pulse edges from being coupled into the load. (See Items 2, 3, 4.)
6. The high-pass filter on the input side must block the flow of pulse and bias currents unless a diode pair is used, as shown by the dotted lines in Figure 9. Use of a diode pair doubles the insertion loss, but also doubles the isolation and provides harmonic cancellation, which may be significant in some applications.

By applying these principles a circuit may have insertion loss less than 3 dB, isolation over 40 dB, **both** T_{ON} and T_{OFF} of typically tens of nanoseconds from an 8-volt pulse source and with only 2 volts bias.

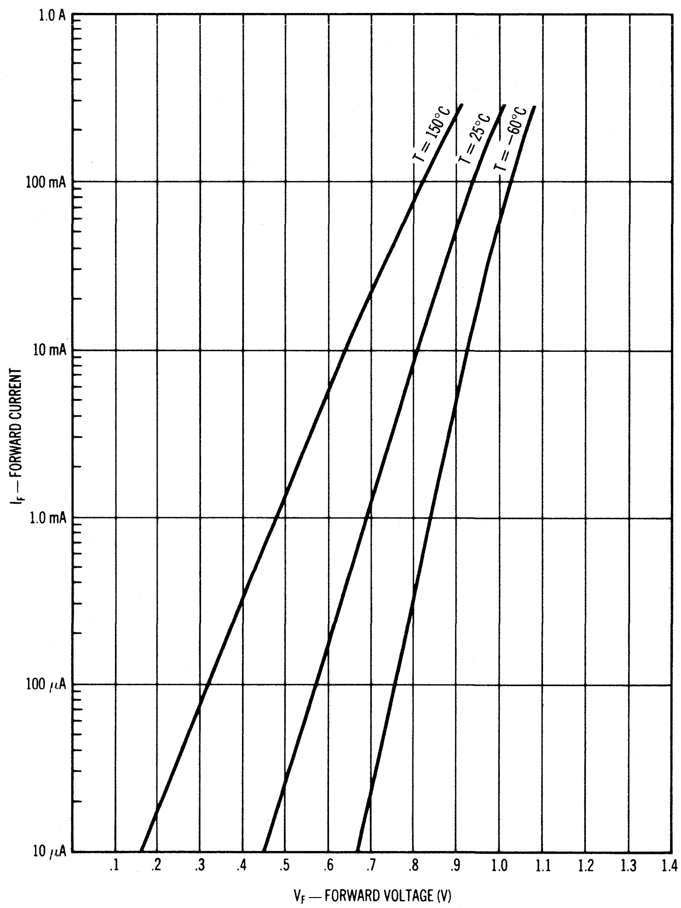


Figure 10. Typical Forward Conduction Characteristics.

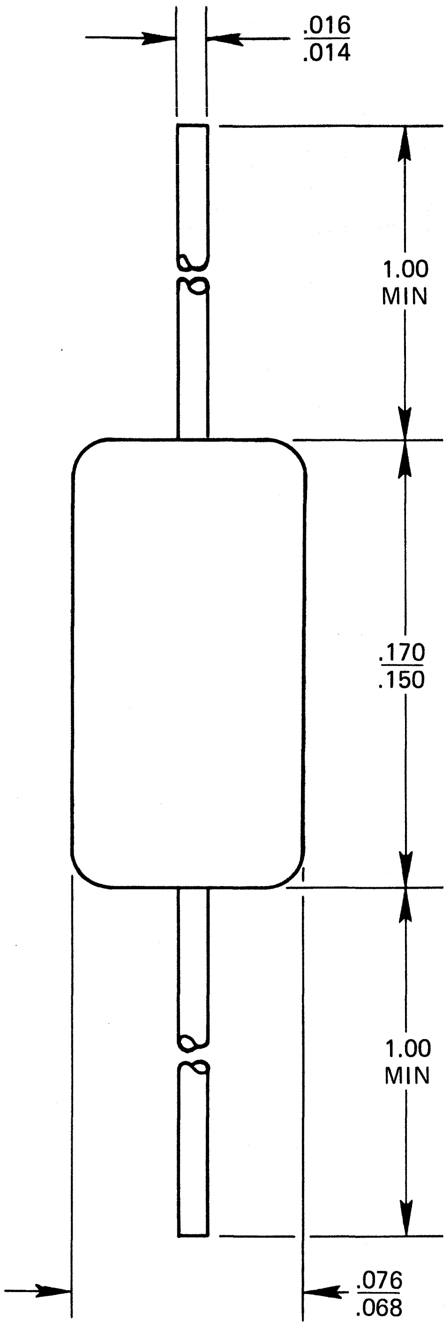
RELIABILITY

Hewlett-Packard PIN diodes are suitable for high reliability space applications where maximum performance stability under the most adverse conditions is required. Maintenance of product reliability during manufacture has resulted in the use of HP diodes in major aerospace and national defense programs.

HEWLETT hp PACKARD

CURRENT-CONTROLLED RF RESISTOR

model
5082-3003



Features

RF resistance variation with bias specified at 500 MHz.

Large resistance swing (1 Ω - 10,000 Ω typical).

Long lifetime for low intermodulation.

Useful application down to 10 MHz.

Tight resistance tracking between units.

Low resistance-temperature coefficient at constant current bias.

Description

The current-controlled RF resistor consists of a specially processed and tested silicon PIN diode. The fabrication process is tightly controlled and units are selected on the basis of similarity of RF resistance variation with bias. RF resistance is measured and specified on each unit at 500 MHz and at two bias points. The RF resistance versus bias slope is also specified to tight limits to further assure tracking of individual devices. Long lifetime assures usefulness at operating frequencies down to 10 MHz at small signal levels.

Applications

The current-controlled RF resistor (CCR) is a very useful device for realizing current-controlled RF attenuators, RF AGC circuits, constant impedance leveling circuits, electronically controlled RC circuits, variable Q resonating networks and filters, modulating circuits, and as an element in any circuit that requires the use of a dc or low-frequency control of an RF resistance.

The CCR has a resistance characteristic that is accurately described by $R = KI^{-x}$ in the range of 0.01 mA to 1 mA. When displayed on log-log coordinates, as shown in Figure 1, this characteristic plots as a straight line with a slope of $-x$, and at 1 mA $R = K$. The equation constants for the HP 5082-3003 are typically $K = 13$ and $x = 0.88$.

To assure repeatability of the RF resistance characteristic from unit to unit, the high and low resistance values are specified to within ±15% and ±11%, respectively. To assure tight tracking between units, the slope is also specified to be in the range of 0.9-0.86. This is particularly useful when several CCR's in an attenuator or modulator circuit must track each other closely. For very close tracking, the individual CCR's can be biased with a slight offset with respect to a reference CCR. This is shown in Figure 1.

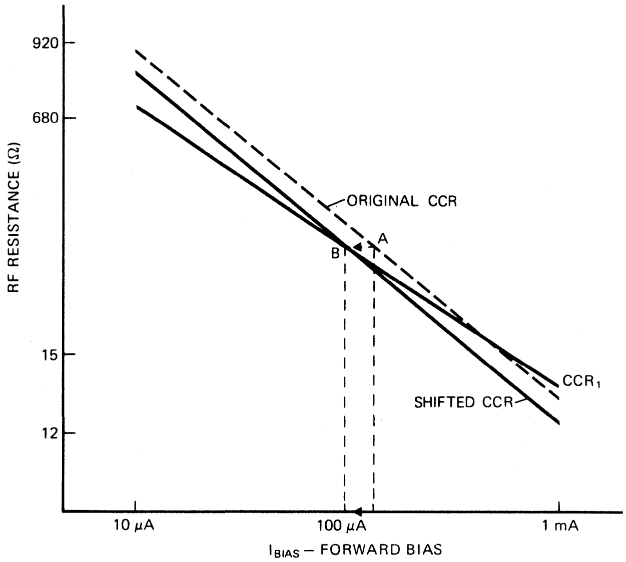


Figure 1. Tracking of Individual CCR's by Bias Current Offset

The characteristic curve of CCR_1 is used as reference. The characteristic curve of CCR_2 is moved over from A to B by a current offset until they intersect at CCR_1's 0.1 mA position.

$$\text{If } R_1 = K_1 I_1^{-x_1}$$
$$\text{and } R_2 = K_2 I_2^{-x_2}$$

then to shift R_2 to any current points on R_1, the following relation would be used:

$$I_2 = \left(\frac{K_2}{K_1}\right)^{\frac{1}{x_2}} I_1^{\frac{x_1}{x_2}}$$

At RF, the equivalent circuit of the CCR can be represented as shown in Figure 2.

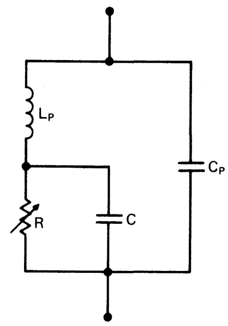


Figure 2. Equivalent RF Equivalent Circuit of CCR

L_P and C_P are the package inductance and capacitance, respectively. The capacitance C is the capacitance of the intrinsic silicon layer of the chip and is typically 0.06 pF. This capacitance does not change with frequency or bias. At constant bias, the RF resistance of the CCR is relatively insensitive to temperature, changing only +15% for a temperature change from 25° to 100°C.

RF Electrical Specifications (T_A = 25°C)

Parameter	Symbol	Max.	Min.	Units	Test Conditions
High Resistance Limit	R_H	920	680	Ohms	DC bias = 10 μA Test Frequency = 500 MHz
Low Resistance Limit	R_L	15	12	Ohms	DC bias = 1.0 mA Test Frequency = 500 MHz
Resistance vs. Bias Slope	x	−0.9	−0.86	—	DC bias = 10 μA & 1.0 mA Test Frequency = 500 MHz

DC Electrical Specifications (T_A = 25°C)

Parameter	Symbol	Max.	Min.	Units	Test Conditions
Breakdown Voltage	V_{BR}	—	100	Volts	I_R = 10 μA
Reverse Capacitance Note 1	C_{VR}	0.3	—	pF	V_R = 50 V f = 1.0 MHz
Series Resistance	R_S	1.5	—	Ohms	I_F = 100 mA
Effective Minority Carrier Lifetime	τ	—	100	ns	I_F = 50 mA

Note 1. Typical reverse bias junction capacitance is 0.06 pF.

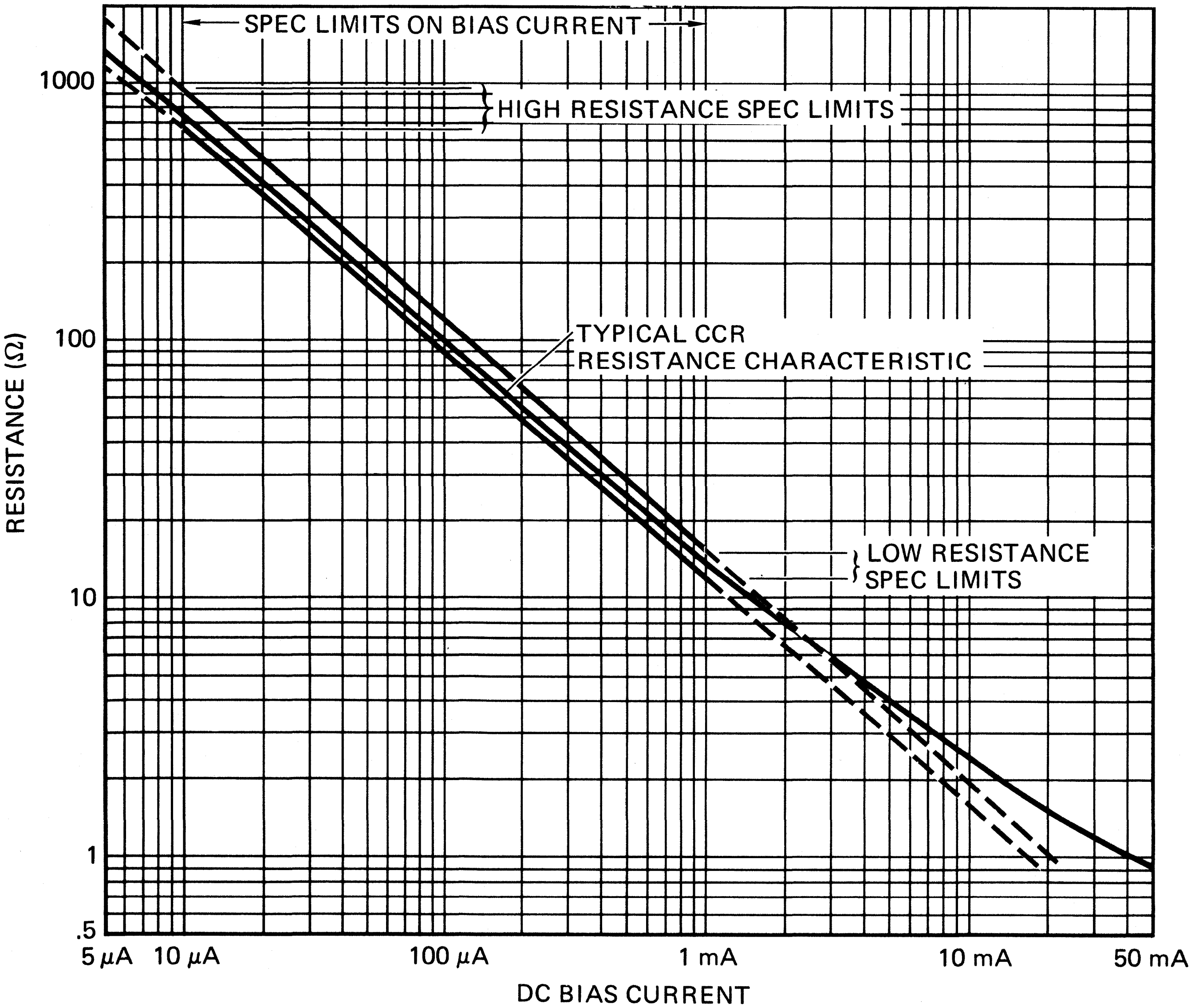
Absolute Maximum Ratings

T_{OPR}—Operating Temperature Range .... −65° to +150°C

T_{STG}—Storage Temperature Range .... −65° to +150°C

P_{DISS}—DC Power Dissipation (at T_A = 25°C) .... 0.250 watts

Figure 3. RF Resistance vs. Bias Characteristic



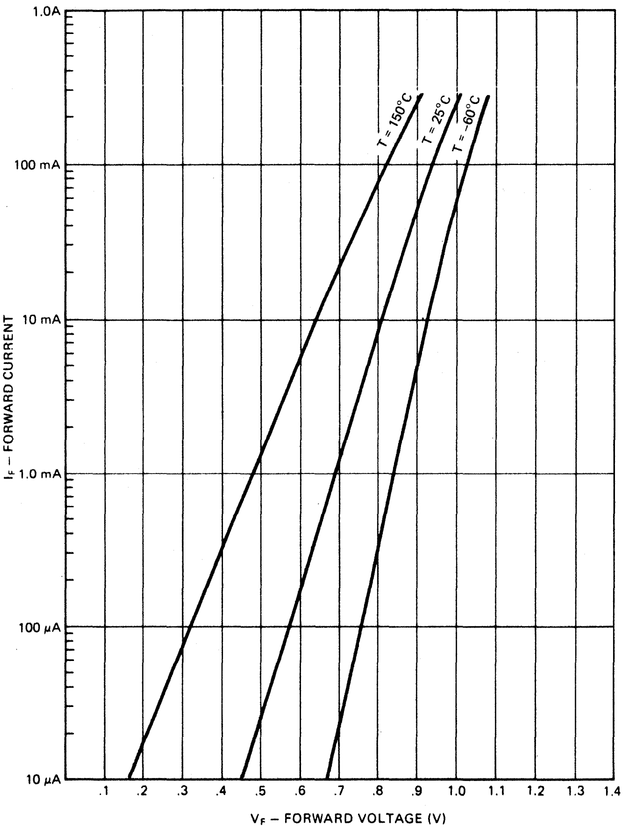


Figure 4. Typical Forward Conduction Characteristics

Typical Mechanical and Environmental Characteristics

PACKAGES

The HP Outline 15 package has a glass hermetic seal with dumet leads. The leads on the Outline 15 package should be restricted so that the bend starts at least 1/16 inch (1,6 mm) from the glass body. With this restriction, Outline 15 package will meet MIL-STD-750, Method 2036, Conditions A and E (4 lb [1,8 kg] tension for 30 minutes). The maximum soldering temperature is 230°C ±5° for 5 seconds. Typical package inductance and capacitance is 2.5 nH and 0.1 pF, respectively. Marking is by digital coding with a cathode band.

RELIABILITY

Hewlett-Packard PIN diodes are suitable for high reliability space applications where maximum performance stability under the most adverse conditions is required. Maintenance of product reliability during manufacture has resulted in the use of HP diodes in major aerospace and national defense programs.

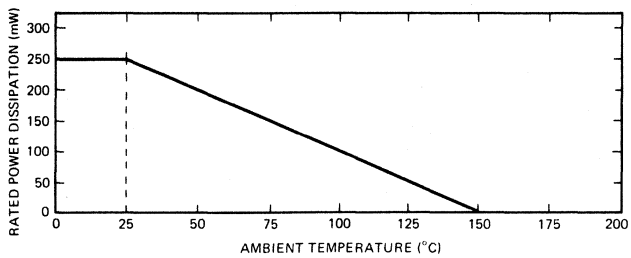


Figure 5. Power Dissipation Derating Characteristics

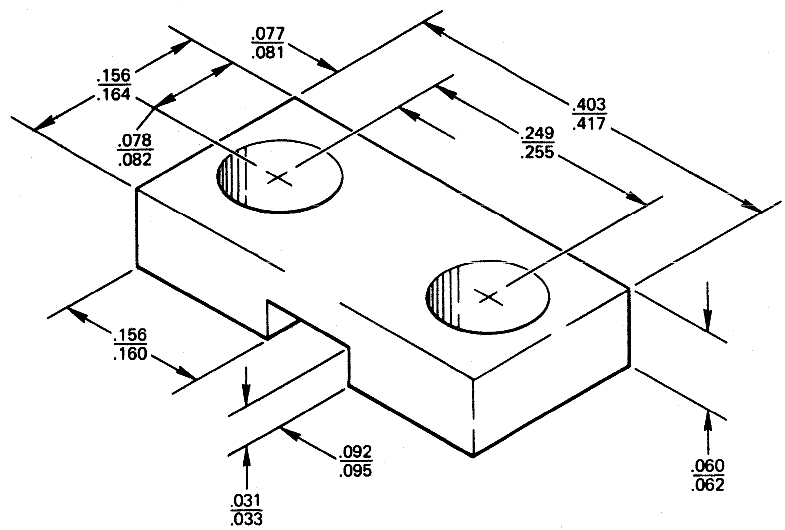
Environmental Capabilities

	MIL-STD-750 Reference	Conditions
Temperature, Storage	1031	See Maximum Ratings
Temperature, Operating	—	See Maximum Ratings
Solderability	2026	230°C as applicable
Temperature, Cycling	1051	5 cycles, –65° to +150°C
Thermal Shock	1056	5 cycles, 0° to +100°C
Moisture Resistance	1021	10 days, 90-98% RH
Shock	2016	5 blows, at 1500 G, X, Y, Z
Vibration Fatigue	2046	32 hrs., X, Y, Z, at 20 G min.
Vibration Variable Frequency	2056	Four 4-min. cycles, X, Y, Z, at 20 G min., 100 to 2000 Hz
Constant Acceleration	2006	20,000 G, X, Y, Z
Terminal Strength	2036	Package Dependent
Salt Atmosphere	1041	35°C fog for 24 hours

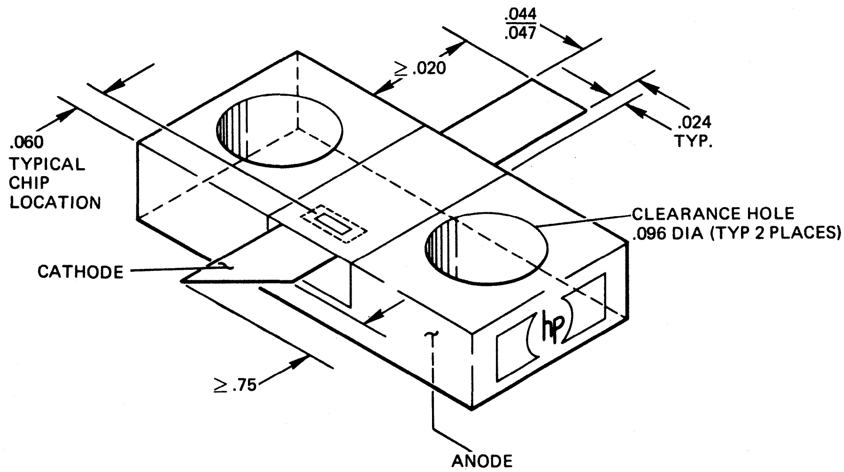
HEWLETT PACKARD

STRIPLINE PIN DIODE

HP 5082-3040



Cover plate for balanced stripline applications.



Stripline PIN diode. Dimensions are identical to the cover plate.

Description and Application

The HP 5082-3040 is a silicon planar passivated PIN diode manufactured using modern processing techniques to provide optimum characteristics for stripline signal conditioning and control applications.

Microwave and UHF systems using stripline circuit techniques have the advantages of small size, light weight, and low cost over systems constructed with waveguide and coaxial devices. Additional stripline advantages are mechanical rigidity and operation over wide frequency ranges. Unfortunately, glass packaged devices designed for lumped circuits and double stud ceramic packages useful for waveguide are not optimally configured for use in stripline. This is especially true when very wide bandwidths must be covered.

The HP 5082-3040 is an optimally integrated shunt diode (see Figure 1) intended for use from HF through 18 GHz without the limitations of matching structures. The package, when zero or reverse biased, appears as a 50-ohm microstrip line. The leads allow good continuity of characteristic impedance when used in 50-ohm stripline circuitry. When forward biased, the resistance appearing across the line is a function of the bias level and varies typically as shown in Figure 2.

When used in a balanced stripline application it is important that the cover cap supplied with the diode be used in order to have good electrical continuity from the upper to the lower ground plane through the package base metal (Figure 3). Higher order modes will be excited if this cover is either left off or if poor electrical contact is made to the ground plane. Shims, "ripple" washers, or "fuzz buttons" can be used to assure good contact to the ground planes.

Absolute Maximum Ratings

T_{OPR}	Operating Temperature Range	−65°C to +125°C
T_{STG}	Storage Temperature Range	−65°C to +125°C
P_{DISS}	DC Power Dissipation (T_A = 25°C)	2.5 watts
θ_{JC}	Thermal Resistance	50°C/W
V_{BR}	Breakdown Voltage	150 volts

Mechanical Specifications

See Outline Drawing 61

Typical Performance Characteristics

From I_F: (mA)	TO V_R: (V)	t_{switch} (ns)
100	10	110
100	50	50
10	10	35

TABLE I. Typical HP 5082-3040 Switching Time at 10 GHz

Electrical Specifications at T_A = 25°C

Symbol	Characteristic	Min.	Max.	Units	Test Conditions
I_S	Isolation from 0.5 to 12.4 GHz	20	—	dB	f = 8-12.4 GHz; I_{BIAS} = 100 mA
I_L	Insertion Loss from 0.5 to 12.4 GHz	—	0.5	dB	f = 8-12.4 GHz; V_R = 0
VSWR	Voltage Standing Wave Ratio from 0.5 to 12.4 GHz	—	1.5	—	f = 8-12.4 GHz; V_R = 0

Environmental Characteristics

Characteristic	MIL-STD-750 Reference	Conditions
Temperature, Storage	1031	−65°C to +125°C
Temperature, Operating	—	−65°C to +125°C
Solderability	2026	230°C as applicable
Temperature, Cycling	1051	5 cycles, −65 to +125°C
Thermal Shock	1056	5 cycles, 0 to +100°C
Shock	2016	5 blows, X_1, X_2, Y_1, Y_2, Z_1, Z_2, @ 1500 G
Vibration Fatigue	2046	32 hours, X, Y, Z @ 20 G
Vibration Variable Frequency	2056	Four 4-min. cycles, X, Y, Z, @ 20 G Min., 100 to 2000 Hz
Constant Acceleration	2006	20,000 G X_1, X_2, Y_1, Y_2, Z_1, Z_2
Terminal Strength	2036	Tension and lead fatigue
Salt Atmosphere	1041	35°C fog for 24 hours
Barometric Pressure	1001	150,000 feet

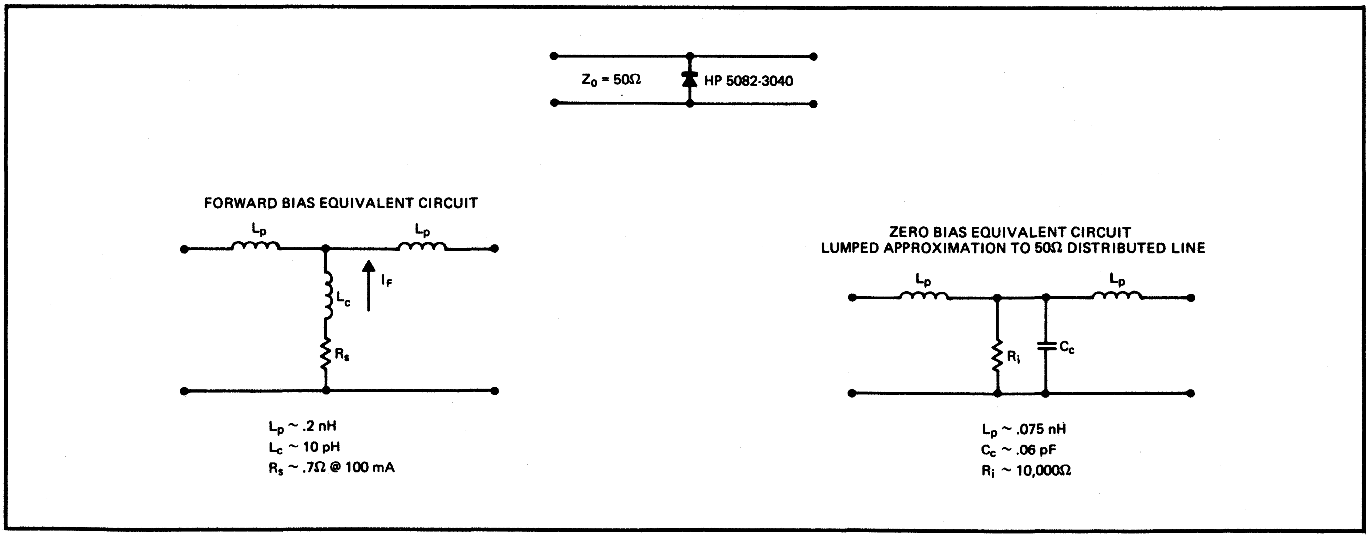


Figure 1. HP 5082-3040 forward and zero bias equivalent circuits.

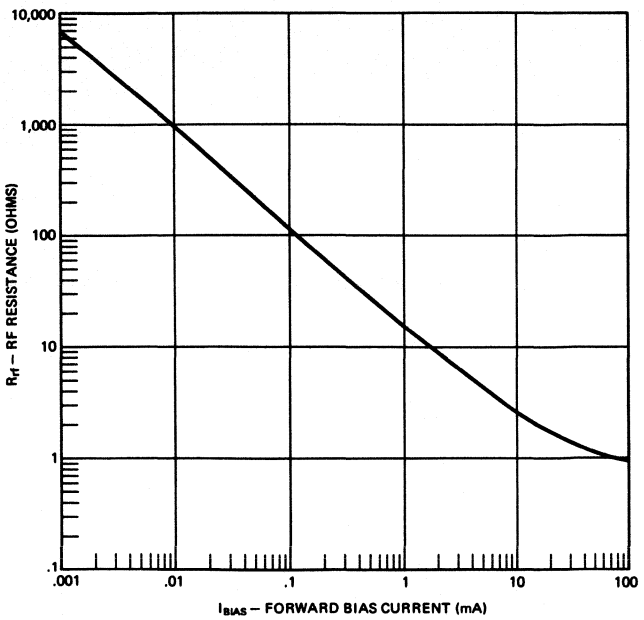


Figure 2. Typical HP 5082-3040 series resistance versus bias current at $T_A = 25°C$.

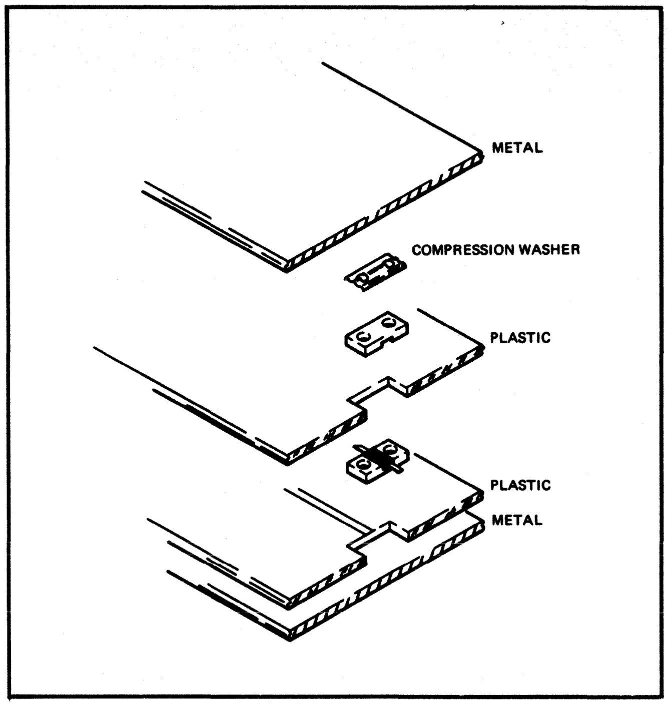


Figure 3. HP 5082-3040 suggested stripline assembly technique. Application Note 922 contains further details.

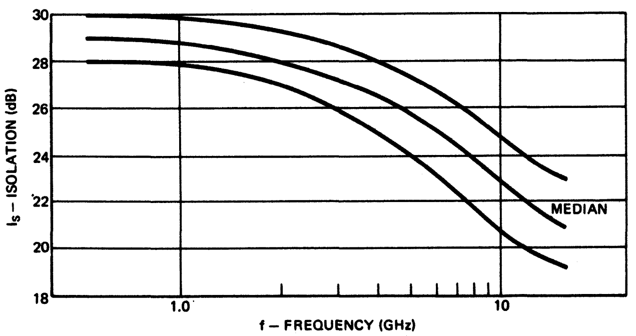


Figure 4. HP 5082-3040 isolation versus frequency at $T_A = 25°C$ and 100 mA bias current.

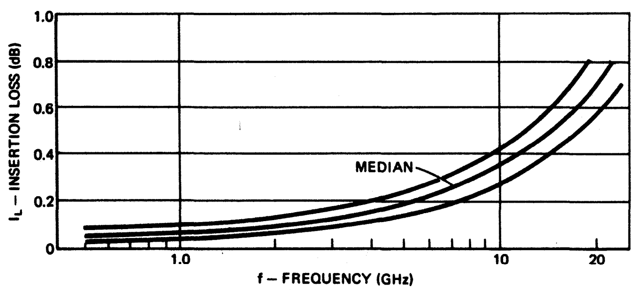


Figure 5. HP 5082-3040 insertion loss versus frequency at $T_A = 25°C$ and zero bias.

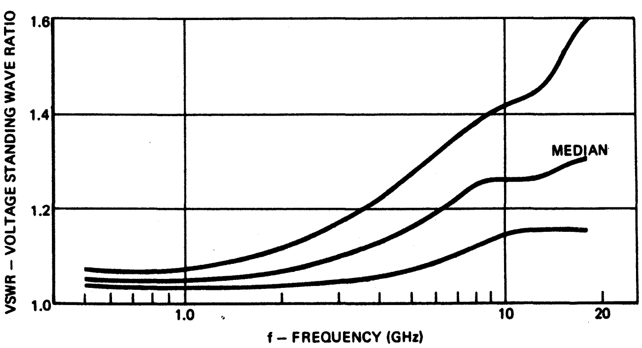


Figure 6. HP 5082-3040 VSWR versus frequency at $T_A = 25°C$ and zero bias.

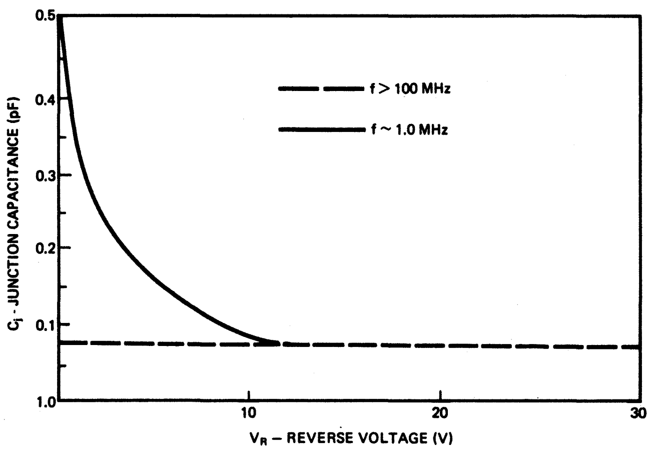


Figure 7. Typical HP 5082-3040 junction capacitance versus reverse bias voltage at $T_A = 25°C$.

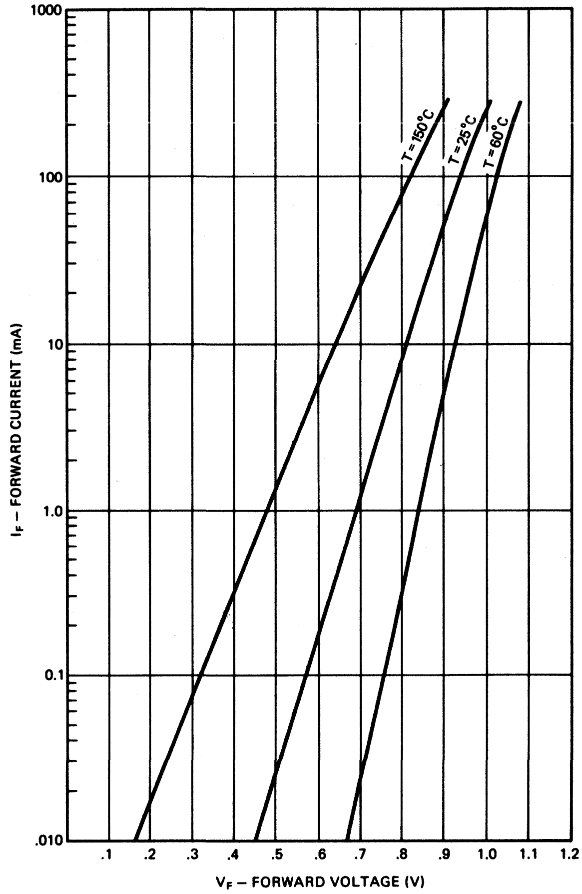


Figure 8. Typical HP 5082-3040 forward conduction characteristics.

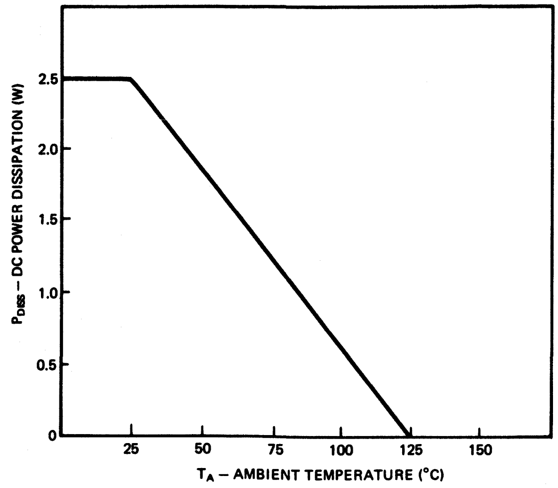


Figure 9. HP 5082-3040 dc power dissipation characteristics.

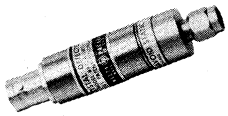
microwave components

HEWLETT PACKARD

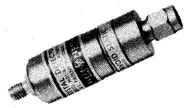
COAXIAL DETECTORS

models 8472A H01-8472A

• ECONOMICAL • FLAT RESPONSE • HIGH SENSITIVITY • LOW SWR



8472A



H01-8472A

These HP detectors are designed to optimize output resistance and capacitance. This feature gives the detectors extremely good pulse detection characteristics when working into low-capacitance, low-resistance loads; when loaded with 50 ohms, pulse rise time is in the nanosecond region. The detectors can be used for peak power measurements, video-modulated signals, microwave power leveling, and as detectors in reflectometers.

Although the flat frequency response of these detectors eliminates the need for matched pairs of detectors in most applications, selected detector pairs are available with extremely well-matched frequency response characteristics for exacting measurements. Flat response and low SWR make these detectors valuable as detecting elements in closed-loop leveling systems. Variations in leveled output power are reduced below the frequency response parameters found in most directional couplers. As a result, the degree of leveling in a swept system is dependent only on coupler flatness.

In reflectometer applications, both flat frequency response and square-law characteristics are important. To provide optimum square-law operation over at least a 30-dB range, these detectors can be equipped with external load resistors.

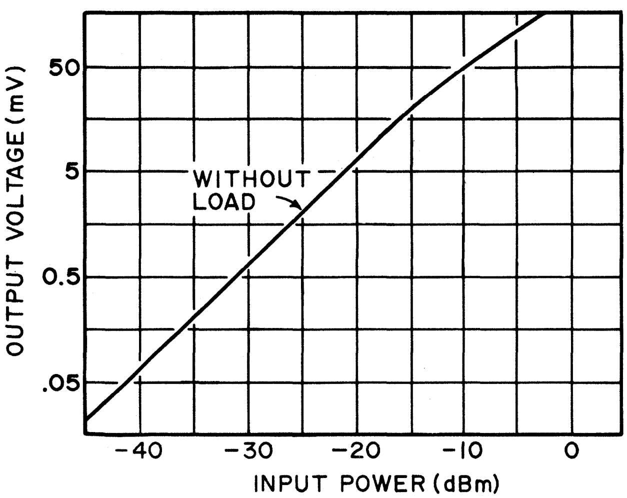


Figure 1. Typical square-law response of HP Model 8472A. Loading decreases sensitivity slightly but increases the square-law response power range.

SPECIFICATIONS	8472A, H01-8472A	
FREQUENCY RANGE[1]	10 MHz to 18 GHz	
FREQUENCY RESPONSE[2]	±0.2 dB/octave (100 MHz to 8 GHz), ±0.5 dB to 12.4 GHz, ±1.0 dB overall	
INPUT IMPEDANCE	50 Ω	
REFLECTION COEFFICIENT	**10 MHz to 4.5 GHz:** 0.091 (1.2 SWR, 20.8 dB Return Loss) **4.5 to 7 GHz:** 0.15 (1.35 SWR, 16.5 dB Return Loss) **7 to 12.4 GHz:** 0.2 (1.5 SWR, 14 dB Return Loss) **12.4 to 18 GHz:** 0.26 (1.7 SWR, 11.7 dB Return Loss)	
OUTPUT IMPEDANCE	15 kΩ max; 10 pF shunt	
MAXIMUM INPUT (Peak or Average)	100 mW	
SENSITIVITY[3] **(Measured at 25°C)**	**High Level:** (<0.35 mW produces 100 mV output) **Low Level (CW):** (>0.4 mV/μW)	
SQUARE-LAW CHARACTERISTIC	See Figure 1	
NOISE	<200 μV p-p with CW power applied to produce 100 mV output	
OUTPUT POLARITY	Negative	
INPUT CONNECTOR	Type OSM Male	
	8472A	**H01-8472A**
OUTPUT CONNECTOR	Type BNC Female	Type OSSM Female
DIMENSIONS: LENGTH DIAMETER	2½ in. (64 mm) 9⁄16 in. (14 mm)	2 1⁄16 in. (53 mm) 9⁄16 in. (14 mm)
WEIGHT: NET SHIPPING	1.5 oz (0,042 kg) 8 oz (0,22 kg)	1.25 oz (0,035 kg) 8 oz (0,22 kg)
PRICE	$175	$190

[1] Below 1 GHz, RF may leak through the output connector; leakage may be eliminated by using a low-pass filter.

[2] Read frequency response on a meter calibrated for square-law detectors, such as the HP 415E SWR Meter.

[3] Sensitivity decreases with increasing temperature, typically 0.015 dB/°C from 0°C to +50°C.

HEWLETT hp PACKARD

COAXIAL ATTENUATORS
DC-18 GHz

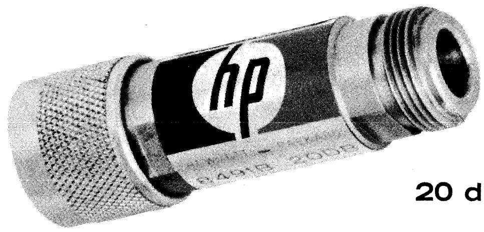
models
8491A/B
8492A

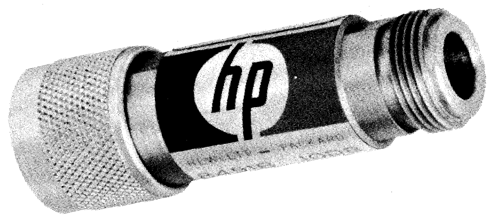
PRECISION ATTENUATORS – DC to 18 GHz

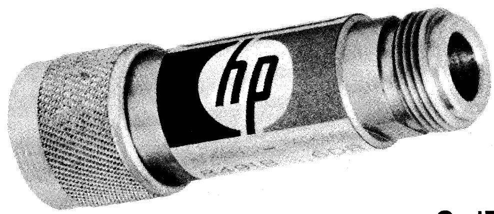
ACCURATE CALIBRATION – Traceable to NBS

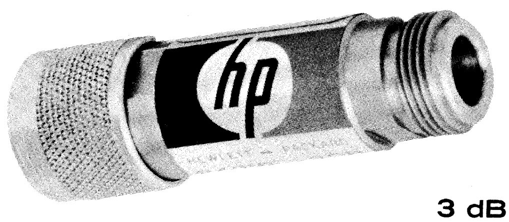
FLAT FREQUENCY RESPONSE
LOW VSWR
} Swept Frequency Tested

ECONOMICAL { $50 ea.—DC to 12.4 GHz
$65 ea.—DC to 18.0 GHz }


20 dB


10 dB


6 dB


3 dB

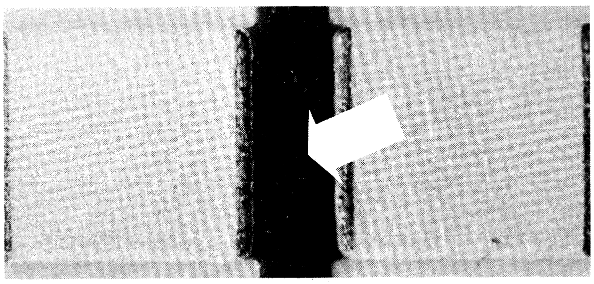
PERFORMANCE AT LOW COST

Hewlett-Packard fixed coaxial and step attenuators provide precision attenuation, flat frequency response, and low VSWR over a frequency range of dc to 18 GHz at low prices. Attenuators are furnished in 3, 6, 10, 20, and 30 dB nominal attenuations by the appropriate option number (e.g., 8492A, Op. 10, is a 10-dB attenuator). Other attenuation values of 40, 50, and 60 dB up to 12.4 GHz are available on request.

In addition to being used for accurate RF substitution measurements of attenuation or return loss, their low price makes these units useful in many other applications. Attenuators are used as isolators to reduce VSWR in order to improve attenuation measurement accuracy, to extend the range of sensitive power meters for higher power measurements, and to reduce power level to sensitive components and instrumentation systems.

HIGH QUALITY THIN FILM ATTENUATOR

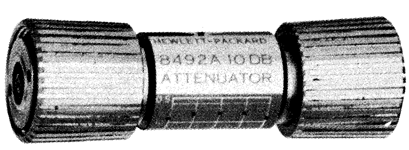
Semi-automated thin film deposition techniques in manufacturing result in a precisely controlled process for depositing the resistive film on the attenuator card base. Uniformity and repeatability of the process result in a high volume yield that requires no hand touch-up of the attenuator to meet specifications. Economies of large scale production with automated equipment allow precision attenuators to be offered at a "pad" price.



Arrow points to resistive film on attenuator using thin film deposition technique. Uniform manufacturing process results in high quality and performance.

LOW-WEAR STAINLESS STEEL CONNECTORS

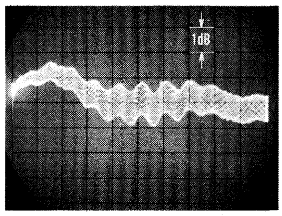
The 8491A/B attenuators are furnished with Type N connectors whose dimensions are compatible with either Mil-C-71 or Mil-C-39012 connector specifications. These connectors are stainless steel for low wear and repeatability. The Model 8492A is furnished with Amphenol precision 7mm connectors (APC-7). These connectors have a sexless mating plane that provides a clearly defined reference plane for precise and unambiguous measurements. The connector requires no adapters since any connector will mate with any other.



SWEPT FREQUENCY TESTED

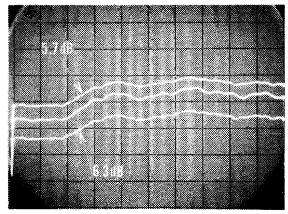
Each HP attenuator is swept frequency tested. Swept frequency VSWR testing with an 18 GHz slotted line ensures that the attenuator meets specifications at all frequencies in the specified range. Spot frequency testing can easily overlook narrow "resonances" in the band.

In addition, attenuation is also swept tested to eliminate the possibility of spot frequency resonances. Frequency response of the HP attenuators is flat over wide frequency ranges. A typical response curve of attenuation, as shown in the accompanying figure, indicates excellent flatness across the specified range of the attenuator.



8.0 FREQ. (GHz) 12.4

Swept SWR of 8491A—20-dB Attenuator taken with HP 817A Swept Slotted Line system from 8.0 to 12.4 GHz. Vertical scale = 1 dB/cm where SWR = $\log^{-1}$ (dB/20). Maximum SWR of 1.16 is well below SWR specification of 1.3.



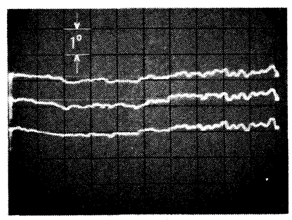
8.0 FREQ. (GHz) 12.4

Center trace shows swept attenuation of 8491A—6-dB Attenuator from 8.0 to 12.4 GHz. Top and bottom traces are 5.7 and 6.3 dB calibrations, respectively. Attenuation response is well within ± 0.3 dB over X-band.

LINEAR PHASE RESPONSE

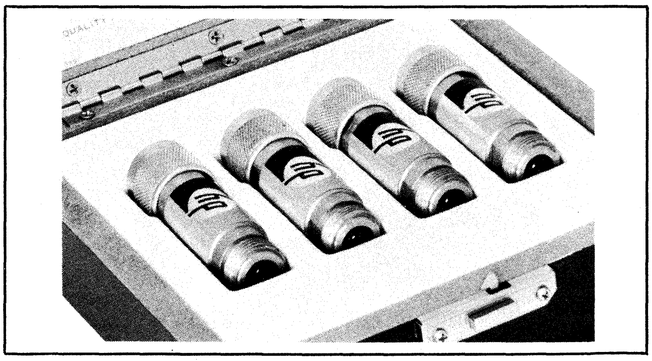
Phase linearity of the HP attenuators is excellent. For applications requiring low distortion of pulses, not only is wide bandwidth desirable but, also, linear phase shift (constant group delay) is an important parameter.

The 8491A/B and 8492A Attenuators offer outstanding phase performance as shown in the accompanying photograph. The linear component of phase shift over the frequency range due to its excess electrical length has been compensated with a line stretcher. The vertical scale represents the nonlinear phase shift characteristics of the component.



1.0 FREQ. (GHz) 2.0

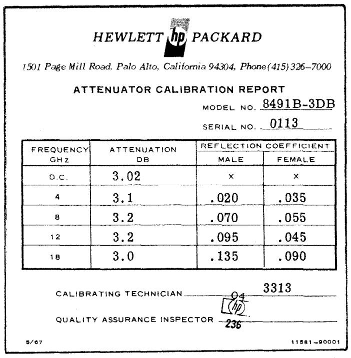
Center trace is phase response of 8491A—6-dB Attenuator from 1.0 to 2.0 GHz taken with HP 8410 Network Analyzer. Top and bottom traces are ± 1° calibration. Linear phase component has been equalized with line stretcher. Response, therefore, shows nonlinear phase deviation of < ± 1/2° over 1-2 GHz band.



ATTENUATOR SET

A set of four HP attenuators, 3, 6, 10, and 20 dB, are furnished in a handsome walnut accessory case. In addition to protecting the units when not being used, the case is also a convenient storage place for the attenuator calibration reports provided with the set of four attenuators. These calibration reports include the accuracy of the measurement and are certified traceable to the National Bureau of Standards.

Attenuation calibrations are stamped on the attenuators at dc, 4, 8, and 12 GHz for the 8491A and at dc, 4, 8, 12, and 18 GHz for the 8491B and 8492A. In addition, the calibration report includes both the attenuation and the reflection coefficient at each port of the attenuator at these frequencies. Calibrations at other frequencies are available on request.


HEWLETT PACKARD
1501 Page Mill Road, Palo Alto, California 94304, Phone (415) 326-7000
ATTENUATOR CALIBRATION REPORT
MODEL NO. 8491B-3DB
SERIAL NO. 0113

FREQUENCY GHz	ATTENUATION DB	REFLECTION COEFFICIENT MALE	REFLECTION COEFFICIENT FEMALE
D.C.	3.02	x	x
4	3.1	.020	.035
8	3.2	.070	.055
12	3.2	.095	.045
18	3.0	.135	.090

CALIBRATING TECHNICIAN 3313
QUALITY ASSURANCE INSPECTOR 236
9/67 11581-90001

SPECIFICATIONS

ACCURACY OF INSERTION LOSS MEASUREMENTS (s_{21}, s_{12}):

DC	± 0.01 dB
0-20 dB	
4-12 GHz	± 0.062 dB
18 GHz	± 0.097 dB
Above 20 dB	± 1% of Attenuation

ACCURACY OF REFLECTION COEFFICIENT MEASUREMENTS (s_{11}, s_{22}):

4-12 GHz	$\Delta \Gamma_L \leq \pm (0.036 + 0.03\ \Gamma_L + 0.045\ \Gamma_L^2)$
12-18 GHz	$\Delta \Gamma_L \leq \pm (0.046 + 0.03\ \Gamma_L + 0.055\ \Gamma_L^2)$

PRICES

Attenuator Set

11581A	(for 8491A)	Includes 3, 6, 10, 20 dB values	$225
11582A	(for 8491B)	Includes 3, 6, 10, 20 dB values	285
11583A	(for 8492A)	Includes 3, 6, 10, 20 dB values	525

SPECIFICATIONS

Frequency Range	8491A DC to 12.4 GHz		8491B DC to 18.0 GHz			8492A DC to 18.0 GHz		
Attenuation Accuracy	DC-12.4		DC-12.4	12.4-18		DC-12.4	12.4-18	
3 dB	± 0.3 dB		± 0.3 dB			± 0.3 dB		
6 dB	± 0.3 dB		± 0.3 dB	± 0.4 dB		± 0.3 dB	± 0.4 dB	
10 dB	± 0.5 dB		± 0.5 dB			± 0.5 dB		
20 dB	± 0.5 dB		± 0.5 dB	± 1 dB		± 0.5 dB	± 1 dB	
30 dB	± 1 dB		± 1 dB			± 1 dB		
SWR	DC-8	8-12.4	DC-8	8-12.4	12.4-18	DC-8	8-12.4	12.4-18
3 dB	1.25	1.35	1.25	1.35	1.5	1.2	1.3	1.5
6 dB						1.2	1.3	1.35
6 dB, 10 dB, 20 dB, 30 dB	1.2	1.3	1.2	1.3	1.5			
10 dB, 20 dB, 30 dB						1.15	1.25	1.3
Calibration Frequencies	DC, 4, 8, 12 GHz		DC, 4, 8, 12, 18 GHz			DC, 4, 8, 12, 18 GHz		
Maximum Input Power	2 W avg, 100 W pk		2 W avg, 100 W pk			2 W avg, 100 W pk		
Connectors (50Ω)	Type N*		Type N*			APC-7**		
Dimensions: in. / mm	2 7/16 x 13/16 diam 62 x 21		2 7/16 x 13/16 diam 62 x 21			2 3/4 x 13/16 diam 70 x 21		
Weight: Net / Shipping	3½ oz (100 g) 8 oz (220 g)		3½ oz (100 g) 8 oz (220 g)			3¼ oz (90 g) 8 oz (220 g)		
Price (specify option) Option 03—3 dB nom. attenuation 06—6 dB nom. attenuation 10—10 dB nom. attenuation 20—20 dB nom. attenuation 30—30 dB nom. attenuation	$50.00 ea.		$65.00 ea.			$125.00 ea.		

40, 50, and 60 dB attenuator values available on request.

* Mate with Mil-C-71 or Mil-C-39012 connectors. ** Amphenol RF Division, Danbury, Connecticut.

HEWLETT hp PACKARD

COAXIAL ATTENUATOR

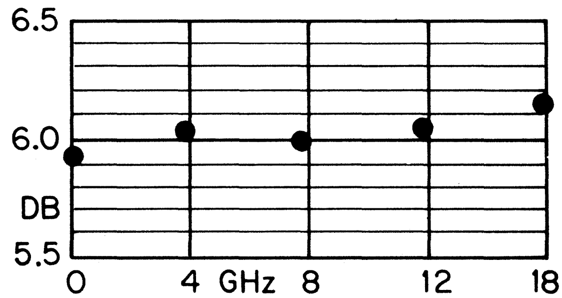
model 8493A/B

- **PRECISION ATTENUATORS**
  Dc to 12.4 and 18 GHz
- **ACCURATE CALIBRATION**
  Traceable to NBS
- **FLAT FREQUENCY RESPONSE LOW SWR**
  Swept Tested
- **SMALL, LIGHTWEIGHT**
  Miniature Connectors
- **ECONOMICAL**
  $60 ea.—Dc to 12.4 GHz
  $75 ea.—Dc to 18 GHz

8493A/B

Calibration graph provided on each nameplate

8493B



Description

The 8493A and 8493B are the latest additions to the Hewlett-Packard line of low-cost precision coaxial attenuators. Fitted with OSM®-type connectors, these small, lightweight attenuators are expressly for use in miniature coaxial systems, where size and weight are often critical.

The 8493A and 8493B operate over frequency ranges of 0 to 12.4 and 18 GHz respectively, and are available with nominal attenuation values of 3, 6, 10, and 20 dB. Actual attenuation values at 0, 4, 8, 12, and 18 GHz are indicated on a calibration chart right on the attenuator nameplate. These attenuators also feature flat frequency response and low SWR, important parameters in precision broadband measurements.

®Omni Spectra Inc.

High Quality Thin Film Attenuator

The high quality and low cost of these attenuators result from semi-automated thin film deposition techniques used in the manufacturing process. This is a precisely controlled process for depositing the resistive film on the attenuator card base (see Figure 1). Uniformity and repeatability of the process assure a high-volume yield requiring no hand touch-up. Thus these precision attenuators are available at a "pad" price.

Swept-Frequency Tested

Each 8493A and 8493B is swept-frequency tested for frequency response and swr over critical parts of the band. These tests insure that the attenuators operate properly at all frequencies in the specified range. In addition to flat response and low swr, these attenuators have excellent phase linearity (constant group delay). This characteristic makes them extremely well suited for pulse applications in which pulse distortion is critical.

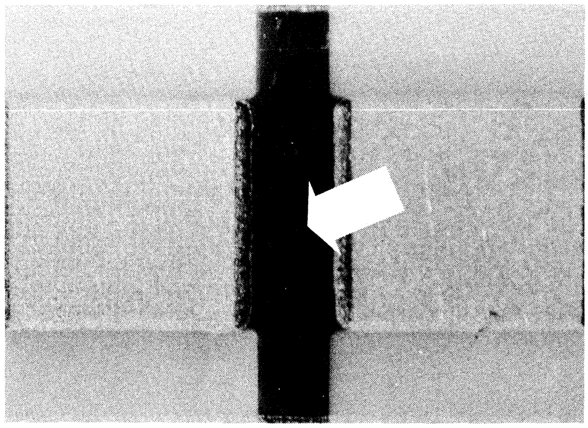


Figure 1. Arrow points to resistive film on attenuator using thin film deposition technique. Uniform manufacturing process results in high quality and performance.

SPECIFICATIONS

	8493A		**8493B**		
Frequency Range	**DC to 12.4 GHz**		**DC to 18.0 GHz**		
Attenuation Accuracy	DC-8	8-12.4	DC-12.4	12.4-18	
3 dB	± 0.3 dB		± 0.3 dB		
6 dB	± 0.3 dB		± 0.3 dB	± 0.4 dB	
10 dB	± 0.5 dB		± 0.5 dB		
20 dB	± 0.5 dB		± 0.5 dB	± 1 dB	
SWR	DC-8	8-12.4	DC-8	8-12.4	12.4-18
3 dB	1.25	1.35	1.25	1.35	1.5
6 dB 10 dB 20 dB	1.2	1.3	1.2	1.3	1.5
Calibration Frequencies	DC, 4, 8, 12 GHz		DC, 4, 8, 12, 18 GHz		
Maximum Input Power	2 W avg, 100 W pk		2 W avg, 100 W pk		
Connectors (50Ω)	OSM-type, one male, one female		OSM-type, one male, one female		
Dimensions	1¼″ long, ½″ dia. 38 x 13 mm		1¼″ long, ½″ dia. 38 x 13 mm		
Weight	Net, 0.6 oz. (20 g) Shipping, 3 oz. (60 g)		Net, 0.6 oz. (20 g) Shipping, 3 oz. (60 g)		
Price (specify option) Option 03—3 dB nom. attenuation 06—6 dB nom. attenuation 10—10 dB nom. attenuation 20—20 dB nom. attenuation	$60.00 ea.		$75.00 ea.		

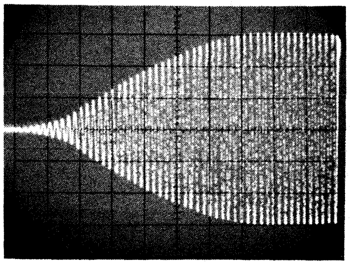
HEWLETT PACKARD

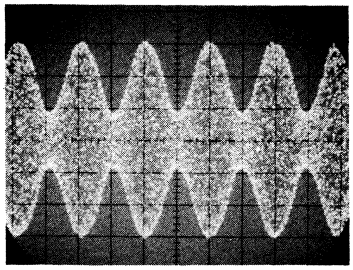
PIN MODULATORS 8730 series

SINUSOIDAL AND COMPLEX AM WITHOUT INCIDENTAL FM

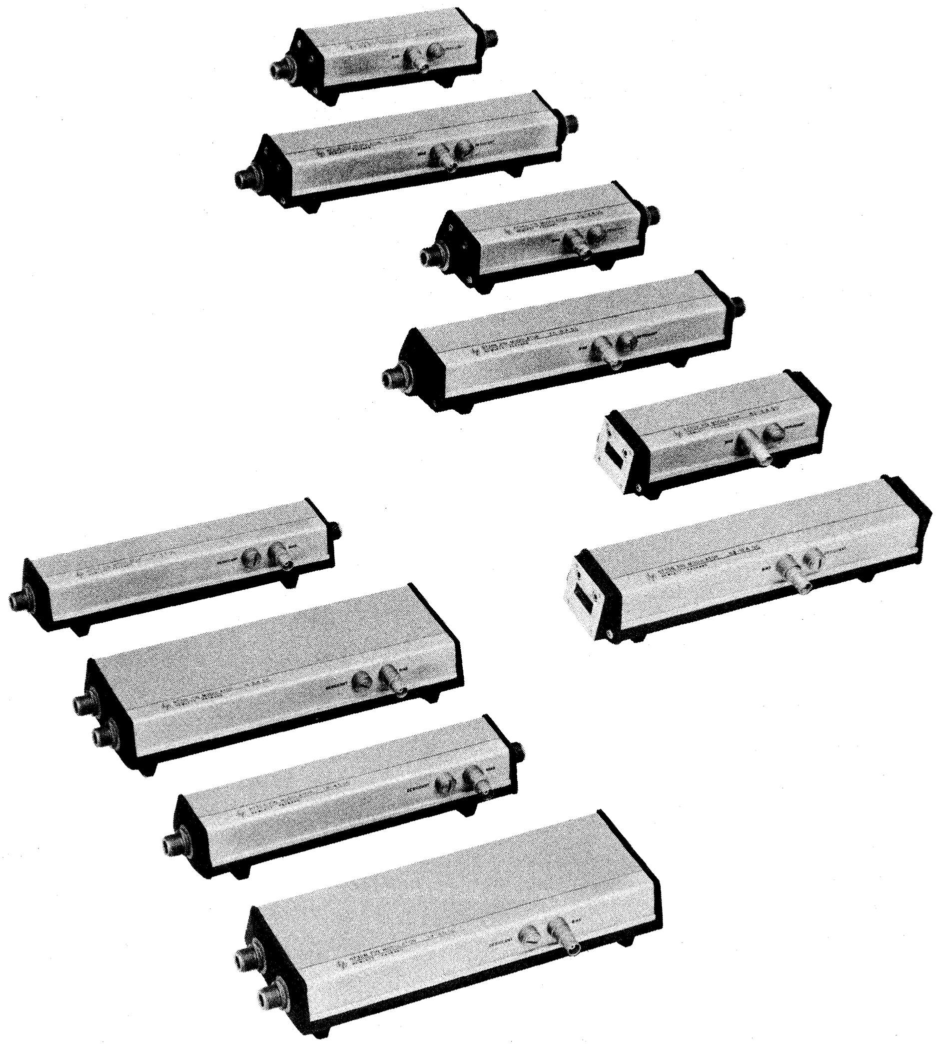
RF PULSING, <30 NSEC RISE TIME AND 80 db ON/OFF RATIO

CONSTANT INPUT, OUTPUT MATCH


30 nsec rise time
(4 nsec/cm)


low-distortion AM


closed-loop power leveling
(leveled and unleveled
sweeps, 1-2 Gc)



PIN DIODE MODULATORS

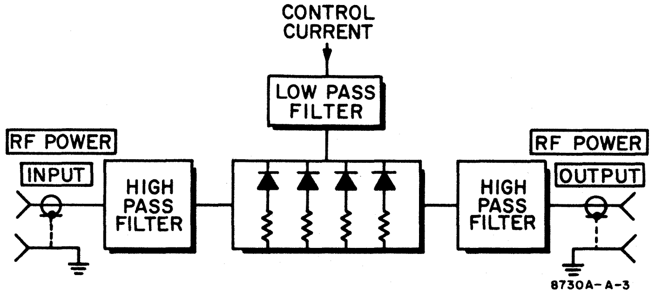
These versatile modulators permit microwave signal sources, including klystrons, to be pulse modulated, leveled, or amplitude modulated with sinusoidal or complex waveforms. Incidental FM is minimized because modulation is accomplished by absorption of RF power which results in a nearly constant impedance match between the modulator and either the source or the load as RF frequency is swept. The source thus operates continuously at its optimum output level, regardless of the type of amplitude modulation impressed on the signal. The absorption type of modulation avoids the bandwidth limitations imposed by high-Q RF output circuits and provides extremely fast rise times. The fast-rise capability makes the PIN modulator suitable for use as a signal gate or as a nonreflecting RF switch. Two or more PIN modulators can be placed in series and operated independently to provide multiple, complex modulation, and attenuation functions.

The 8730 PIN modulator series is available in coaxial configurations covering the range from 0.8 to 12.4 GHz in four overlapping bands. An X-band waveguide configuration is also available. Two models are available within each band: an "A" model providing at least 35 dB of attenuation, and a "B" model providing at least 80 dB.*

THE PIN DIODE

The PIN modulator is a current-controlled absorption attenuator consisting of a number of PIN diodes mounted as shunt elements across a transmission line. At signal frequencies above 100 MHz, diode current remains quite constant throughout the signal cycle and the diode presents an essentially constant impedance to the signal, even if the diode is reverse biased during an appreciable portion of the cycle. A block diagram of a typical modulator is shown below.

* A special configuration, H10-8731B, covers 400 to 900 MHz and 35 dB attenuation range.



Simplified Block Diagram of PIN Modulator

SPECIFICATIONS

Model	Frequency Range (GHz)	Dynamic Range (dB)	Max. Residual Attenuation (dB)[1]	Typical Rise Time (nsec)[3]	Typical Decay Time (nsec)[3]	SWR, Min. Atten.	SWR, Max. Atten.	Fwd. Bias Input Res. (ohms)	RF Conn. Type	Price
8731A	0.8 - 2.4	35	1.5	40	30	1.5	1.8	300	N	$300.00
8731B	0.8 - 2.4	80	2.0	30	20	1.6	2.0	100	N	525.00
8732A	1.8 - 4.5	35	2.0	40	30	1.5	1.8	300	N	300.00
8732B	1.8 - 4.5	80	3.5[2]	30	20	1.6[4]	2.0	100	N	525.00
8733A	3.7 - 8.3	35	2.0	30	20	1.8	2.0	300	N	325.00
8733B	3.7 - 8.3	80	3.0	30	20	2.0	2.2	100	N	550.00
8734A	7.0 - 12.4	35	4.0	30	20	1.8	2.0	300	N	350.00
8734B	7.0 - 12.4	80	5.0	30	20	2.0	2.2	100	N	575.00
8735A	8.2 - 12.4	35	4.0	30	20	1.7	2.0	300	Wg[5]	350.00
8735B	8.2 - 12.4	80	5.0	30	20	2.0	2.2	100	Wg[5]	575.00
H10-8731B[6]	0.4 - 0.9	35	2.0	40	30	1.25[7]	1.5[7]	300	N	525.00

Maximum Ratings: Maximum input power, peak or CW: 1 watt; bias limits: +20 V, −10 V.

Bias Polarity: Negative voltage increases attenuation.

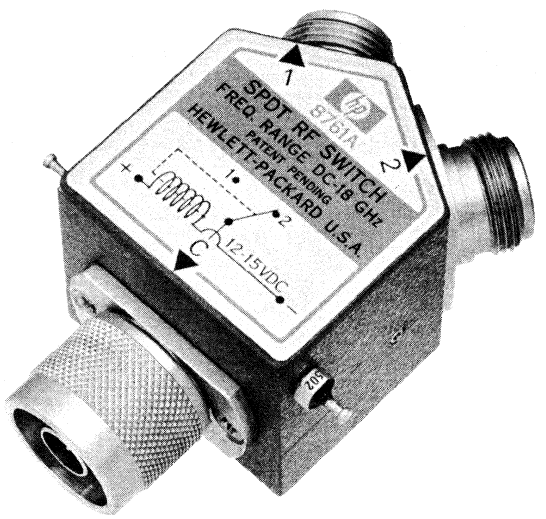
RFI: Radiated leakage limits are below those specified in MIL-I-6181D at input levels less than 1 mW. At all input levels radiated interference is sufficiently low to obtain rated attenuation.

[1] With +5 V bias.
[2] <3.5 dB, 1.8 to 4 GHz; <4 dB, 4 to 4.5 GHz.
[3] Driven by HP Model 8403A Modulator.
[4] 1.6 SWR, 1.8 to 4 GHz; 2.0 SWR, 4 to 4.5 GHz.
[5] Fits 1 x ½ in. (WR 90) waveguide.
[6] External high-pass filters required.
[7] Excluding high-pass filters.

HEWLETT PACKARD

COAXIAL SWITCH
DC to 18 GHz

model
8761



- SINGLE-POLE, DOUBLE-THROW
- BROADBAND
- LOW INSERTION LOSS
- LOW VSWR
- 12- OR 26-VOLT SWITCHING
- MAGNETIC LATCHING
- CHOOSE FROM 7 CONNECTOR TYPES
- AVAILABLE WITH BUILT-ON TERMINATION
- CONVENIENT CONNECTOR CONFIGURATION

DESCRIPTION

The HP 8761 is a single-pole, double-throw coaxial switch with excellent electrical and mechanical characteristics for 50Ω transmission systems operating from dc to 18 GHz. Each switch is fully tested to ensure low standing-wave ratio, low insertion loss, and good isolation over an extremely broad frequency range. In addition, the 8761 is small and light, making it ideal for applications where space is limited. It is easily panel-mounted with a single connector available for input/output. In more complex switching arrangements, standard connector options allow one 8761 to work directly into two others, eliminating interconnecting cables and connector pairs to minimize combined VSWR. For systems applications, a connector compatible with semirigid coax is available to provide low VSWR with little connector bulk.

Type: Single-pole, double-throw, break-before-make.
Characteristic Impedance: 50 Ω
Standing-wave Ratio: Looking into one of the connected ports with 50 Ω on the other; third port open.*

8761

Frequency	Connector Type		
	7-mm	N	3-mm
DC - 12.4 GHz	<1.15	<1.20	<1.25
DC - 18 GHz	<1.20	<1.25	<1.30

Looking into one of the connected ports with the built-on termination on the other; third port open.*

8761 with built-on termination

Frequency	Connector Type		
	7-mm	N	3-mm
DC - 12.4 GHz	<1.20	<1.25	<1.30
DC - 18 GHz	<1.25	<1.30	<1.35

* These specifications apply when connected ports are of the same connector type; for mixed connector types, the larger of the two VSWR's applies. N-connector VSWR specifications apply to Option 4 connectors.

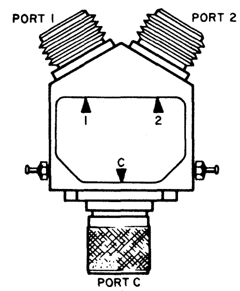
Insertion Loss:
DC - 12.4 GHz: <0.5 dB
DC - 18.0 GHz: <0.8 dB
Isolation:
DC - 12.4 GHz: >50 dB
DC - 18.0 GHz: >45 dB.
Power: Safely handles 10 W average, 5 kW peak without built-on termination; built-on termination rated at 2 W average, 100 W peak.
Switching Energy: 1.5 W for 20 ms (permanent magnet latching).
Solenoid Voltages (dc or pulsed):
8761A: 12 - 15 V
8761B: 24 - 30 V
Switching Speed: 35 - 50 ms (includes settling time).
Life: >1,000,000 switchings.
Dimensions: 1.6 x 1.5 x 1.5 in. (41 x 38 x 38 mm), excluding connectors and solenoid terminals.
Weight: Net, 5-8 oz (140-220 g). Shipping, 8-11 oz (220-300 g).
Price: Model 8761, $150 each, 1-9; $140 each, 10-24.
Model 8761 with built-on termination on any one port, add $35 each.
Prices on request for larger quantities.

Ordering Information

Specify solenoid voltage and connectors (including built-on 50 Ω termination) by the alphabetic suffix on the switch model number and the appropriate three-digit option number.

Option Code	Connector Type
0	N Jack*
1	N Plug
2	7-mm Jack
3	7-mm Plug
4	7-mm for UT-250 Coax
5	3-mm Jack
6	3-mm Plug
7	50 Ω Termination

* "Jack" identifies the connector with fixed threads; "plug" identifies the connector with the coupling nut.



PORT 1 PORT 2 PORT C

8761A OPTION 001

DENOTES SOLENOID VOLTAGE
A: 12–15V
B: 24–30V

DENOTES CONNECTOR CONFIGURATION
(SEE TABLE)

Connectors

Type N
The precision Type N connector dimensions conform to MIL-C-39012.

Precision 7-mm
Two versions of the precision 7-mm connectors available on the 8761 mate with the APC-7* connector, but differ slightly from the standard APC-7 to conserve space. One of these versions has a fixed threaded sleeve (7-mm jack) and the other has a coupling nut (7-mm plug). When mated with each other, or with a standard APC-7, these connectors preserve the low reflection coefficient of the basic APC-7 connector.

The third precision 7-mm connector available on the 8761 is designed to use with a 0.250-inch outer diameter, semirigid coaxial cable. This connector is the same as the 7-mm jack connector described above, except that the center conductor is female and accepts the center conductor of the semirigid coax. This assembly permits compact connections to the 8761 and is ideal when coax interconnections are necessary and the overall VSWR must be kept to a minimum.

Miniature 3-mm
The 3-mm connectors mate with the popular OSM** series.

* Registered trademark: Amphenol RF Division, Danbury, Connecticut.
** Registered trademark: Omni Spectra, Inc., Detroit, Michigan.

HEWLETT hp PACKARD

PIN Absorptive Modulator

HP 33000A

HIGH POWER . . . 2 watts cw, 100 watts peak pulse
BROAD BANDWIDTH . . . 0.8 to 4.0 GHz
WIDE DYNAMIC RANGE . . . 1.7 to 40 dB
LOW VSWR . . . 1.9:1 at any attenuation
HYBRID INTEGRATED SOLID STATE

The HP 33000A combines hybrid integrated PIN diode switching modules, advanced design broadband hybrid couplers, low VSWR 50-ohm loads and broadband bias circuitry in a small size, rugged, absorptive modulator.

All active elements are hermetically sealed and all internal joints are welded or thermal compression bonded to assure high reliability under environmental stress.

APPLICATION

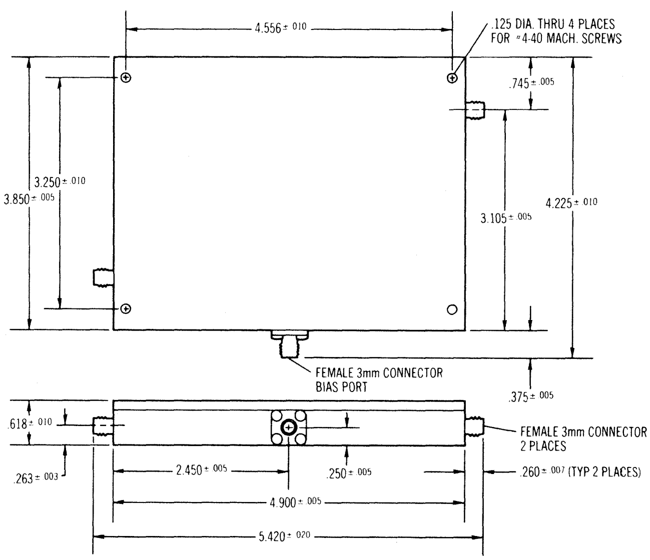
The HP 33000A is intended for use as a modulator, switch, or attenuator in those systems which employ load sensitive elements, such as reflex klystrons or backward wave oscillators, and where low standing wave conditions are required to maintain reasonable system accuracy. Typical applications are sweep generator leveling, receiver AGC, distance measuring systems, phased array radar systems and simulators.

ABSOLUTE MAXIMUM RATINGS

Maximum Incident RF Power
CW .... 2 watts
1 μs, 0.001 du Pulse .... 100 watts
Maximum Bias Current .... 200 mA
Maximum Bias Voltage .... − 1.0 volt to + 50 volts

MECHANICAL CHARACTERISTICS

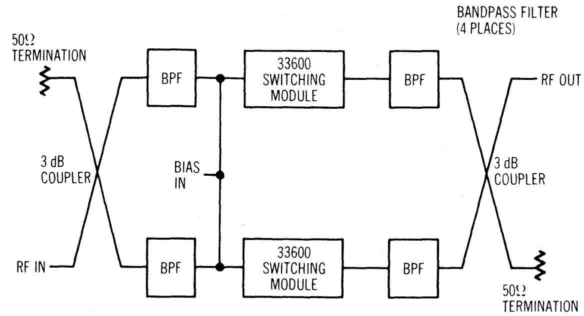
Size .... As shown in the outline drawings
Weight .... 1.12 pounds (0,51 kg)
Materials ..... Case, aluminum; connectors, stainless steel
Finish .... Case, gray paint—wrinkle finish. Connectors, gold plated—50 microinches ($1,27 \times 10^{-3}$ mm) minimum



Dimensions in inches

ENVIRONMENTAL RATINGS

Temperature, Storage .... − 65°C to + 95°C
Temperature, Operating .... − 55°C to + 95°C
Humidity (MIL-STD-202C) .... Method 106, 10 days, 25°C to 65°C, 95% RH
Shock (MIL-STD-202C) .... Method 213, condition C, 100g-6 ms duration, 5 blows each X_1, X_2, Y_1, Y_2, Z_1, Z_2. Non-operating.
Vibration Fatigue .... 60 Hz, 20g for 32 hours each, X, Y, and Z planes, 96 hours total. Non-operating.



Physically the HP 33000A Absorptive Modulator comprises HP 33602A PIN Diode Switching Modules, broadband couplers, loads, and bias circuit in a configuration as described above. PIN diodes have appreciable storage time and do not rectify signals above 100 MHz. However, when bias current is applied, the diodes conduct, and their resistance decreases. PIN diodes act as low and constant reactance variable resistors. As described in the data sheet for HP 33602A/33603A/33604A Switching Modules, these PIN diodes are mounted in shunt across the RF transmission line. Their resistance and degree of attenuation to an RF signal are functions of the bias current. In the HP 33000A configuration the PIN diodes direct RF signals into either a low VSWR 50 Ω load or into an RF port. The HP 33000A is symmetrical in performance and either RF port can be used for input or output with low VSWR at any attenuation level. Thus incidental FM and bandwidth limitations normally associated with other methods of amplitude modulation are avoided.

TYPICAL PERFORMANCE CHARACTERISTICS

Rise Time

When driven by a 50-volt pulse from an HP 214A Square Wave Generator from a 100 mA bias condition to a residual attenuation condition, the time to change from 10% of detected RF voltage to 90% of detected RF voltage is typically 40 nanoseconds. Other drive configurations are described in HP Application Note 914.

ELECTRICAL SPECIFICATIONS at $T_A = 25°C$

Usable Frequency Range 0.8 to 4.0 GHz.

Characteristic	Bias Condition	0.8 to 2.0 GHz Spec.	0.8 to 2.0 GHz Typical	2.0 to 4.0 GHz Spec.	2.0 to 4.0 GHz Typical	Units
Residual Attenuation	0 mA	1.7 max.	1	2.3 max.	1.5	dB
Dynamic Range	100 mA	35 min.	40	40 min.	45	dB
VSWR	0 mA	1.5 max.	1.3	1.7 max.	1.4	—
VSWR	0-100 mA	1.7 max.	1.5	1.9 max.	1.6	—

Video Leakage

In fast switching applications a portion of the high speed bias drive signal will leak into the RF transmission line and appear at the RF ports. For example, during rise time tests a triangular pulse of less than 5 mV amplitude and base width of 25 nanoseconds was measured with a 15 ns rise time 50-volt drive pulse.

RF Leakage

The level of RF signal appearing at the bias port is typically 40 dB below the level of signals applied to either RF port.

Noise, Harmonics, and Spurious Signals

Performance of the HP 33000A is set by the performance of the HP 33602A Modules. These units behave as thermal resistances shunted across the transmission line, and have an excess noise temperature of less than 20° Kelvin. Noise figure will therefore exceed the residual attenuation value by less than 0.2 dB for any bias level. Harmonic products generated internally are at least 40 dB below fundamental signal levels.

Attenuation

The HP 33000A exhibits no fine grain attenuation. Variation of attenuation with bias current, frequency, and temperature is shown by Figures 1, 2, and 3. During a twenty-day environmental test cycle the resettability of attenuation vs. bias current was found to be typically within 5% of the attenuation, measured in dB. Bias voltage polarity for increase of attenuation is negative.

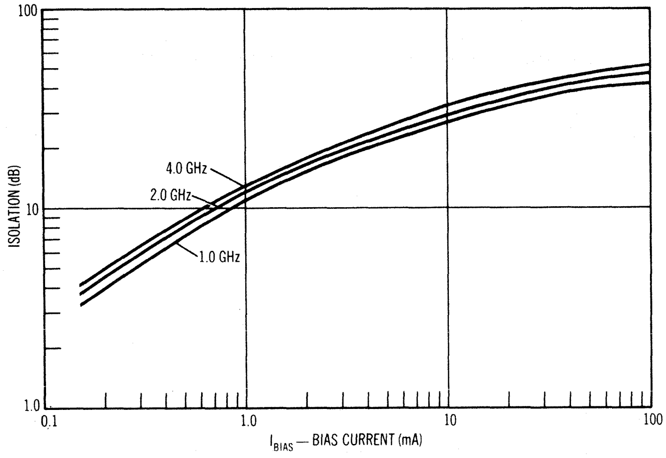


Figure 1. Isolation vs. bias current at various frequencies.

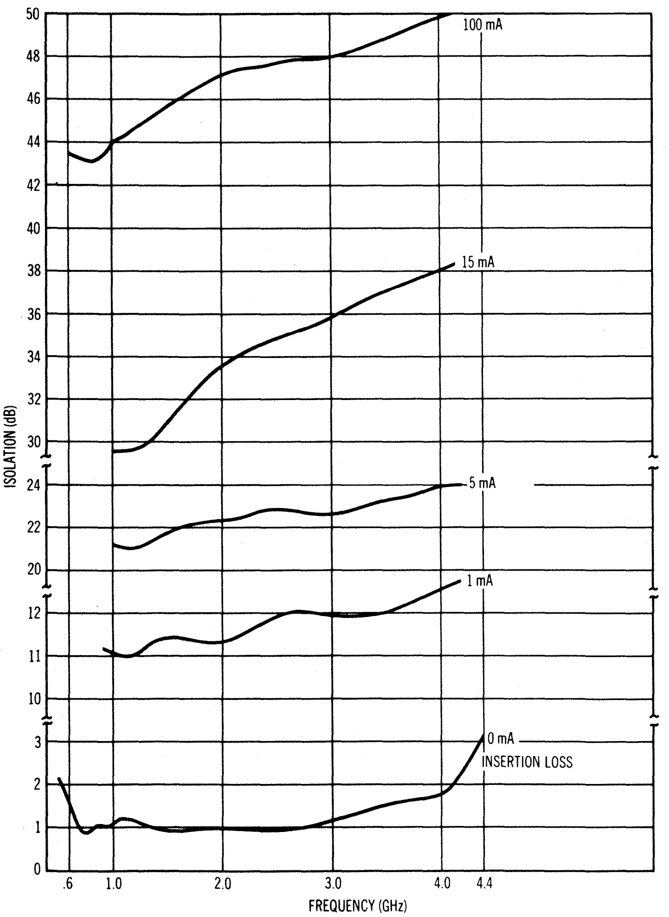


Figure 2. Isolation vs. frequency for various bias currents.

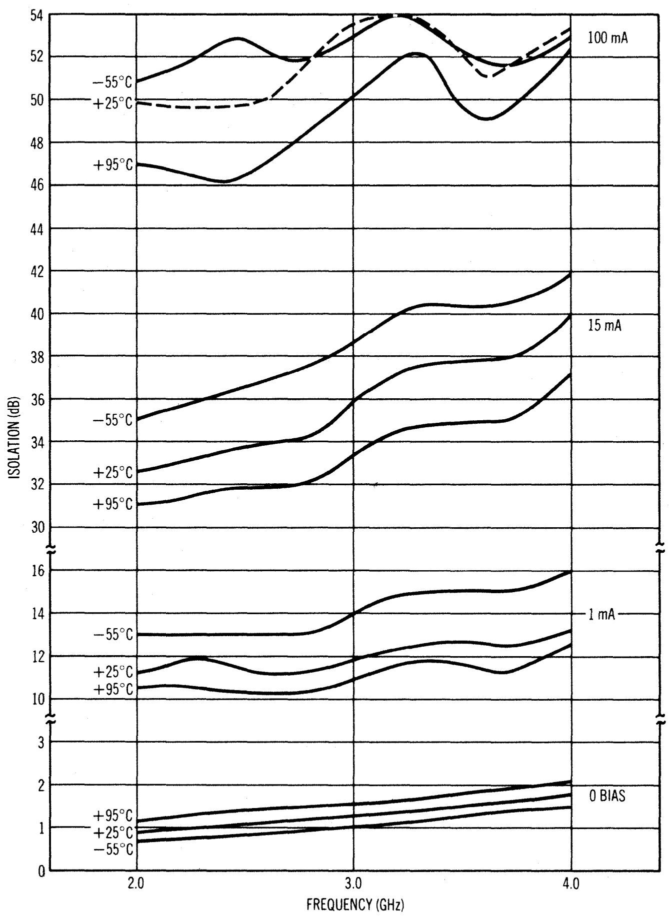


Figure 3. Isolation vs. frequency for various bias currents and temperatures.

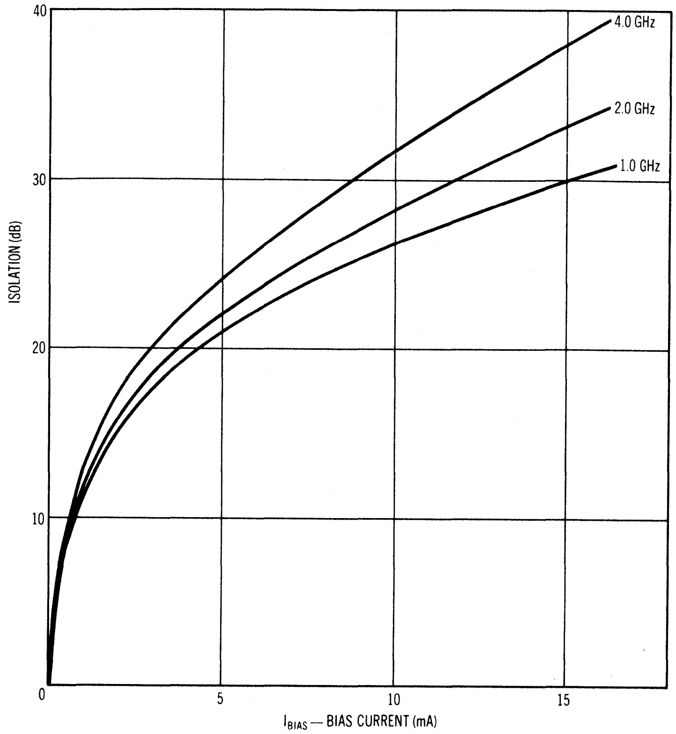


Figure 4. Isolation vs. bias current—linear plot.

VSWR and Phase Shift

Figures 5 and 6 show typical variation of VSWR and phase angle vs. frequency for various bias conditions. Phase shift from either RF port to the other is a constant 140° plus approximately 42 cm equivalent air equivalent length.

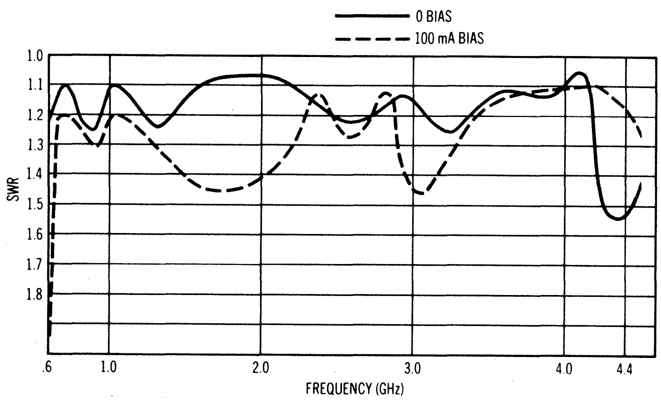


Figure 5. Typical VSWR vs. frequency for various bias conditions.

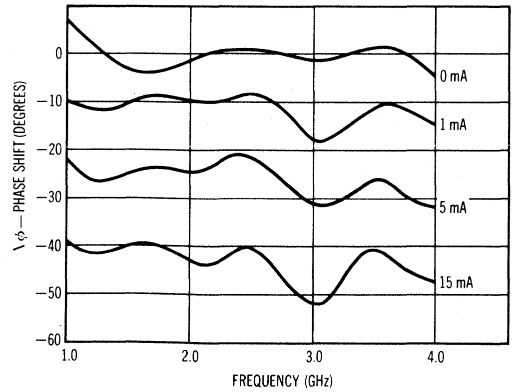


Figure 6. Typical phase shift (port-to-port) vs. frequency for various bias conditions.

Bias Port Impedance

Figure 7 shows the typical V-I curves measured at the bias port for forward bias voltage polarities. Further description of bias characteristics is available in data sheets for HP 33600A Switching Modules. Note: RF input ports are dc shorts with current handling capacity of 1 ampere.

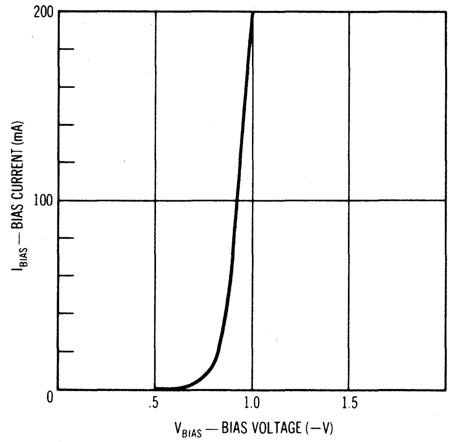


Figure 7. Bias port forward V-I characteristics.

POWER HANDLING DERATING

The derating curve of Figure 8 defines derating factors to be applied to pulse and cw incident power handling ratings to accommodate the effects of ambient temperature variation.

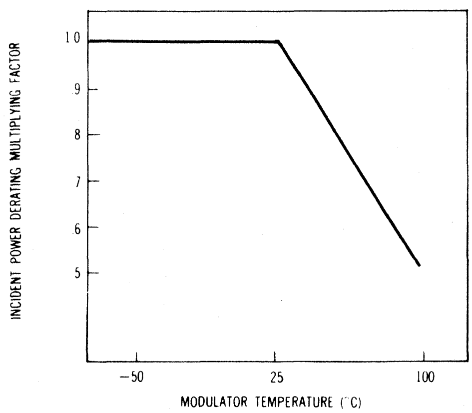


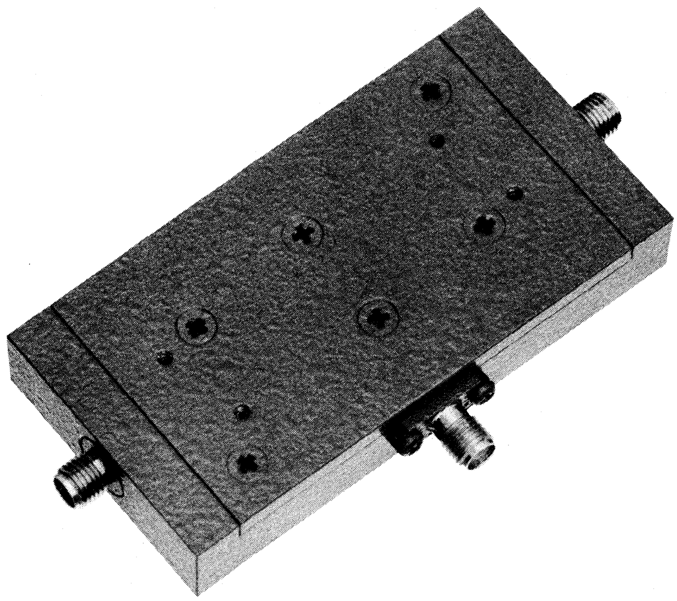
Figure 8. Power—temperature derating.

HEWLETT PACKARD

PIN Absorptive Modulator

HP 33001A

HIGH POWER . . . 2 watts cw, 100 watts peak pulse
BROAD BANDWIDTH . . . 8 to 18 GHz
WIDE DYNAMIC RANGE . . . 2.5 to 45 dB
LOW VSWR . . . 2.0:1 at any attenuation
SMALL SIZE



The HP 33001A combines hybrid integrated PIN diode switching modules, advanced design broadband hybrid couplers, low VSWR 50-ohm loads and broadband bias circuitry in a small size, rugged, absorptive modulator. . . .

All active elements are hermetically sealed and all internal joints are welded or thermal compression bonded to assure high reliability under environmental stress.

APPLICATION

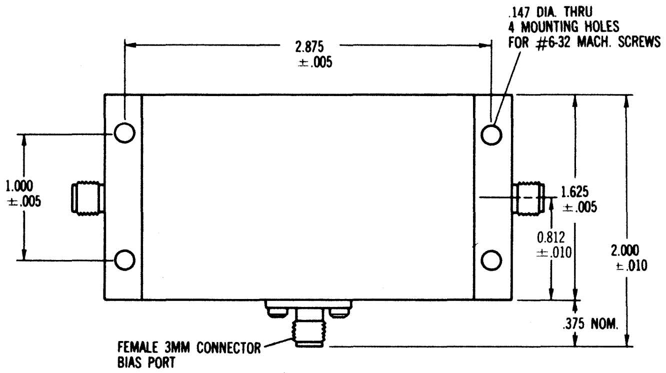
The HP 33001A is intended for use as a modulator, switch, or attenuator in those systems which employ load sensitive elements, such as reflex klystrons or backward wave oscillators, and where low standing wave conditions are required to maintain reasonable system accuracy. Typical applications are sweep generator leveling, receiver AGC, distance measuring systems, phased array radar systems and simulators.

ABSOLUTE MAXIMUM RATINGS

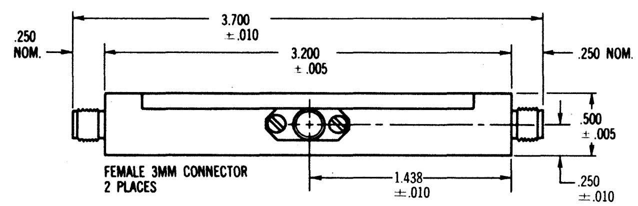
Maximum Incident RF Power
CW .... 2 watts
1 μs, 0.001 du Pulse (0-50 mA bias) .... 100 watts
(50-200 mA bias) .... 200 watts
Maximum Bias Current .... 200 mA
Maximum Bias Voltage .... − 1 volt to + 50 volts

MECHANICAL CHARACTERISTICS

Size .... As shown in the outline drawing
Weight .... 0.25 pound (0,11 kg)
Materials ...... Case, aluminum; connectors, stainless steel
Finish .... Case, gray paint—wrinkle finish. Connectors, gold plated—50 microinches ($1{,}27 \times 10^{-3}$ mm) minimum



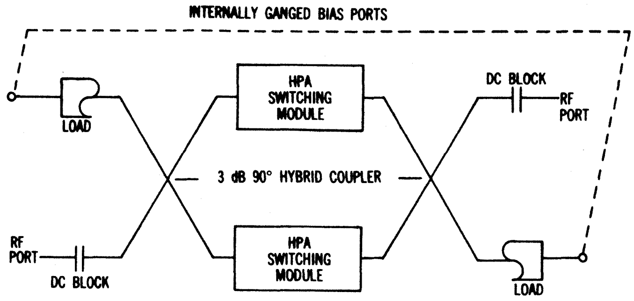
Dimensions in inches



ENVIRONMENTAL RATINGS

Temperature, Storage .... − 65°C to + 95°C
Temperature, Operating .... − 55°C to + 95°C
Temperature Cycling ...... Non-operating. MIL-T-5422E condition 25 cycles—60 minutes at extremes. No dwell.
Humidity .... Method 106, 10 days, 25°C to 65°C, 95% RF per MIL-STD-202C
Shock .... Method 213, condition A, 100g-6 ms duration, 5 blows each X_1, X_2, Y_1, Y_2, Z_1, Z_2, MIL-STD-202C. Non-operating.
Vibration Fatigue ...... Method 2046, 60 Hz, 20g for 96 hours, X, Y, and Z planes per MIL-STD-750A. Non-operating.

CIRCUIT DESCRIPTION



Physically the HP 33001A Absorptive Modulator, comprises HP 33602A PIN Diode Switching Modules, broadband couplers, loads, and bias circuit in a configuration as described above. PIN diodes have appreciable storage time and do not rectify signals above 100 MHz. However, when bias current is applied, the diodes conduct, and their resistance decreases. PIN diodes act as low and constant reactance variable resistors. As described in the data sheet for HP 33602A/33603A/33604A Switching Modules, these PIN diodes are mounted in shunt across the RF transmission line. Their resistance and degree of attenuation to an RF signal are functions of the bias current. In the HP 33001A configuration the PIN diodes direct RF signals into either a low VSWR 50 Ω load or into an RF port. The HP 33001A is symmetrical in performance and either RF port can be used for input or output with low VSWR at any attenuation level. Thus incidental FM and bandwidth limitations normally associated with other methods of amplitude modulation are avoided.

TYPICAL PERFORMANCE CHARACTERISTICS

Rise Time

When driven by a 10-volt pulse from an HP 214A Square Wave Generator from a 50 mA bias condition to a residual attenuation condition, the time to change from 10% of detected RF power to 90% of detected RF power is typically 50 nanoseconds. Other drive configurations are described in HP Application Note 914.

ELECTRICAL SPECIFICATIONS AT T_A = 25°C

Usable Frequency Range 8.0 to 18 GHz.

Characteristic	Test Condition	Limits Min.	Limits Max.	Typical	Units
Residual Attenuation	0 bias	—	2.8	2.0	dB
Dynamic Range	100 mA bias current	45	—	50	dB
VSWR	0 bias	—	1.8:1	1.5:1	—
VSWR	0-100 mA bias current	—	2.0:1	1.7:1	—

Video Leakage

In fast switching applications a portion of the high speed bias drive signal will leak into the RF transmission line and appear at the RF ports. For example, during rise time tests a triangular pulse of less than 0.2 volt amplitude and base width of 50 nanoseconds was measured with a 15 ns rise time 10-volt driving pulse.

RF Leakage

The level of RF signal appearing at the bias port is typically 40 dB below the level of signals applied to either RF port.

Noise, Harmonics, and Spurious Signals

Performance of the HP 33001A is set by the performance of the HP 33602A Modules. These units behave as thermal resistances shunted across the transmission line, and have an excess noise temperature of less than 20° Kelvin. Noise figure will therefore exceed the residual attenuation value by less than 0.2 dB for any bias level. Harmonic products generated internally are at least 40 dB below fundamental signal levels.

Attenuation

The HP 33001A exhibits no fine grain attenuation. Variation of attenuation with bias current, frequency, and temperature is shown by Figures 1, 2, 3, and 4. At maximum bias current, isolation over operating temperature limits does not fall below 45 dB. During a twenty-day environmental test cycle the resettability of attenuation vs. bias current was found to be typically within 5% of the attenuation, measured in dB. Bias voltage polarity for increase of attenuation is negative.

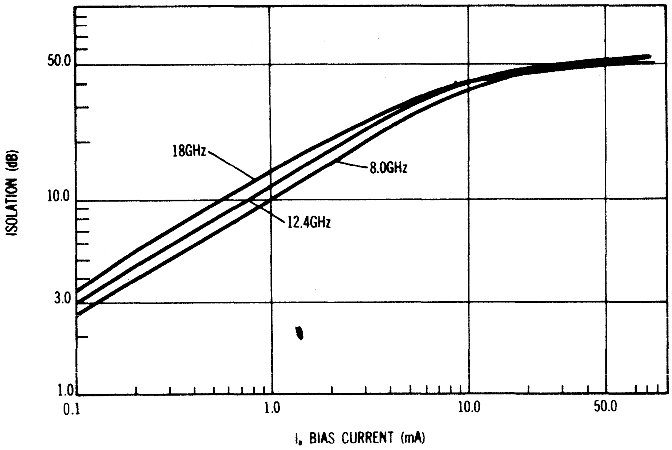


Figure 1. Attenuation vs. bias current at various frequencies.

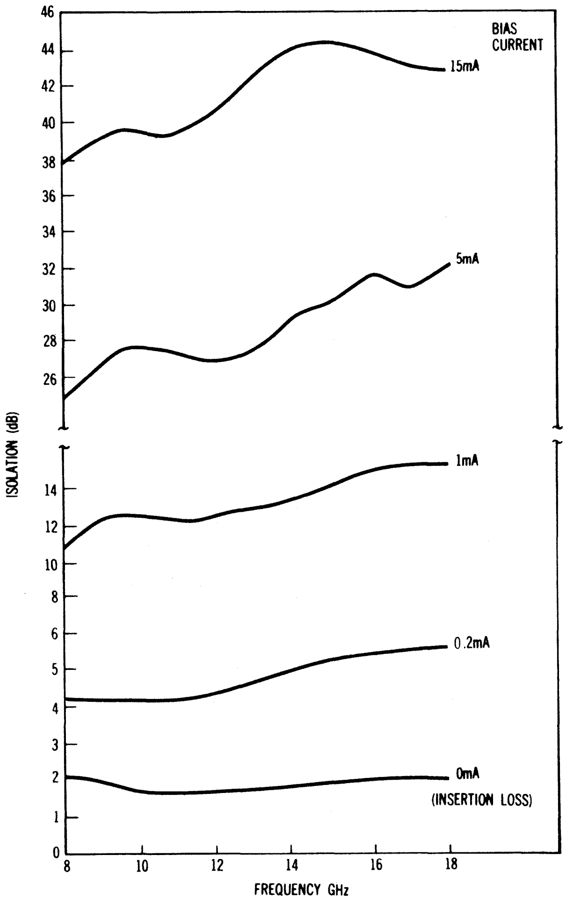


Figure 2. Attenuation vs. frequency for various bias currents.

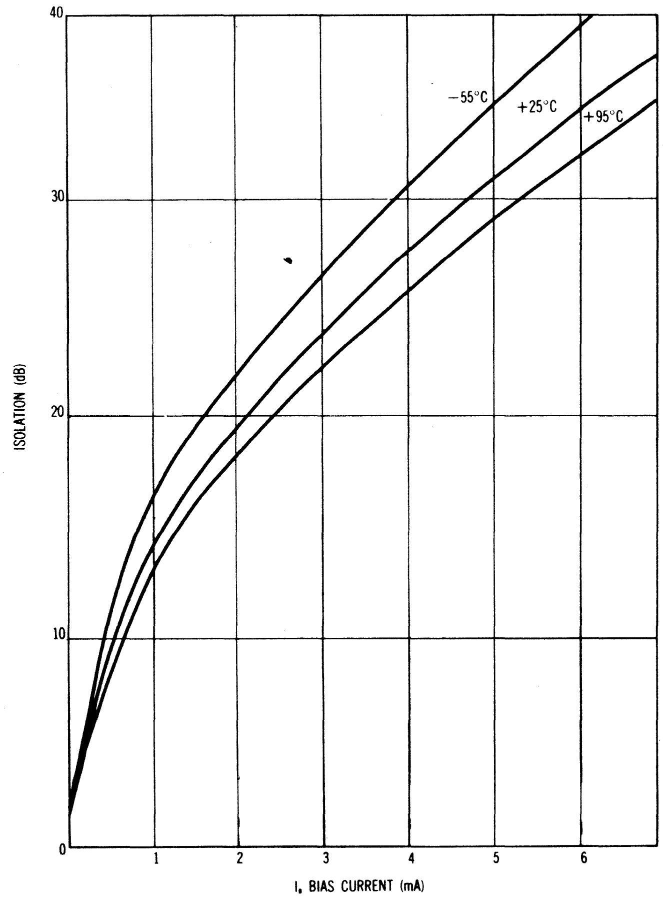


Figure 3. Attenuation vs. bias current at various temperatures at 12.4 GHz.

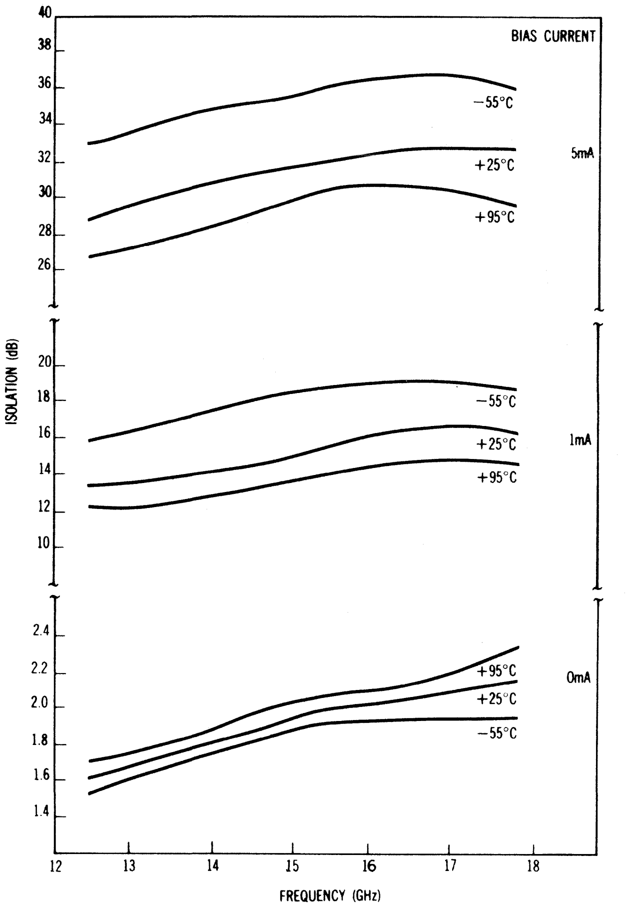


Figure 4. Attenuation vs. frequency for various bias currents and temperatures.

VSWR and Phase Shift

Figures 5 and 6 show typical variation of VSWR and phase angle vs. frequency for various bias conditions. Phase shift from either RF port to the other is a constant 70° plus approximately 13.2 cm equivalent air equivalent length.

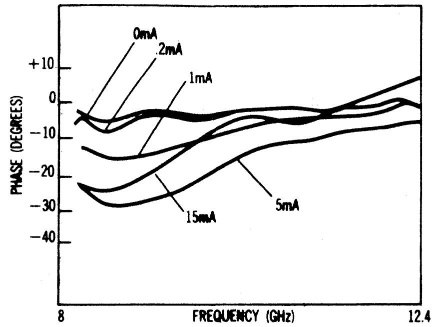


Figure 5. Typical phase shift (port-to-port) vs. frequency for various bias conditions.

Bias Port Impedance

Figure 7 shows the typical V-I curves measured at the bias port for both forward (Figure 7a) and reverse (Figure 7b) bias voltage polarities. Further description of bias characteristics is available in data sheets for HP 33600A Switching Modules.

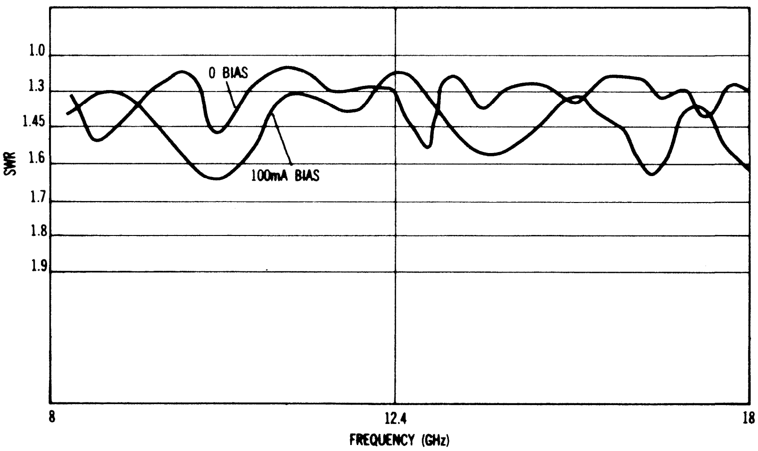


Figure 6. Typical VSWR vs. frequency for various bias conditions.

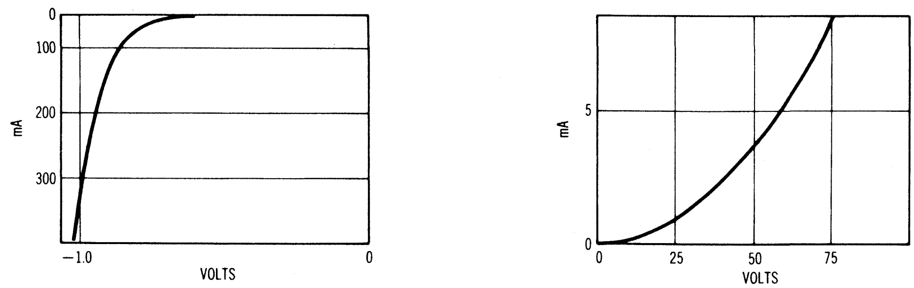


Figure 7. Typical V-I curves showing forward and reverse bias voltage polarities.

POWER HANDLING DERATING

The derating curve of Figure 8 defines derating factors to be applied to pulse and cw incident power handling ratings to accommodate the effects of ambient temperature variation.

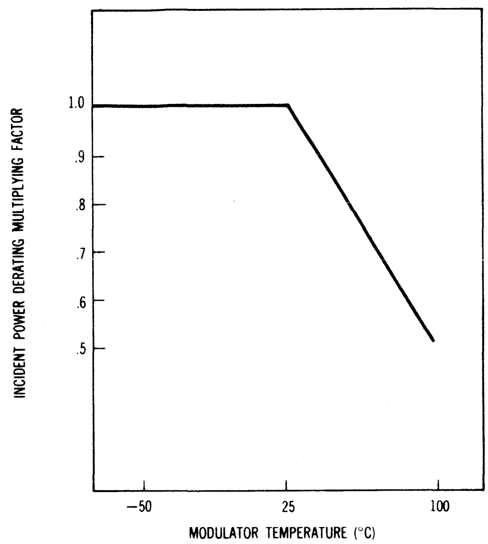


Figure 8. Power—temperature derating.

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PERFORMANCE SUMMARY

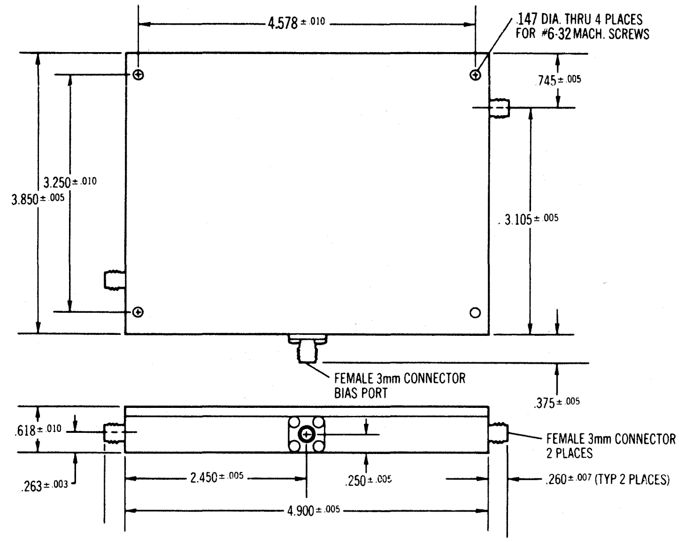
PIN ABSORPTIVE MODULATORS

HP
33000A/B
33008A/B
33001A/B

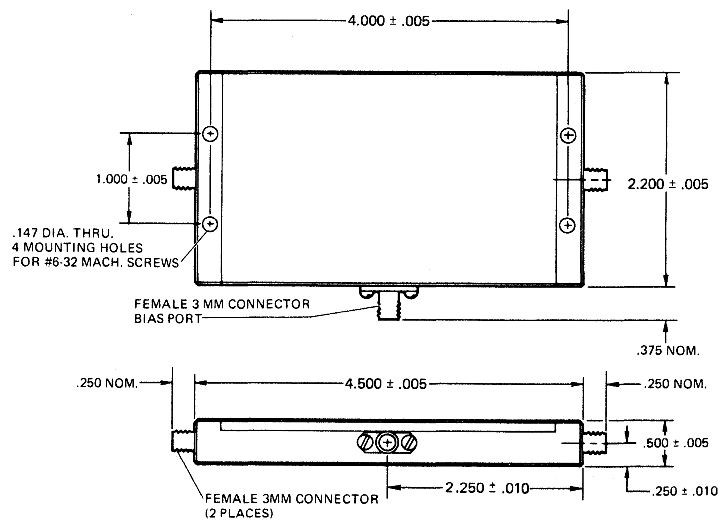
FOR: MODULATING • ATTENUATING
SWITCHING • LEVELING

MODEL	CHARACTERISTIC	TYPICAL PERFORMANCE		
33000A (D/S Available) 0.8 - 4.0 GHz Rise Time: 50 nsec		0.8 - 2 GHz	2 - 4 GHz	
	Insertion Loss (0 mA)	1 dB	1.5 dB	
	Dynamic Range (100 mA)	40 dB	45 dB	
	VSWR (0 mA)	1.3	1.4	
	VSWR (0 - 100 mA)	1.5	1.6	
33000B (Tent. Data) 0.8 - 4.0 GHz Rise Time: 100 nsec		0.8 - 2 GHz	2 - 4 GHz	
	Insertion Loss (0 mA)	1.7 dB	2.0 dB	
	Dynamic Range (200 mA)	60 dB	75 dB	
	Dynamic Range (400 mA)	70 dB	85 dB	
	VSWR (0 mA)	1.3	1.5	
	VSWR (0 - 400 mA)	1.5	1.7	
33008A (Tent. Data) 3.7 - 8.3 GHz Rise Time: 50 nsec	Insertion Loss (0 mA)	1.5 dB		
	Dynamic Range (100 mA)	50 dB		
	VSWR (0 mA)	2.0		
	VSWR (0 - 100 mA)	2.0		
33008B (Tent. Data) 3.7 - 8.3 GHz Rise Time: 100 nsec	Insertion Loss (0 mA)	2.0 dB		
	Dynamic Range (200 mA)	85 dB		
	VSWR (0 mA)	2.0		
	VSWR (0 - 200 mA)	2.0		
33001A (D/S Available) 8 - 18 GHz Rise Time: 50 nsec		8 - 12.4 GHz	12.4 - 15 GHz	15-18 GHz
	Insertion Loss (0 mA)	2.0 dB	2.0 dB	2.0 dB
	Dynamic Range (100 mA)	50 dB	50 dB	50 dB
	VSWR (0 mA)	1.5	1.5	1.5
	VSWR (0 - 100 mA)	1.7	1.7	1.7
33001B (Tent. Data) 8 - 18 GHz Rise Time: 100 nsec	Insertion Loss (0 mA)	2.0 dB	3.0 dB	4.0 dB
	Dynamic Range (100 mA)	85 dB	75 dB	75 dB
	VSWR (0 mA)	1.5	1.7	1.7
	VSWR (0 - 100 mA)	1.7	1.7	1.7

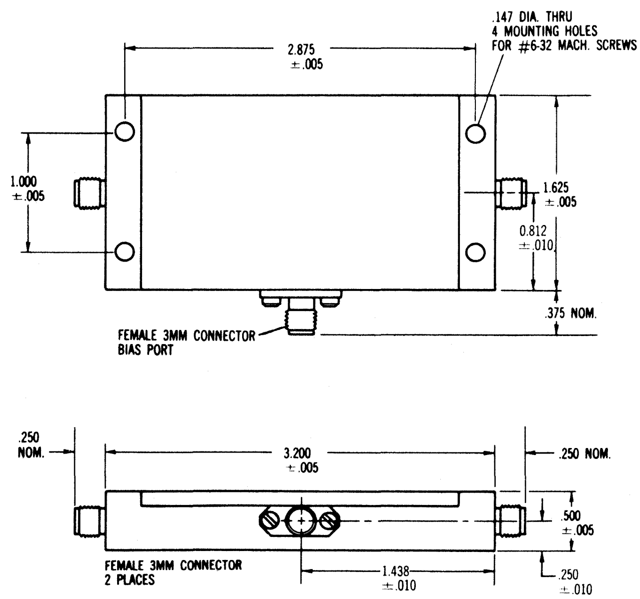
HP PIN Absorptive Modulators are compact, reliable, rugged components that combine: (1) hybrid integrated, 50-ohm PIN diode module, (2) advanced-design broadband couplers, (3) low VSWR 50-ohm loads, and (4) broadband bias circuitry. New HP Modulators cover the spectrum from 0.8 GHz to 18 GHz in three frequency bands: 0.8 - 4.0 GHz (HP 33000A/B); 3.7 - 8.3 GHz (HP 33008A/B); 8 - 18 GHz (HP 33001A/B). Two maximum attenuation levels are available—40 dB in "A" versions, 80 dB in "B" versions. All versions have low SWR (2:1 at any attenuation), and are useful as modulators, switches, or attenuators in systems that employ load-sensitive elements (such as reflex klystrons or BWO's). Typical applications are found in sweep generator leveling, receiver AGC, distance measuring systems, phased array radar systems, and simulators.



33000 A/B



33008 A/B



33001 A/B

Dimensions in inches

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COAXIAL MICROWAVE STEP RECOVERY DIODE MODULES

HP
33002A/B
33003A/B
33004A/B
33005A/B

SINE WAVE DRIVE: ½ Watt Nominal at 100, 250, and 1000 MHz

NARROW OUTPUT PULSES: 130 Picoseconds Typical
> 10 Volt Amplitude

BROADBAND OUTPUT COMB: Frequency Spectrum Lines at All Integral Multiples of Input Frequency to 12 GHz and Above

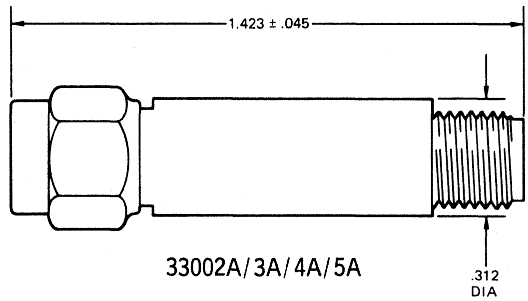
HIGH POWER PER LINE: > -30 dBm Per Line to 12.4 GHz for 100 MHz, ½ Watt Input Higher Power For Higher Input Frequencies

MATCHED INPUT: 50 ohms

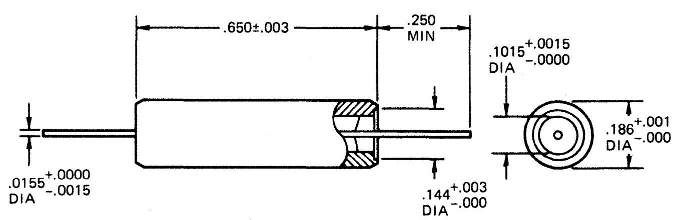
SELF BIASED

MINIATURE SIZE

RUGGED, ALL SOLID STATE, HYBRID INTEGRATED CONSTRUCTION



33002A/3A/4A/5A



33002B/3B/4B/5B

DESCRIPTION

HP33002/3/4/5A/B are integrated step recovery diode "impulse train" generating circuits matched to 50Ω at four input frequencies (100, 250, 500 and 1000 MHz). All elements necessary to produce the impulse are integrated into the hermetically sealed cylindrical module. Modules are also available mounted in a 3 mm connector housing which contains a DC return, self biasing the diode in comb applications. All internal joints are welded or thermal compression bonded for high reliability.

APPLICATIONS

Driven at the appropriate input frequency, the output of these devices is a train of narrow, high amplitude pulses at a repetition rate equal to the input frequency. The resulting "comb" spectrum consists of lines at all multiples of f_{IN} up to and beyond 12.4 GHz. The outputs are useful in many applications such as: measurements of spectral behavior of various linear components (filter, slow wave structures); frequency and amplitude calibration of receivers, systems, antenna; frequency marking systems; reference frequency production for phase locked systems; sampling phase-lock systems; LO drivers for coherent receiving techniques; CW multiplier of high order and low power level; pulse circuit applications.

Absolute Maximum Ratings

Maximum power at input frequency, 25°C . . . . .75 Watts
Maximum forward current . . . . .5 Ampere
Maximum reverse voltage . . . . 20 volts
Maximum operating temperature . . . . 75°C

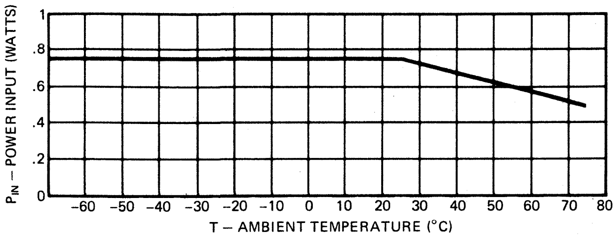


Figure 1. Power Derating Curve

Environmental Characteristics

Temperature storage . . . . –55°C to +100°C
Temperature operating . . . . –55°C to +75°C
Temperature cycling . . . . . Method 1051, Test Condition A
Temperature shock . . . . . Method 1056, Test Condition A ("B" versions only)
Moisture Resistance . . . . . MIL-STD-750A, Method 1021.1
Shock (nonoperating) . . . . MIL-STD-750A, Method 2016.1, 5 blows each X_1, Y_1, Y_2, orientations .5 Ms, 1500 gs
Vibration . . . . MIL-STD-750A, Method 2046

Mechanical Characteristics

Size . . . . See outline drawing
Weight . . . . 10 grams
Materials . . . . Outer case, Kovar; connectors, stainless steel
Finish . . . . Gold plated, 50 microinch minimum

Electrical Specifications

Input Frequency

(HP 33002A)	100 ±5 MHz (useful at slightly reduced performance 100 ±10 MHz)
(HP 33003A)	250 ±12.5 MHz (useful at slightly reduced performance 250 ±25 MHz)
(HP 33004A)	500 ±25 MHz (useful at slightly reduced performance 500 ±50 MHz)
(HP 33005A)	1000 ±50 MHz (useful at slightly reduced performance 1000 ±100 MHz)

Input VSWR . . . . Less than 2:1 at center frequency.

Output Description

The output of these devices consists of a train of very short pulses periodic with the input frequency. Described by its frequency spectrum, the output consists of power at all frequencies which are integral multiples of f_{in} up to and beyond 12.4 GHz. All specifications are for 0.5 watt drive at 25°C case temperature.

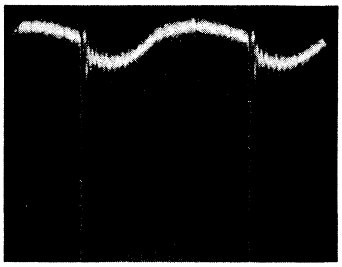
Time Domain

In the time domain, the output is characterized by the pulse height, pulse width and the excess feed-through of the fundamental frequency component to the output. See Table I. (Fundamental feed-through < +15 dBm.)

TABLE I. Output Pulse Specifications, 0.5 Watt drive, 25°C

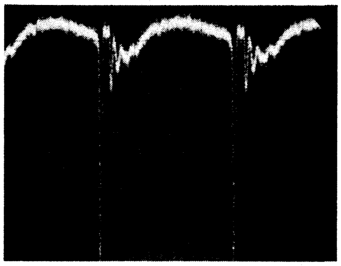
Parameter / Device Drive Freq.	Pulse Height Typ.	Pulse Height Min.	Pulse Width Typ.	Pulse Width Max.
HP 33002A 100 MHz	15	10	130	140
HP 33003A 250 MHz	15	10	130	140
HP 33004A 500 MHz	15	10	130	140
HP 33005A 1000 MHz	10	8	130	140

Typical pulse displays, using the test set-up described below are shown for each of the devices in Figures 2, 3, 4, and 5.



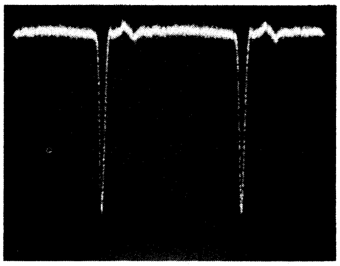
2 VOLTS/cm
2 ns/cm

Figure 2. Impulse Waveform 33002A/B (100 MHz)



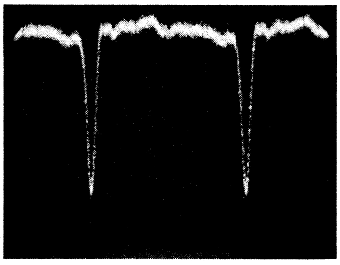
2 VOLTS/cm
1 ns/cm

Figure 3. Impulse Waveform 33003A/B (250 MHz)



3 VOLTS/cm
500 ps/cm

Figure 4. Impulse Waveform 33004A/B (500 MHz)



2 VOLTS/cm
200 ps/cm

Figure 5. Impulse Waveform 33005A/B (1000 MHz)

Frequency Domain

In the frequency domain the output is characterized by a line spectrum. The spacing of the lines is equal to the input frequency. Figures 6, 7, 8, and 9 show the typical line spectra of each device and the specified minimum power outputs.

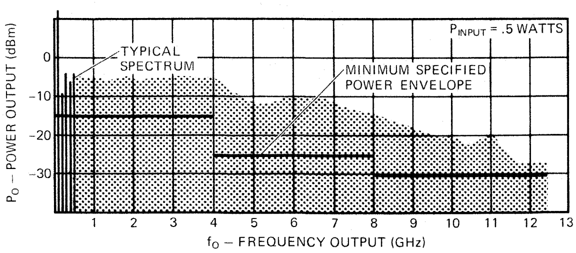


Figure 6. Spectrum Envelope of 33002A/B (100 MHz)

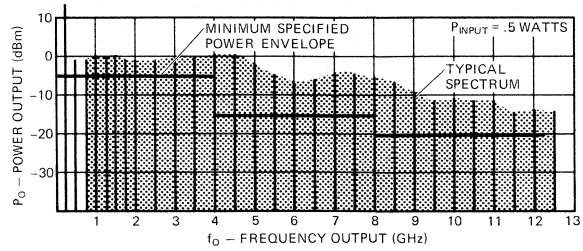


Figure 7. Spectrum Envelope of 33003A/B (250 MHz)

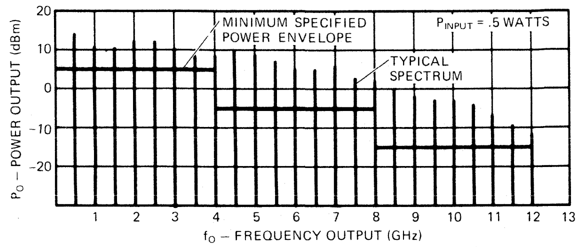


Figure 8. Spectrum Envelope of 33004A/B (500 MHz)

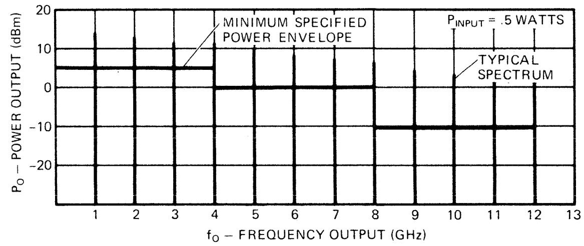


Figure 9. Spectrum Envelope of 33005A/B (1000 MHz)

Table II shows typical and minimum power outputs for three frequency bands.

Input VSWR

The input VSWR is a function of the input power. The devices have all been optimized for minimum VSWR at the nominal center frequency with .5 watt drive. Below .5 watts, the VSWR begins increasing as shown in Figures 10, 11, 12 and 13. The point of minimum VSWR may be adjusted if external bias is applied to the diode (C001 versions only, which have no dc return).

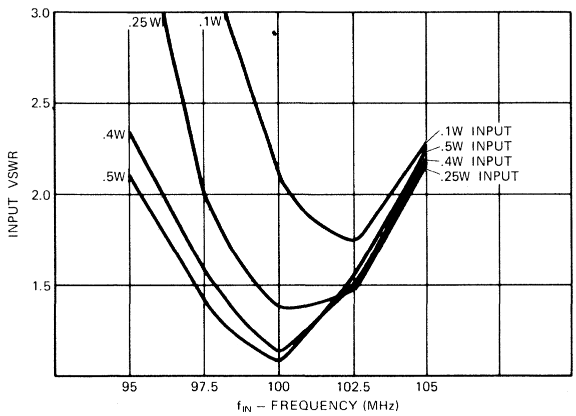


Figure 10. 33002A/B

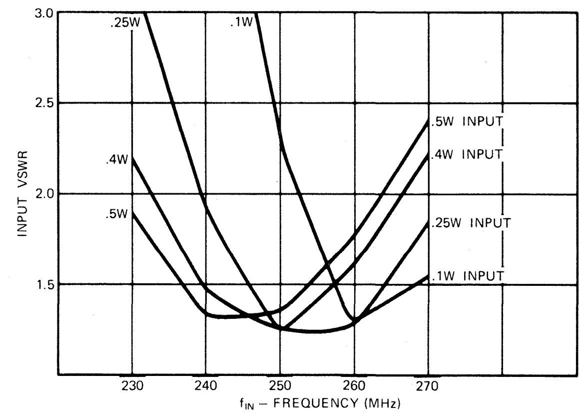


Figure 11. 33003A/B

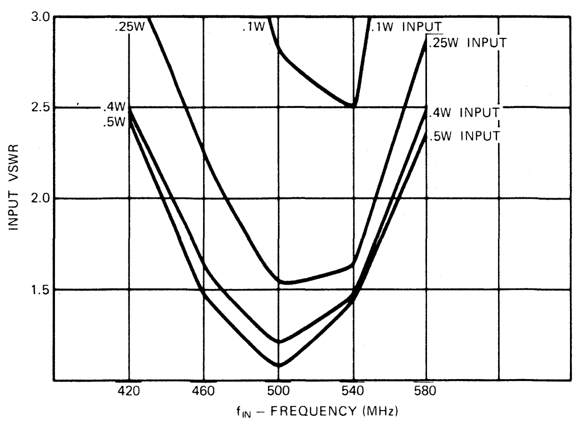


Figure 12. 33004A/B

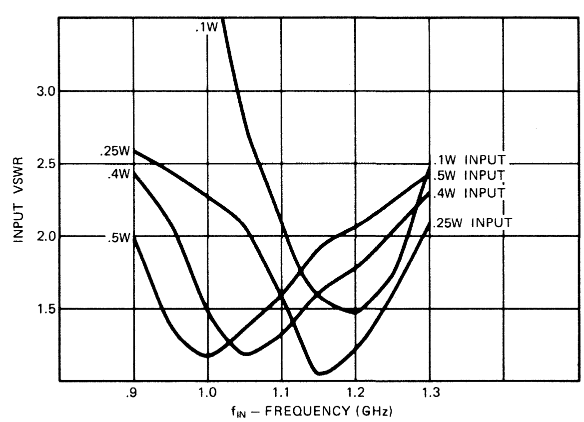


Figure 13. 33005A/B

VSWR Characteristics

TABLE II. Typical Line Spectra

	P_O (dBm) 0-4 GHz* Min. Typ.	P_O (dBm) 4-8 Min. Typ.	P_O (dBm) 8-12.4 Min. Typ.	0.5 watts drive feedthrough of fundamental frequency
HP 33002 (100 MHz)	-15	-25	-30	≈+15 dBm
HP 33003 (250 MHz)	- 5	-15	-30	≈+15 dBm
HP 33004 (500 MHz)	+ 5	- 5	-15	≈+15 dBm
HP 33005 (1000 MHz)	+ 5	0	-10	≈+15 dBm

*Fundamental line excluded.

Bias

The circuit diagram of a module without connectors is shown in the drawing of Figure 14. Bias can be introduced to the diode from either end of the module by using standard biasing tees. The required bias for typical comb operation is approximately zero volts. This is achieved in the modules with connectors by placing a broadband dc return in the output connector assembly. (Figure 15).

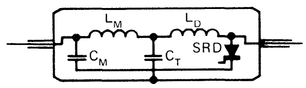


Figure 14. Electrical Schematic of "B" Versions

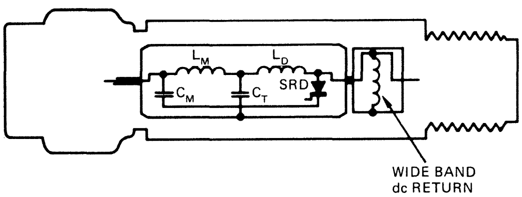


Figure 15. Electrical Schematic of "A" Versions

Temperature Effects

The comb generator is designed to operate over wide ambient temperatures (-55°C to +75°C). The VSWR remains within about 20% and typical line variation is about 3 dB over this temperature range.

Stability

No spurious outputs are generated when the load VSWR is < 3:1 (any phase angle), except for the HP 33005's (1000 MHz) which require a load VSWR of < 2:1 for stability.

Test Set-ups

There are at least two ways to measure the comb generators; in the time domain using a very fast sampling scope; or in the frequency domain, using several sweepers (as L.O.'s), mixers and an IF. Measurements made using a spectrum analyzer must be interpreted very carefully because of the large number of spurious responses when driven by the extremely wideband comb generated by these devices.

Time Domain

The test set-up used in measuring the pulse train characteristics of the comb generator is shown in Figure 16. The dc bias, shown as optional, is used only for the testing of the "B" versions of the module since the comb generator with connectors contains an internal dc return which provides biasing to the diode.

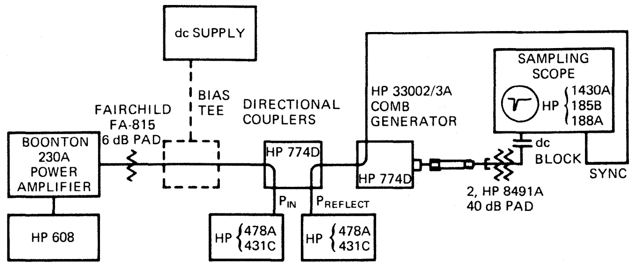


Figure 16. Test Setup, Time Domain Characterization

Frequency Domain

Testing in the frequency domain can be done with the set-up shown in Figure 17. Evaluation of the comb generator requires appropriate equipment changes to cover the full range (1-2 GHz, 2-4 GHz, 4-8 GHz and 8-12 GHz). The set-up shown is specifically for 4-8 GHz. The detected IF output will have two responses in time for each line of the comb (since the mixer responds at both signal and image frequencies as the signal sweeps by). A trace of the total 4-8 GHz pattern is obtained on the scope and recorded. Calibration is done by replacing the comb input to the mixer with a known signal level at several critical frequencies across the band.

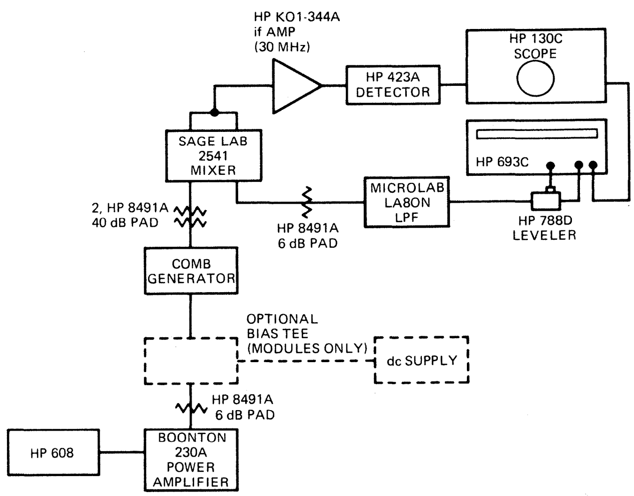


Figure 17. Test Setup, 4-8 GHz Frequency Domain Characterization

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SOLID STATE SPDT MICROWAVE SWITCH

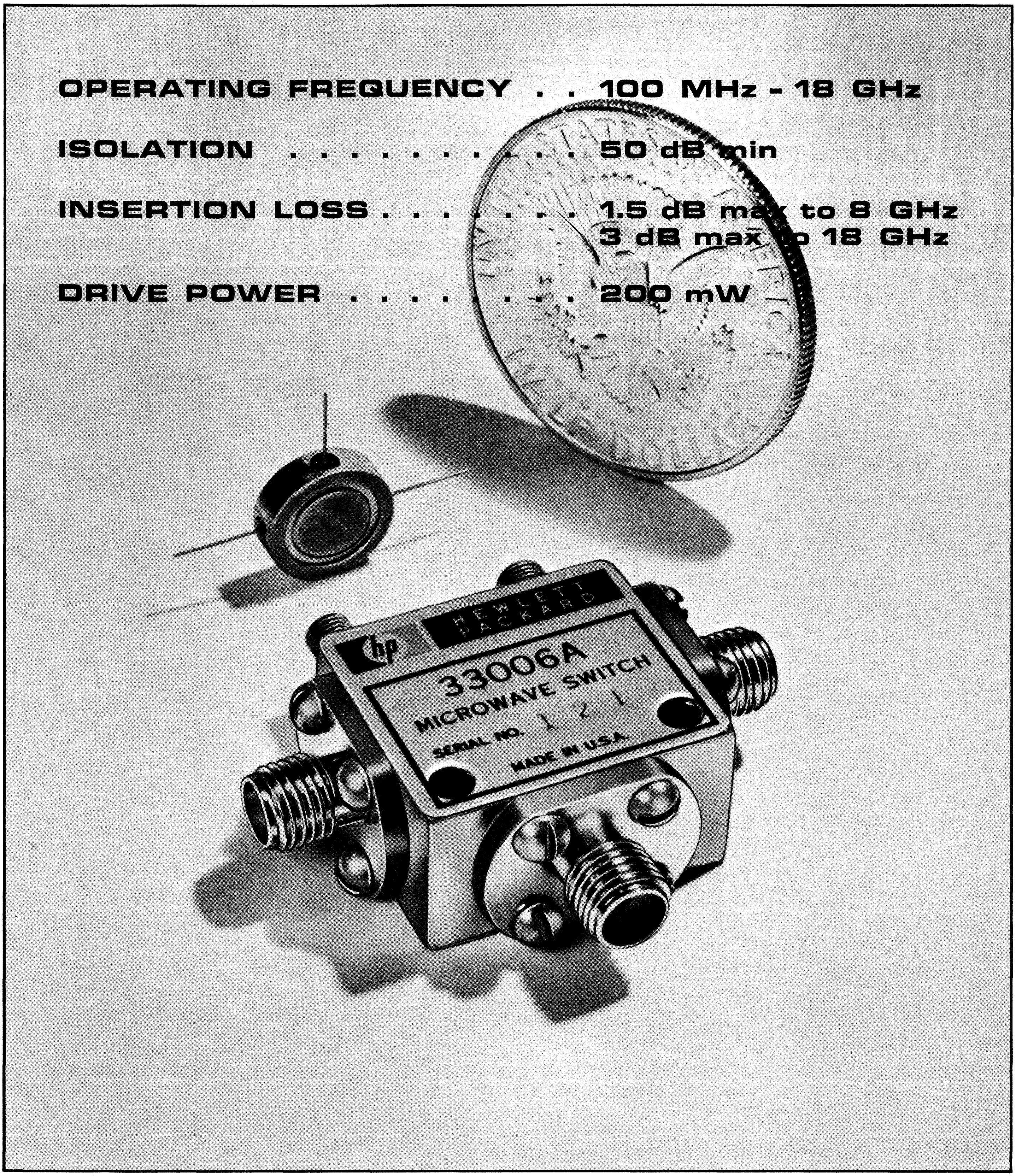
HP 33006A 33007A

OPERATING FREQUENCY . . 100 MHz - 18 GHz

ISOLATION . . . . 50 dB min

INSERTION LOSS . . . . 1.5 dB max to 8 GHz
3 dB max to 18 GHz

DRIVE POWER . . . . 200 mW



DESCRIPTION

The HP-33006A SPDT switch combines a hermetically sealed diode switching module with the bias circuits necessary to obtain high performance over a broad frequency range. The unit is tightly closed and nickel coated to permit operation in severe environments.

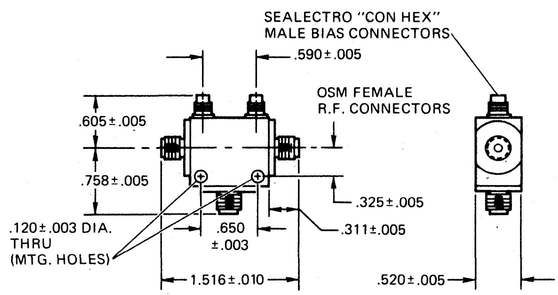
The HP-33007A SPDT switch is a hermetically sealed module for use in symmetrical stripline circuits with 1/8 inch ground plane spacing. External bias circuits are supplied by the user.

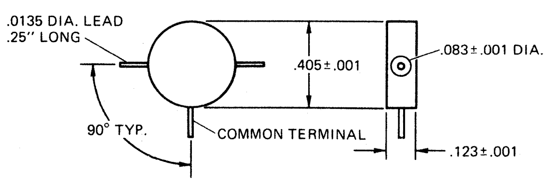
APPLICATION

The HP SPDT switches are intended for very broad band applications or for narrow band uses within the .1 to 18 GHz range. They offer solid state speed and reliability for switching functions in phase shifters, phased array antennas, T-R switches, redundant systems and antenna lobing circuits.

MECHANICAL CHARACTERISTICS

	33006A	33007A
Mounting Position	Any, two 4-40 clearance mtg. holes provided	Any
Size	Shown on Outline Drawing	
Weight	35 grams maximum	3 grams maximum
Material	Body: aluminum	Leads, Cover and body ring: kovar
	RF conn.: stainless steel	
	Bias conn.: brass	Center: copper-tungsten Seals: glass
Finish	Body: nickel plate	Gold, 50μ-inch minimum
	Conn.: nickel-rhodium plate	
Connector Type	Bias: Sealectro Con-Hex Thread-on Male	Not Applicable
	RF: OSM Female	





ENVIRONMENTAL CHARACTERISTICS

	33006A	33007A
	MIL-STD –202C Reference and Conditions	MIL-STD 750 Reference and Conditions
Temperature (Storage and operating)	–65 to +125°C	–65 to +125°C
Temperature Cycling	Method 107 B Condition B	Method 1051.1 Condition B
Thermal Shock	—	Method 1056.1 Condition A
Humidity	Method 106 B Condition B	Method 1021.1, Omit Initial Conditioning
Mechanical Shock	Methoc 213 C Condition C	Method 2016.1
Vibration, Variable Frequency	Method 204 A Condition B	Method 2056
Vibration Fatigue	—	Method 2046

ABSOLUTE MAXIMUM RATINGS

	33006A	33007A
Maximum Steady State Bias Current	± 100 mA dc	± 100 mA dc
Maximum Reverse Bias Voltage	Not Applicable	80V
Maximum incident power @ 25°C Ambient (See Figure 2 for temperature derating)	1 watt CW 50 watts pulse @ 1 μsec 1% duty cycle	
Maximum DC Voltage, R.F. Center Conductor to Ground	100 Volts	Not Applicable

ELECTRICAL SPECIFICATIONS

All specifications are at 25°C unless noted otherwise, and, excepting VSWR, refer to any terminal. VSWR at the isolated terminal is high, typically 20:1. With both arms on or off, VSWR is high at any port.

The bias required is 50 mA forward for the transmitting arm and 50 mA reverse for the isolated arm.

BASIC OPERATION

Referring to the circuit diagram (Fig. 1), if positive bias is applied to arm 1 and negative bias to arm 2, the series diode of arm 1 and shunt diodes of arm 2 are forward biased and exhibit low R.F. impedance. The series diode of arm 2 and the shunt diodes of arm 1 are reverse biased and appear as high impedances to R.F. Consequently, an R.F. signal will flow in arm 1 and be blocked from arm 2. Reversing the bias, switches the signal flow to the opposite arm.

TABLE I VSWR, INSERTION LOSS, ISOLATION AND PHASE TRACKING SPECIFICATIONS

Type	PARAMETER	0.1-1 GHz Spec.	0.1-1 GHz Typ.	1-4 GHz Spec.	1-4 GHz Typ.	4-8 GHz Spec.	4-8 GHz Typ.	8-12 GHz Spec.	8-12 GHz Typ.	12-18 GHz Spec.	12-18 GHz Typ.
33006A	VSWR, Common and Transmitting Arm	1.4:1 max.	1.3:1	1.4:1 max.	1.3:1	1.6:1 max.	1.5:1	1.8:1 max.	1.6:1	2.0:1 max.	1.8:1
	Insertion Loss (dB) Transmitting Arm	1 max.	0.8	1.5 max.	1.2	1.5 max.	1	2.5 max.	2.3	3 max.	2.5
	Isolation (dB)	70 min.	75	70 min.	75	60 min.	70	55 min.	60	50 min.	55
	Phase Tracking, Arm to Arm	← Within 15° →									
33007A	VSWR, Common and Transmitting Arm	1.3:1 max.		1.4:1 max.		1.4:1 max.		1.6:1 max.		1.8:1 max.	
	Insertion Loss (dB) Transmitting Arm	1 max.		1 max.		1.5 max		2.0 max.		2.5 max.	
	Isolation (dB)	70 min.	75	70 min.	75	60 min.	70	55 min.	60	50 min.	55
	Phase Tracking, Arm to Arm	← Within 15° →									

Switching Speed — 200 nsec maximum when driven as described below

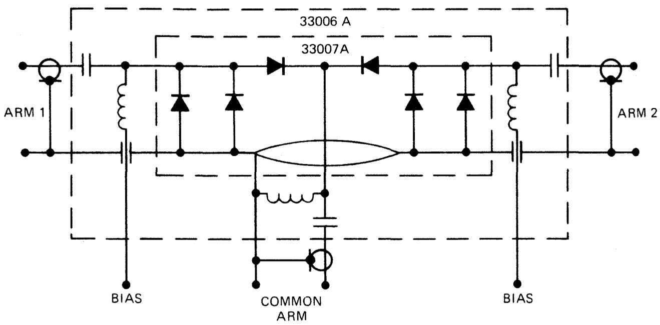


Figure 1. Switch Circuit Diagram

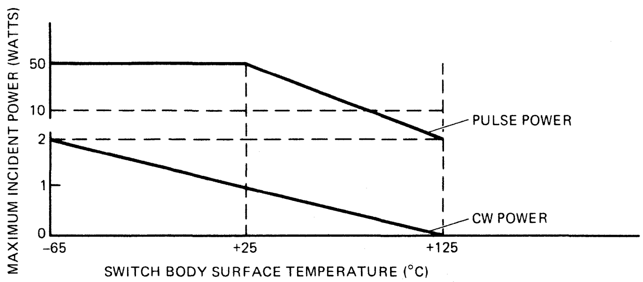


Figure 2. Temperature Derating of Incident Power

HARMONICS AND NOISE

The harmonic signal generated by the 33006A/33007A depends on input frequency and power level, increasing with both increasing input power and decreasing frequency. For 1 watt input, 2nd harmonic is 20 dB below the fundamental @ 500 Mz, 25 dB @ 1.3 GHz and 40 dB @ 6 GHz.

The switch appears as a thermal noise generator with less than 20°K excess noise temperature. The resulting noise figure does not exceed the insertion loss by more than .2 dB at room temperature.

SWITCHING

The switching or transfer time specified previously is defined as shown in Figure 3. It is the interval between the instant the signal in one arm has dropped .5 dB below the insertion loss level and the instant the signal in the opposite arm rises to within .5 dB of the insertion loss value.

The switching time is dependent on storing and removing charge from the pin switching diodes. Simply switching to the steady current values results in approximately 2 μsec switching time. For 200 nsec operation a spiked drive is necessary to quickly redistribute the stored charge. A typical graph of current vs time is shown in Figure 4.

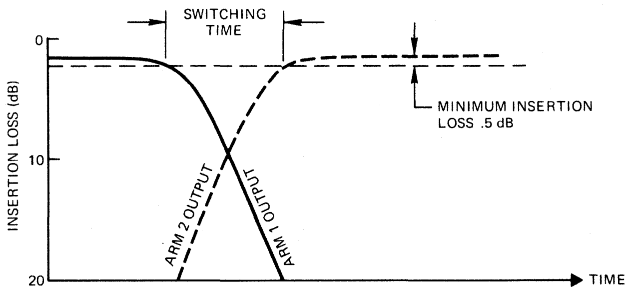


Figure 3. Definition of Switching Time

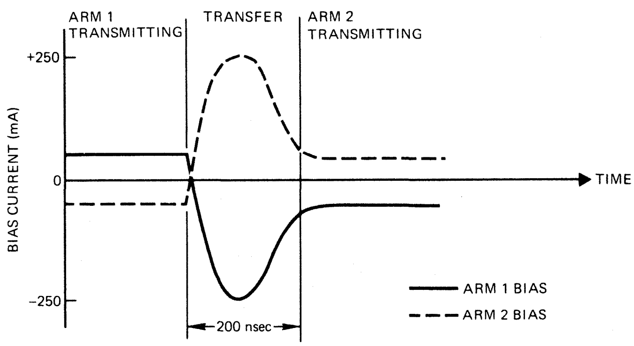


Figure 4. Transient Current for 200 nsec Switching

During the transfer interval the bias voltage reaches ±5V peak at the bias insertion points, necessitating high pass filtering on the R.F. circuit if video feedthrough is a concern.

A representative circuit capable of supplying the necessary switching spikes and holding currents is shown in Figure 5.

For the circuit shown, all resistors are 1 watt unless shown otherwise. Leads should be short as possible to reduce stray reactances. The bias supplies should be at A-C ground.

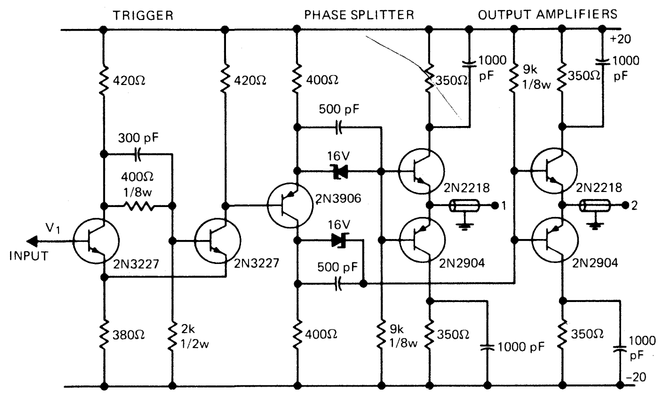


Figure 5. Representative Circuit

Note: for V1 > +3 volts, output 1 positive
V1 < -3 volts, output 2 positive

V-I CHARACTERISTICS

For aid in drive circuit design, the dc V-I curve of the switches is shown in Figures 6a and 6b.

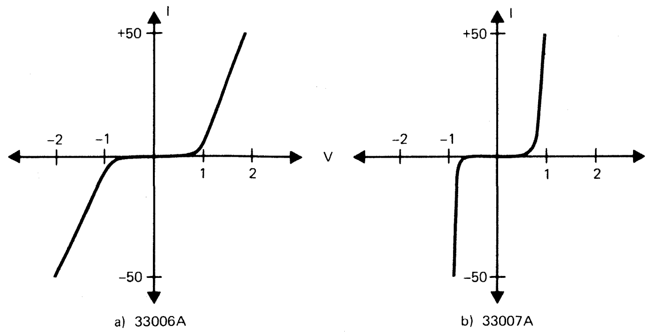


Figure 6. DC V-I Characteristics

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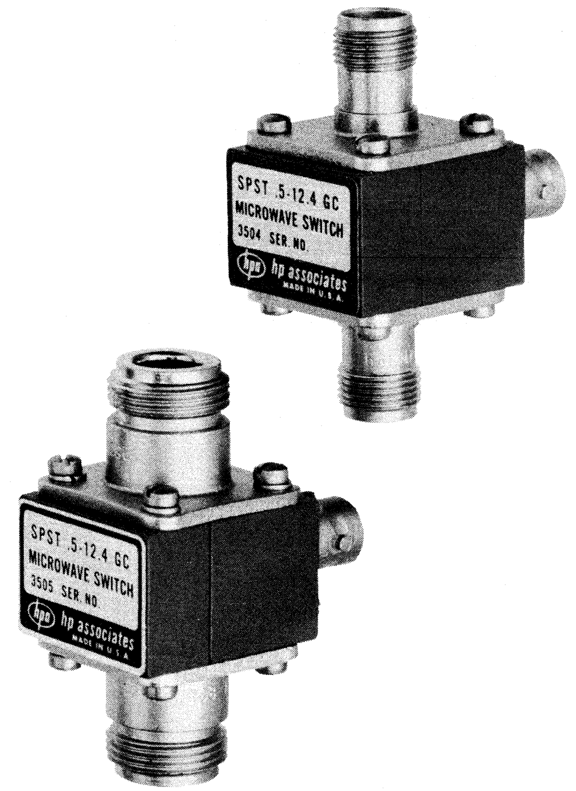
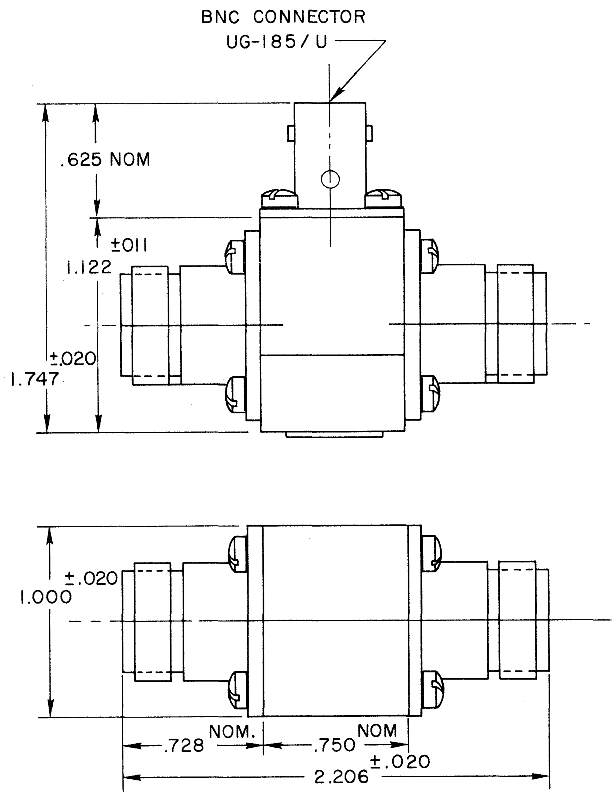
MICROWAVE SWITCH

HPA 3501/3/4/5





- **BROAD BANDWIDTH—200 MHz to 12.4 GHz**
- **LOW INSERTION LOSS—0.5 to 1.5 dB**
- **HIGH ISOLATION—25 to 50 dB**
- **ALL SOLID STATE**

Switch No.	Bias Terminal	RF Terminal	Bias Polarity For Switch—OFF
3501	BNC	TNC	Positive
3503	BNC	N	Positive
3504	BNC	TNC	Negative
3505	BNC	N	Negative

DESCRIPTION

The HPA 3501/3/4/5 are broadband solid-state switches or attenuators suitable for use from 200 MHz to 12.4 GHz. They consist of two silicon PIN diodes which are functionally integrated into a broadband 50 Ω microwave structure and bias circuit.

APPLICATION

These versatile diode switches are ideally suited for a large variety of high frequency and microwave circuits including: Pulse Modulators, Phase Shifters, Phased Array Antennas, T-R Switches, Limiters, Attenuators, Automatic Gain Control Circuits, Power Leveling Circuits, Redundant Microwave Systems, Signal Synthesizers, Frequency Synthesizers, Suppressed Carrier Modulators, Pulse Shapers, Antenna Lobing Circuits.

ABSOLUTE MAXIMUM RATINGS

Maximum Diode Junction Temperature	150°C
Maximum Switch Power Dissipation (Derating per Fig. 11)	1.25 W @ 25°C
Maximum Diode Power Dissipation (Single Diode)	0.7 W @ 25°C
Maximum Bias Current	200 mA
Maximum Voltage (Center Conductor to Ground)	500 volts DC at standard temperature and pressure
Minimum Diode Breakdown Voltage	65 volts
Thermal Resistance Junction/Case	100°C/watt
Pulse Thermal Resistance Junction/Case	(as below)

For RF pulse lengths less than 30 microseconds the thermal resistance is dependent on the pulse duration. Its value in °C/watt is equal to the numerical value of the pulse duration expressed in microseconds, i.e., for a 10 μsec pulse the thermal resistance is 10°C/watt, thus the internal temperature rise is:

$$T_{Junction} - T_{Case} = P \times t(\mu\text{sec}) \text{ for } t < 30\ \mu\text{sec}$$

MECHANICAL CHARACTERISTICS

Size	As shown in the Outline Drawing, Figure 1
Weight	With Type N connector, 6 oz. With Type TNC connector, 5.2 oz.
Mounting Position	Any position. The switch may be mounted by replacing any two of the RF or bias connector screws with longer 4-40 screws for attaching a mounting bracket. Do not remove connectors.

ENVIRONMENTAL CHARACTERISTICS

Temperature, Storage	— 65°C to + 125°C
Temperature, Operating	— 65°C to + 125°C (Derating per Fig. 11)
Temperature Cycling	MIL-STD 202C, Test method 102, Condition C
Shock	75G 6 ms duration; MIL-STD 202C, Test method 213, Condition B
Vibration	10-2000 Hz, 15G; MIL-STD 202C, Test method 204A, Condition B
Humidity	MIL-STD 202C, Test method 103B, Condition B
Barometric Pressure	50,000 ft. MIL-STD 202C, Test method 105C, Condition B

ELECTRICAL SPECIFICATIONS AT 25°C

Frequency Range	200 MHz to 12.4 GHz. Performance above 12.4 GHz limited by connectors.
Impedance	All specifications are for 50 Ω.
Symmetry	Specifications apply to either direction of transmission. (See Isolation at Bias Terminal for an exception to symmetrical performance.)

ISOLATION AND INSERTION LOSS: (See Figure 8)

	Insertion Loss ($V_{bias} = 20$ V)		Isolation ($I_{bias} = 50$ mA)	
Frequency (GHz)	Max.	Typ.	Min.	Typ.
0.2 - 0.5	0.7 dB	0.5 dB	20 dB	25 dB
0.5 - 1.0	0.4	0.2	25	28
1.0 - 2.0	0.5	0.3	30	35
2.0 - 3.0	0.7	0.5	35	40
3.0 - 4.0	1.0	0.7	40	45
4.0 - 6.0	1.0	0.8	45	50
6.0 - 8.0	1.2	0.9	45	50
8.0 - 12.4	1.5	1.0	45	50

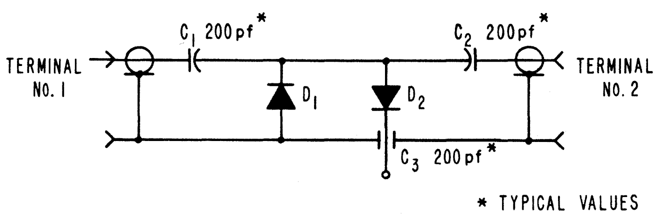


Figure 2. Switch control circuit. Diagram shown represents Models 3504 and 3505.

VSWR

		Frequency (GHz) 0.2 - 12.4
Switch ON	Maximum	2.0
	Typical	1.5
Switch OFF	High; dependent on bias current and frequency. 30:1 is typical VSWR.	

HARMONIC DISTORTION

Harmonics are generated by the PIN diodes in the HPA SPST switch. Harmonic output levels depend upon signal level, bias level and frequency. For frequencies above 350 MHz, generated harmonics are a minimum of 40 dB below the fundamental output level

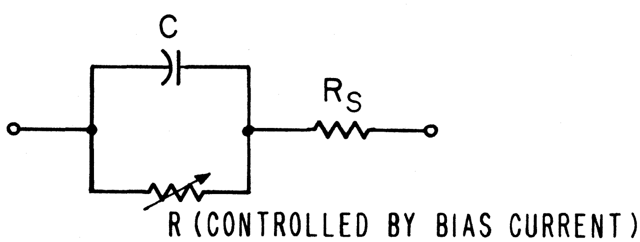


Figure 3. Typical PIN diode microwave equivalent circuit.

SWITCHING SPEED

	Maximum	Typical
Switch OFF-ON	300 ns	125 ns
Switch ON-OFF	100 ns	40 ns

CIRCUIT DIAGRAM

The control circuit of the HPA SPST switch is shown in Figure 2.

Two silicon PIN diodes shunt the RF line when forward biased and, under zero or reverse bias, are integral parts of a broadband RF network designed to provide a 50-ohm line impedance through the switch in the ON condition. The switch is ON when it is passing RF power (zero or reverse bias) and OFF when it is reflecting RF power (forward bias). A diode equivalent circuit showing typical values is given in Figure 3.

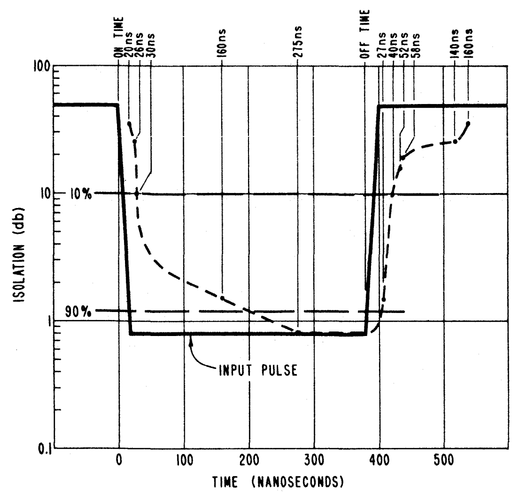


Figure 4. Typical switching speed for full operation. R_F frequency = 7.25 GHz.

SWITCHING SPEED

A typical RF pulse shape is shown by Figure 4. The rise and fall times depend on the attenuation levels at which the switch is considered to be ON or OFF. These times also depend on the magnitude of bias current and on the bias pulse shape.

Switching speed on production units is measured in the circuit shown in Figure 5.

The switching speed is read as the interval between the 10% to 90% points of the detected RF signal. Note that a high-pass filter with a DC return is provided on the input of the switch. The high-pass filter is a desirable addition to prevent drive pulse leakage onto the RF line. DC returns on both sides of the switch are necessary to achieve the rated switching speed, since complete depletion of diode stored charge is dependent upon these paths to ground. A low-pass filter for introducing the pulse and bias is also a desirable circuit feature. Typical switching speed from 50 dB of isolation to the full ON condition and the input driving pulse are shown in Figure 4.

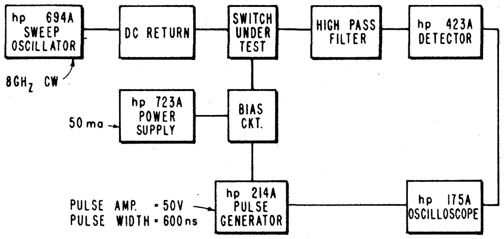


Figure 5. Block diagram of circuit used for switching speed test.

Biasing for Fast Switching. Faster switching can be obtained by operating at the lowest possible forward bias current consistent with the necessary isolation level. Faster switching may also be obtained by suitable shaping of the bias current waveform as illustrated in Figure 6.

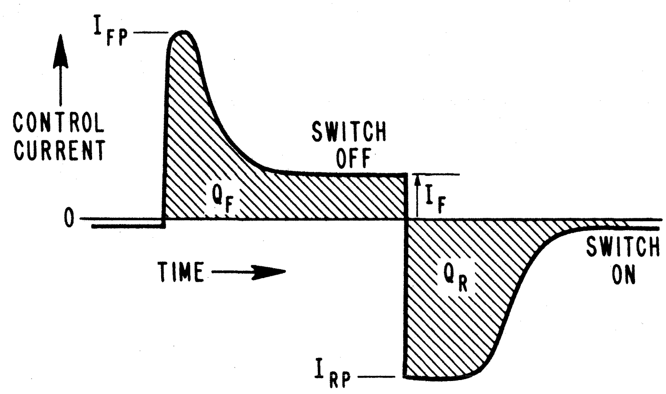


Figure 6. Control current pulse shape for fast switching.

The initially high peak turn-OFF current I_{FP} is used to effect a rapid decrease in diode impedance. I_{FP} must be reduced to I_F to assure that the stored charge Q_R, which is approximately equal to $I_F \times 10^{-7}$ coulombs, is kept to a minimum. I_F should not exceed the value necessary for the desired isolation in the OFF condition. Similarly a high peak turn-ON current I_{RP} is desirable to quickly remove the charge stored in the diodes and return them to the high impedance state. The values of I_{FP} and I_{RP} and their duration must stay within the limits of the peak bias current and the maximum power dissipation.

Typical voltage-current performance of the diodes, looking into the bias terminal is shown in Figure 7.

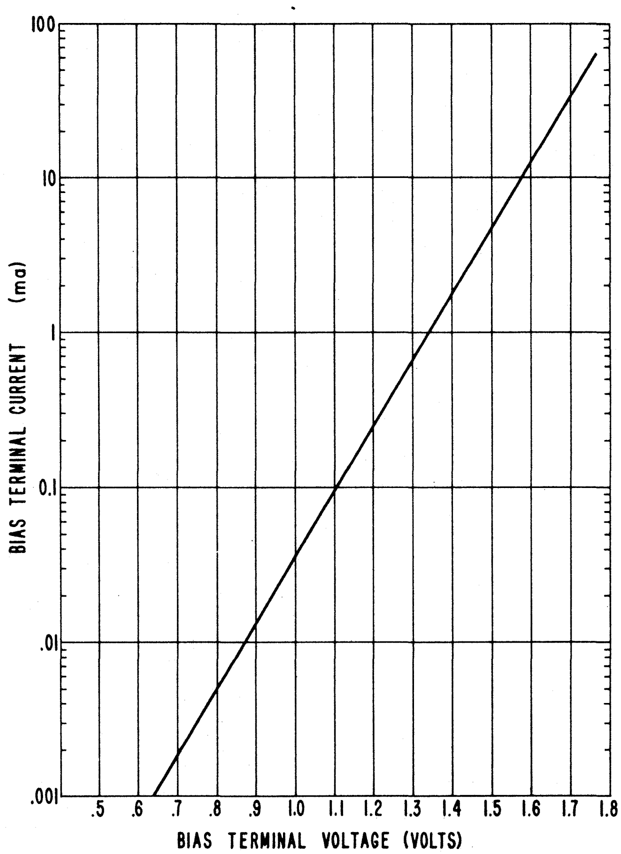


Figure 7. Voltage-current characteristics looking into bias port.

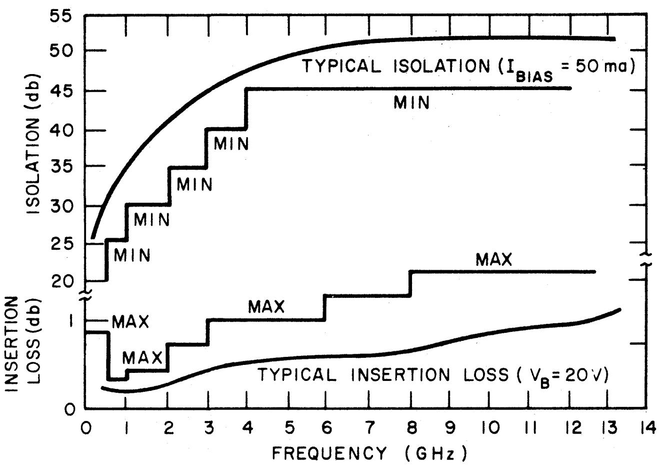
TYPICAL CHARACTERISTICS

Phase Shift. The phase shift characteristics of the switch are a function of frequency and the electrical length at a specific bias. The air equivalent electrical lengths for the two principal bias conditions are:

Switch ON ....3.25 cm face to face excluding connectors
Switch OFF ....1.625 cm face to short excluding connectors

VARIABLE ATTENUATOR CHARACTERISTICS

HPA SPST switches are useful as continuously variable, current-controlled attenuators. Although the attenuation at any particular bias current varies with RF frequency and temperature, the attenuation monotonically increases with increasing bias current, making the switch usable as an attenuator in such applications as AGC circuits, power leveling, and dynamic range extension. A typical plot of attenuation vs. bias current for various frequencies is given in Figure 9. Typical variation of attenuation as a function of bias current and frequency are shown in Figures 8 and 9. The HPA 3501/3/4/5 switch exhibits no fine grain attenuation structure.



► **Figure 8.** Isolation and insertion loss characteristics.

ISOLATION AT BIAS TERMINAL

RF leakage to the bias terminal is greater from one RF connector than from the other. This characteristic is caused by the non-symmetrical position of the bias lead with respect to the diodes (see Figure 2), and is the only exception to the symmetry of the switch. Typical isolation data is given in the table below.

TABLE I
Minimum RF Isolation at Bias Terminal

	ON	OFF
Terminal No. 1	36 dB	31 dB
Terminal No. 2	33 dB	23 dB

(Terminal No. 1 is down when the label can be read.)

The values given in Table I are the minimum isolation. Over most of the frequency range, the isolation is greater.

NOISE GENERATION

The output noise figure is less than 0.2 dB above insertion loss at any bias level.

RF POWER HANDLING CAPABILITY

The RF power that can be safely handled by the switch is dependent on the breakdown voltage of the diodes, the maximum diode power dissipation, the bias state of the switch, i.e., whether the switch is ON, OFF, or in an attenuation condition, and the frequency of the RF signal.

Maximum signal power handling capability of the switch as a function of attenuation and frequency are shown in the Average Power curves of Figure 10. Under pulsed signal conditions, the diode breakdown voltage limits the peak power that can be handled in the low attenuation range. This is shown in the top curves of Figure 10 for a typical 2 μsec pulse at 2% duty cycle. There are four operating conditions which are of interest and warrant additional comment.

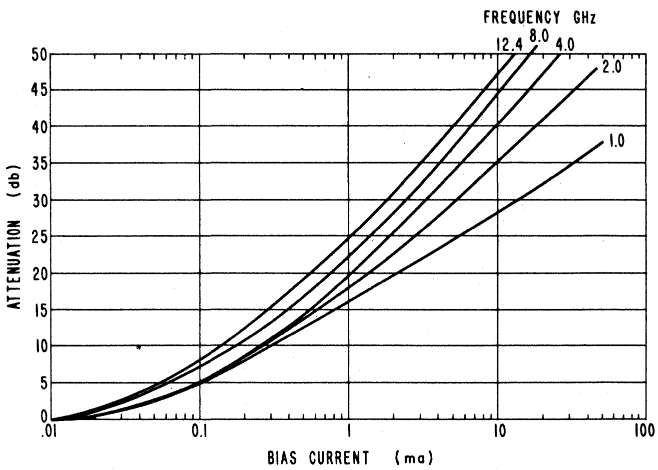


Figure 9. Typical isolation vs. bias current and frequency.

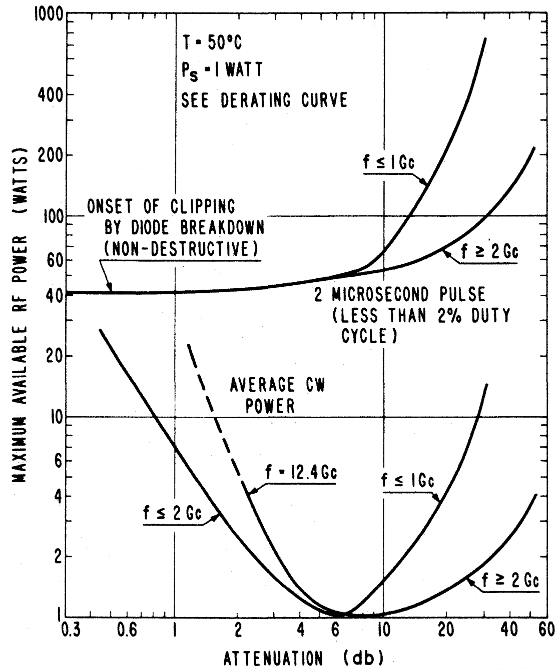


Figure 10. Power handling capabilities.

Condition	Comments
Switch ON Frequency $\leq$ 2 GHz Attenuation (α) $\leq$ 6 dB	For frequencies below 1 GHz and high power levels some modulation of insertion loss may occur because of current flow during half of the RF cycle. A reverse bias voltage $\geq$ 10% of the RF voltage will minimize this effect. Less power can be handled than at higher frequencies. The curve labeled f $\leq$ 2 GHz is the one to use for frequencies $\leq$ 2 GHz. For example, when the switch is ON (α = 1 dB) the maximum available power that can be handled at 1 GHz is 7 watts.
Switch ON Frequency $\geq$ 2 GHz $\alpha \leq$ 6 dB	For 0.3 dB $< \alpha <$ 1.0 dB diode breakdown voltage is the limiting factor under pulsed signal conditions. For 1.0 $< \alpha <$ 6 dB, the maximum available power for frequencies between 2 and 12.4 GHz can be found by linear interpolation between the curves labeled f $\leq$ 2 GHz and f = 12.4 GHz.
Switch OFF Frequency $\leq$ 1 GHz $\alpha \geq$ 10 dB	The curve labeled $\leq$ 1 GHz should be used. For example, an attenuation of 30 dB will permit a maximum available power of 10 watts.
Switch OFF Frequency $\geq$ 2 GHz $\alpha \geq$ 10 dB	Less maximum available power can be used than at lower frequencies. The curve labeled f $\geq$ 2 GHz should be used for frequencies $\geq$ 2 GHz. Between 1 and 2 GHz linear interpolation should be used.

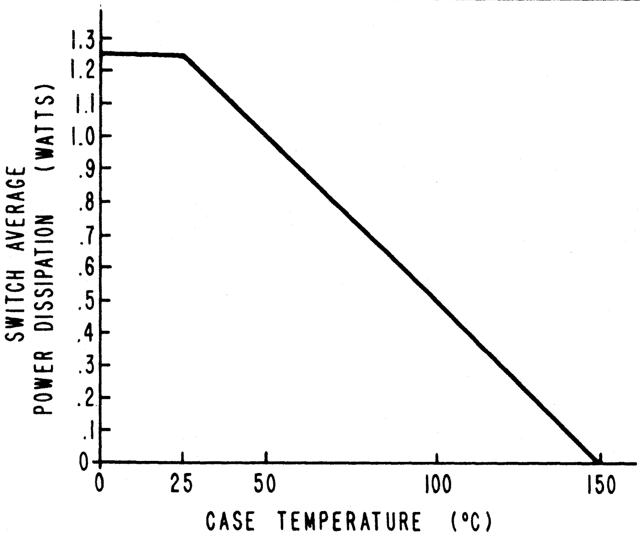


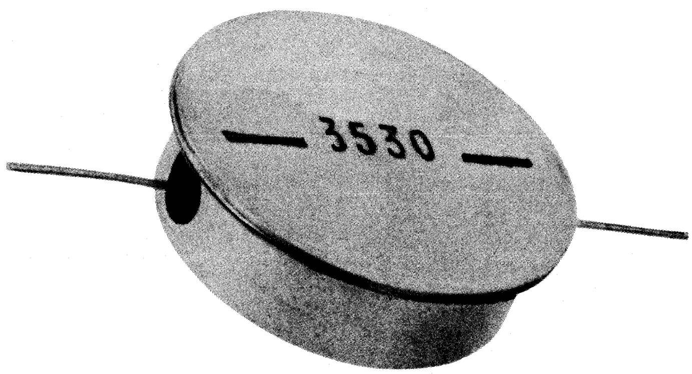
Figure 11. Temperature derating curve.

In the attenuation mode the maximum power dissipation in the switch occurs for 6 dB attenuation. In this state the switch dissipates 1/2 of the available power. This dissipation will be divided between the two diodes equally at low frequencies, unequally at high frequencies. A conservative rating is obtained by assuming all of the dissipation to be in one diode. Therefore:

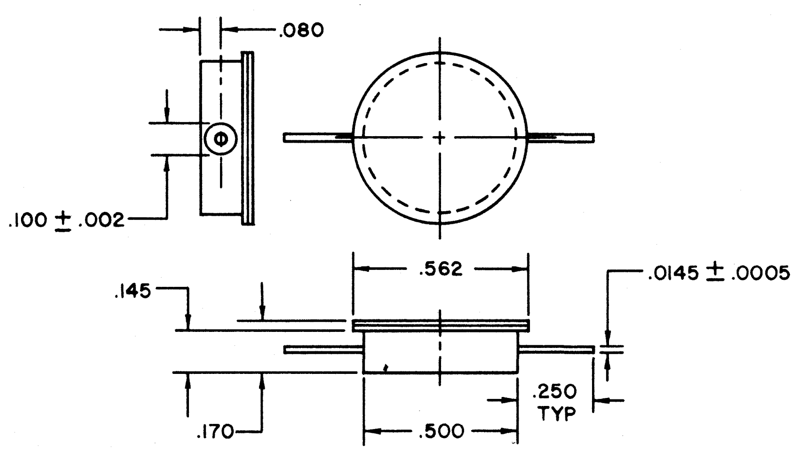
Maximum available RF power (25°C) 1.25 watts
(see derating curve, Figure 11)

HEWLETT PACKARD

MICROWAVE SWITCH HPA 3530



- **BROAD BANDWIDTH—DC to 12.4 GHz**
- **LOW INSERTION LOSS—0.5 to 1.5 dB**
- **HIGH ISOLATION—25 to 50 dB**
- **FAST SWITCHING—50 nanoseconds typical**
- **MINIATURE SIZE—Weight 4.3 grams**
- **HERMETICALLY SEALED**
- **ALL SOLID STATE**



ALL TOLERANCES ± .005" EXCEPT AS NOTED

DESCRIPTION

The HPA 3530 is a broad-band solid-state switch or attenuator suitable for use from DC to 12.4 GHz. It consists of two oxide passivated silicon PIN diodes which are functionally integrated into a broad-band 50-ohm microwave structure. The dimensions of the switch are optimized for use in 50 ohms stripline. The housing is hermetically sealed and all internal joints are welded or thermal compression bonded, using proven materials to assure reliable operation under severe environmental conditions.

APPLICATION

The HPA 3530 is a versatile diode switch ideally suited for a large variety of high frequency and microwave circuits including: Pulse Modulators, Amplitude Modulators, Phase Shifters, Multiple Throw Switches, Phased Array Antennas, T-R Switches, Limiters, Attenuators, Automatic Gain Control Circuits, Power Leveling Circuits, Redundant Microwave Systems, Signal Synthesizers, Frequency Synthesizers, Suppressed Carrier Modulators, Pulse Shapers, Antenna Lobing Circuits.

ABSOLUTE MAXIMUM RATINGS

Maximum Switch Power Dissipation .... see Figures 9 and 10

Maximum Forward Bias Voltage .... 1 volt

Diode Breakdown Voltage .... 100 volts

MECHANICAL CHARACTERISTICS

Size .... As shown in the Outline Drawing on Page 1

Weight .... 4.3 grams

Materials: Case .... Kovar

Cover .... Nickel

Leads .... Kovar

Finish: Case and Leads .... Gold Plated, 50 μinches minimum

ENVIRONMENTAL CHARACTERISTICS

Temperature, Storage .... — 65° to + 150°C

Temperature, Operating .... — 65° to + 150°C

Temperature Cycling .... Method 1051, Test Condition B

Thermal Shock .... Method 1056, Test Condition A

Humidity .... Method 1021.1, omit initial conditioning

Shock .... Method 2016.1, 5 blows each X_1, Y_1, Y_2, Z orientations, 0.5 ms pulse, 1500 G min., non-operating

Vibration Fatigue .... Method 2046, 60 Hz, 20 G min., non-operating

Vibration Variable Frequency .... Method 2056

Constant Acceleration .... Method 2006, 2000 G

ELECTRICAL SPECIFICATIONS

All specifications are at 25°C and apply to either RF port since the switch is electrically and mechanically symmetrical.

USABLE FREQUENCY RANGE .... DC to 12.4 GHz

VSWR

Switch ON .... 2 maximum
1.5 typical

Switch OFF .... High, dependent on bias current and frequency, typically 50:1

VSWR is determined in a 50Ω system.

ISOLATION AND INSERTION LOSS

Frequency (GHz)	Insertion Loss ($V_R = +5V$) Max.	Typ.	Isolation ($I_{bias} = 100$ mA) Min.	Typ.
DC - 0.5	0.5 dB	0.3 dB	25 dB	28 dB
0.5 - 1.0	0.7	0.3	28	40
1.0 - 2.0	0.7	0.3	35	43
2.0 - 4.0	1.0	0.7	40	48
4.0 - 8.0	1.0	0.7	45	53
8.0 - 12.4	1.5	1.0	45	53

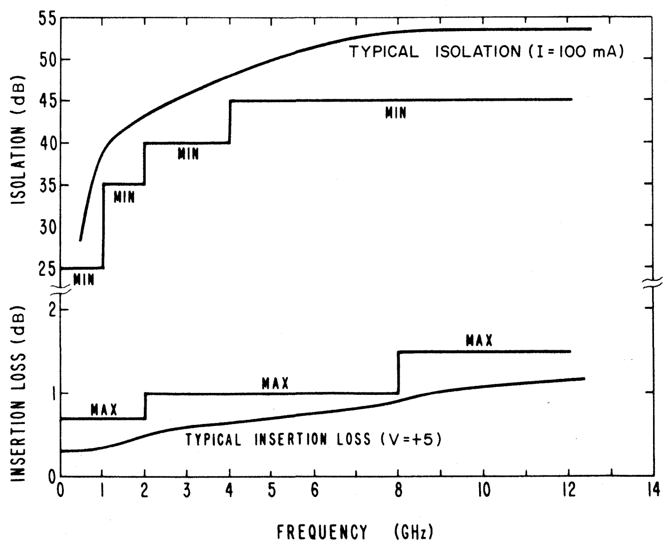


Figure 1. Isolation and Insertion Loss

SWITCHING CHARACTERISTIC

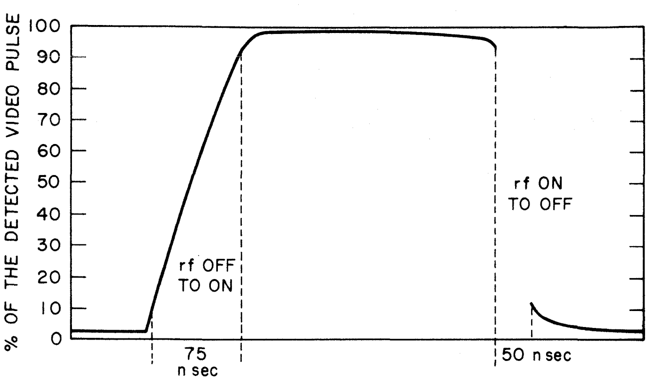
The switching characteristic is measured over a dynamic range of approximately 10 dB of detected RF power. The RF OFF to ON time is measured between 10 dB of isolation and a point 0.45 dB above the insertion loss level of the 3530. The RF ON to OFF time is measured between the insertion loss plus 0.45 dB point and 10 dB of isolation. This is a 10%-90% measurement of the detected video pulse when square law detection obtains in the system.

The measurement is made with the switch biased OFF with a forward current of 100 mA and driven ON by a voltage pulse of 50 volts having a rise and fall time of 20 nanoseconds as obtained from a pulse generator with a 50-ohm source impedance, such as the Hewlett-Packard Model 214A.

SWITCHING SPECIFICATION

Rise Time, $t_{off\ to\ on}$ ....75 nsec maximum

Fall Time, $t_{on\ to\ off}$ ....50 nsec maximum



► **Figure 2.** Typical RF Switching Characteristics

TYPICAL CHARACTERISTICS

Attenuation. The HPA 3530 switch exhibits no fine grain attenuation structure. Typical variation of attenuation as a function of bias current, frequency and temperature are shown in Figures 3, 4, and 5.

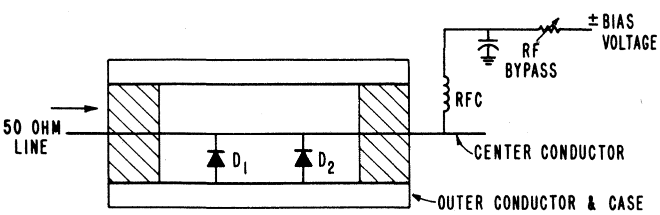
Phase Shift. The phase shift characteristics of the switch are a function of frequency and the electrical length at a specific bias. The air equivalent electrical lengths for the two principal bias conditions are:

Switch ON ....2.5-3.0 cm between front surfaces of the two RF ports, depending on frequency

Switch OFF..........1.3 cm between either front surface and the internal short

APPLICATION INFORMATION

Switch Biasing. Proper biasing of the switch can be understood by reference to the internal circuit of the switch as represented by the following schematic diagram:



The internal compensated microwave structure is not shown since it does not affect the low frequency bias currents. Bias can be applied to either center conductor. The switch is considered to be "ON" or passing an RF signal when the bias voltage is zero or a positive value. Under this condition the diodes are in a high impedance state and the current through them is typically less than one

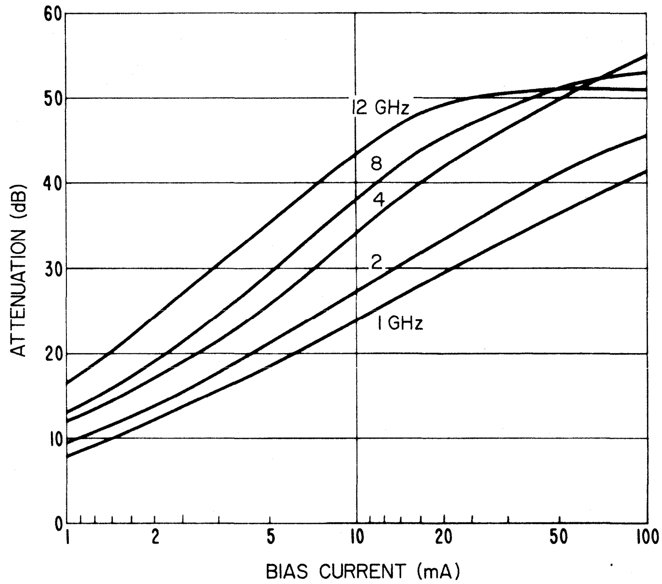


Figure 3. Typical Attenuation vs. Bias Current

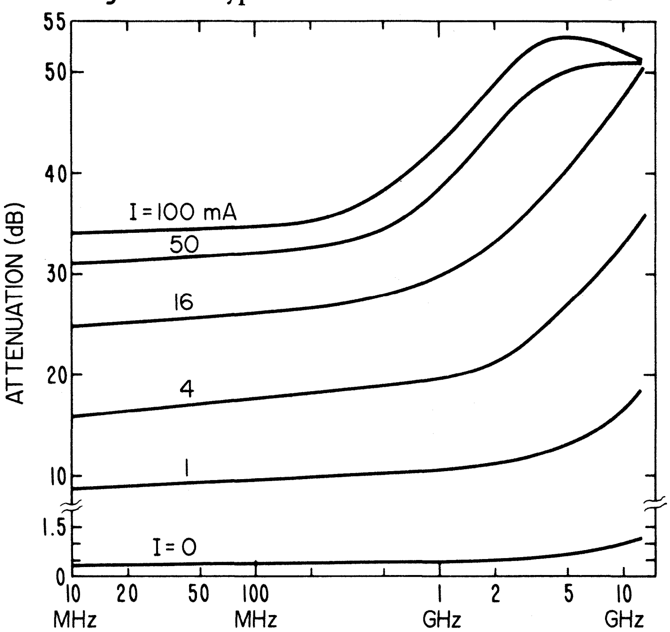


Figure 4. Typical Attenuation vs. Frequency and Bias Current

microampere. The switch is considered to be "OFF" or blocking an RF signal when the bias voltage is negative. Under this condition the diodes are forward biased and are in a low impedance state. The individual diodes are matched and the total bias current is divided equally between them. The magnitude of the forward bias current determines the degree of attenuation provided by the switch as shown in Figure 3. Maximum attenuation, or full isolation, is obtained for bias currents on the order of 100 mA. The forward bias current-voltage characteristic of the switch is shown in Figure 6.

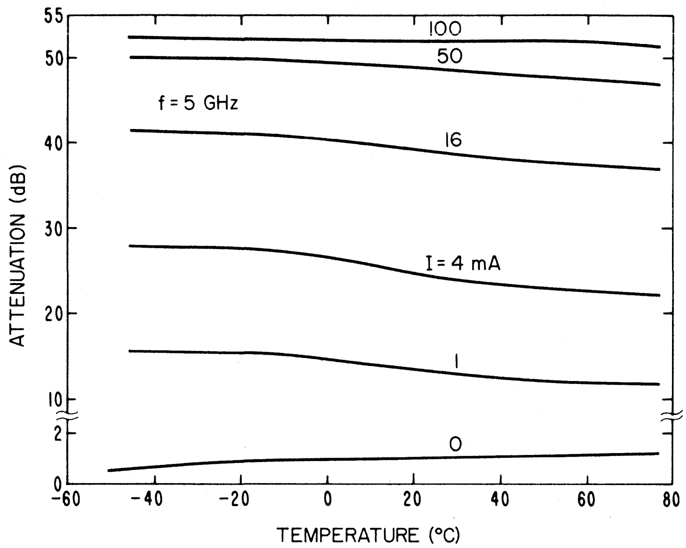


Figure 5. Typical Attenuation vs. Temperature and Bias Current

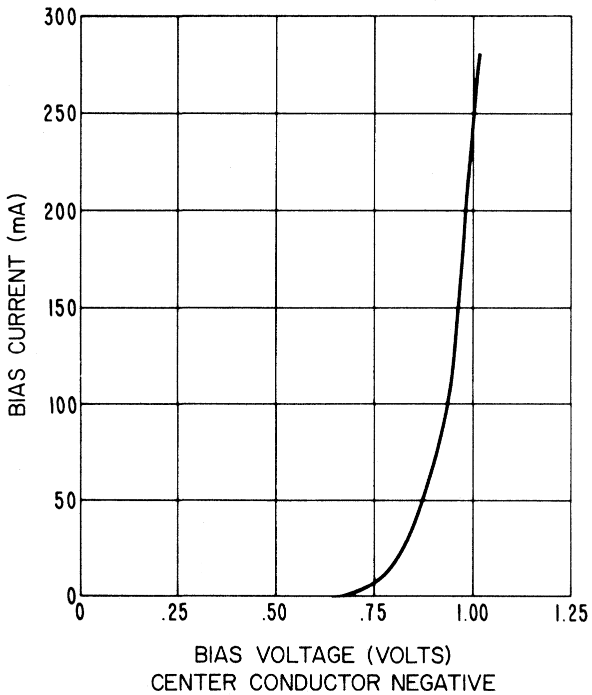


Figure 6. Typical Bias Terminal Voltage vs. Current Characteristic

Biasing for Fast Switching. The rise and fall times of the RF envelope shown in Figure 2 depend on the attenuation levels at which the switch is considered to be ON or OFF, on the magnitude of the bias current, and on the bias pulse shape. Faster switching can be obtained by operating at the lowest possible forward bias current consistent with the necessary isolation level. Faster switching may also be obtained by suitable shaping of the bias current waveform as illustrated in Figure 7.

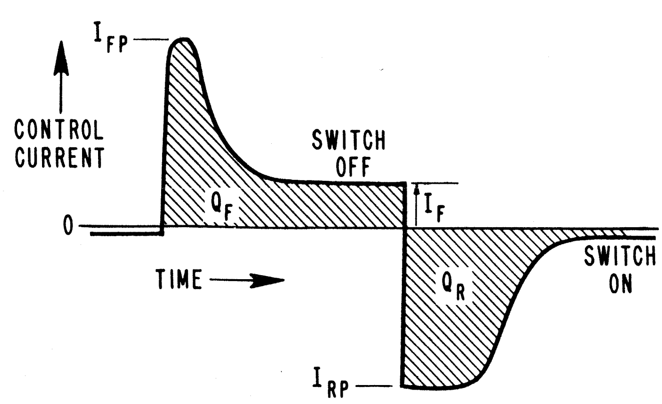


Figure 7. Control Current Pulse Shape for Fast Switching

The initially high peak turn-OFF current I_{FP} is used to effect a rapid decrease in diode impedance. I_{FP} must be reduced to I_F to assure that the stored charge Q_R, which is approximately equal to $I_F \times 10^{-7}$ coulombs, is kept to a minimum. I_F should not exceed the value necessary for the desired isolation in the OFF condition. Similarly a high peak turn-ON current I_{RP} is desirable to quickly remove the charge stored in the diodes and return them to the high impedance state. The values of I_{FP} and I_{RP} and their duration must stay within the limits by the peak bias current and the maximum power dissipation.

An elementary transistor driver suitable for obtaining 50 nanosecond rise and fall times is shown in Figure 8. No pulse shaping is used. The RF filter should not affect the bias pulse but may contain an RF by-pass such as the 45 pf capacitor used in this circuit. Fast switching silicon diodes D_1 and D_2 serve only to offset the emitter voltage so that the second transistor may turn off.

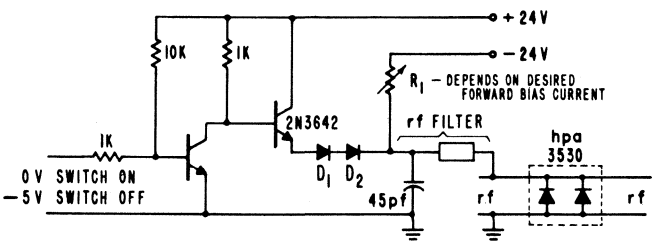


Figure 8. Example of a Transistor Switch Driver

RF POWER HANDLING CHARACTERISTICS

The incident RF power that can be safely handled by the modules is dependent on the breakdown voltage of the diodes, the maximum diode power dissipation, the bias state of the module (i.e., whether the unit is ON, OFF, or in an intermediate attenuation condition), and the frequency of the RF signals.

Maximum safe signal power handling capability of the modules as a function of attenuation and frequency are shown by Figure 9. Note that safe limits for both pulse and CW conditions are given. Under full isolation conditions the limiting factor which defines power handling capability is energy storage capacity of the diodes. Under insertion loss conditions the limiting factor which defines power handling capability is diode breakdown voltage.

The limits defined for pulse power handling assumed a one microsecond pulse at a duty factor of 1% maximum. The table below defines correction factors to be used for pulse durations of 0.5 μsec and 2.0 μsec. These factors may be used directly to modify incident power limitations read from Figure 9.

Pulse Width	3530
0.5 μsec	1.55
2.0 μsec	0.62

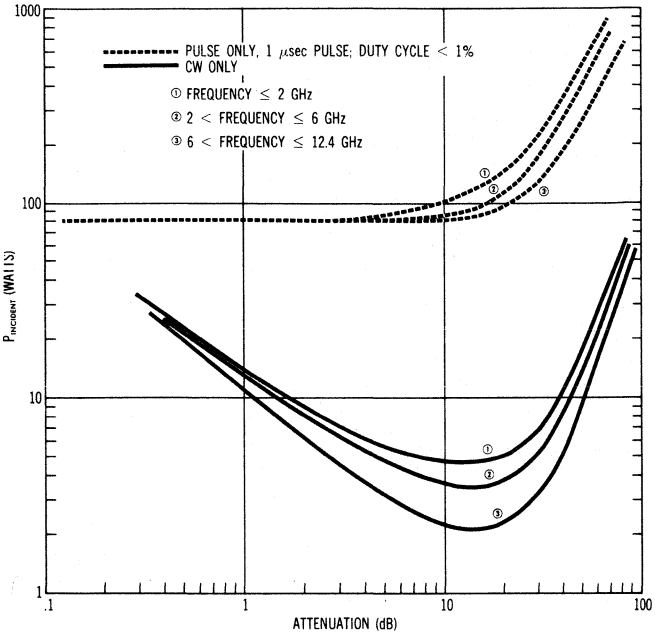


Figure 9. Maximum Allowable Incident Power as a Function of Attenuation

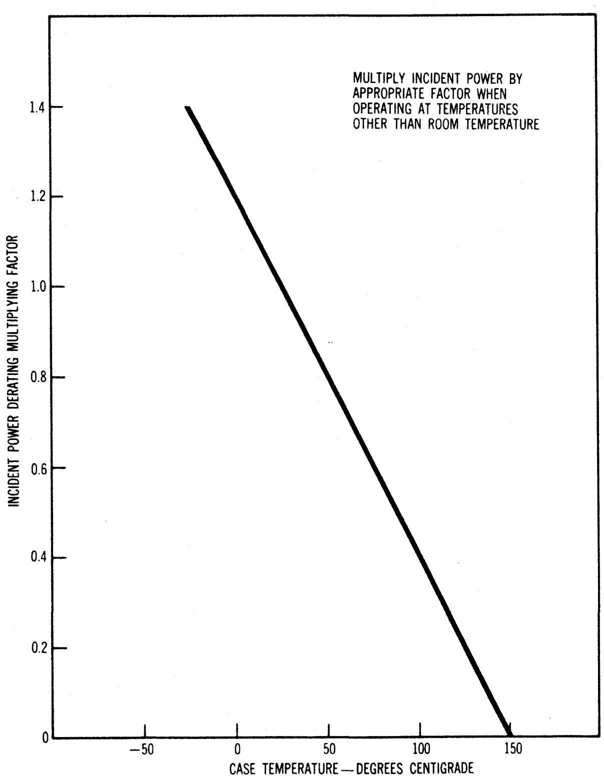


Figure 10. Derating Curve

SWITCH MOUNTING

The switch may be mounted in any position. An appropriate microwave structure for use with the switch is a dielectrically loaded stripline. An example of this application is shown in Figure 11.

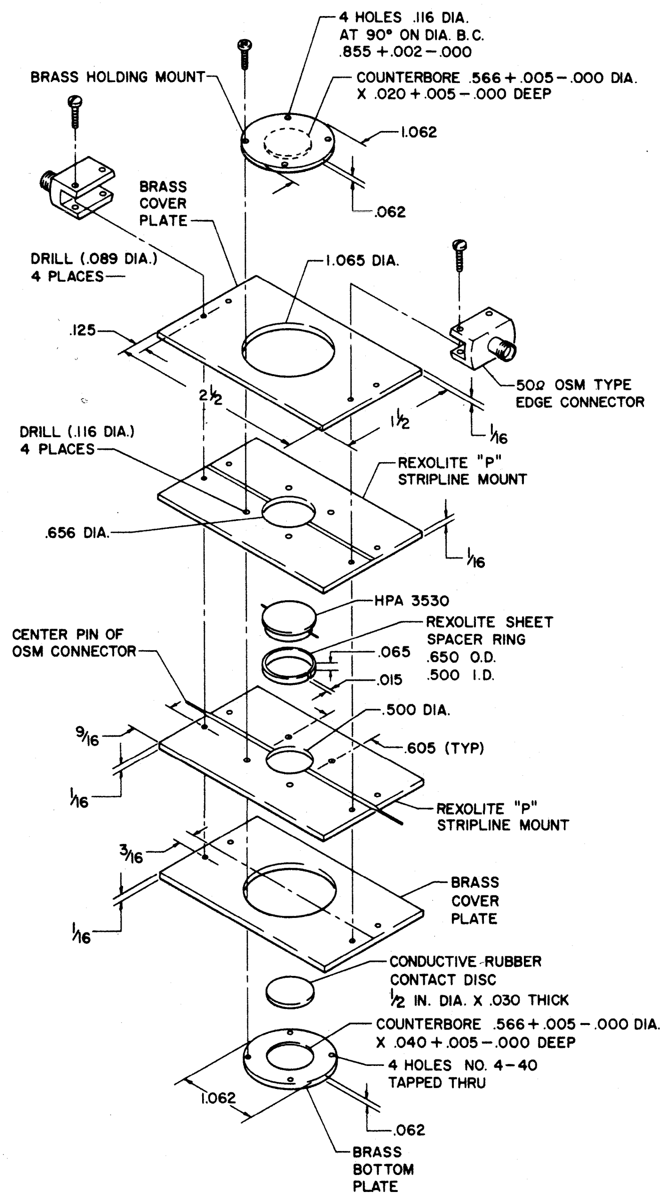


Figure 11.

HEWLETT PACKARD

MICROWAVE SWITCH HPA 3531

BROAD BANDWIDTH—12.4 to 18 GHz

LOW INSERTION LOSS—1.5 dB typical

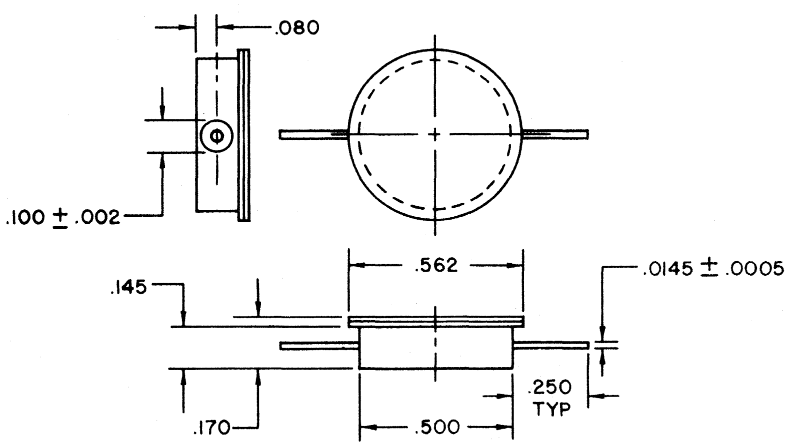
HIGH ISOLATION—45 dB

FAST SWITCHING—50 nanoseconds typical

MINIATURE SIZE—Weight 4.3 grams

HERMETICALLY SEALED

ALL SOLID STATE



ALL TOLERANCES ± .005" EXCEPT AS NOTED

DESCRIPTION

The HPA 3531 is a broad-band solid-state switch or attenuator suitable for use from 12.4 to 18 GHz. It consists of two oxide passivated silicon PIN diodes which are functionally integrated into a broad-band 50-ohm microwave structure. The dimensions of the switch are optimized for use in 50 ohms stripline RF structures. The housing is hermetically sealed and all internal joints are welded or thermal compression bonded, using proven materials to assure reliable operation under severe environmental conditions.

APPLICATION

The HPA 3531 is a versatile diode switch ideally suited for a large variety of high frequency and microwave circuits including: Pulse Modulators, Amplitude Modulators, Phase Shifters, Multiple Throw Switches, Phased Array Antennas, T-R Switches, Limiters, Attenuators, Automatic Gain Control Circuits, Power Leveling Circuits, Redundant Microwave Systems, Signal Synthesizers, Frequency Synthesizers, Suppressed Carrier Modulators, Pulse Shapers, Antenna Lobing Circuits.

ABSOLUTE MAXIMUM RATINGS

Maximum Diode Junction Temperature ....150°C
Maximum Switch Power Dissipation ..See Figures 5 and 6
Maximum Forward Bias Voltage ....1 volt
Diode Breakdown Voltage ....100 volts

MECHANICAL CHARACTERISTICS

Size ....As shown in the Outline Drawing on Page 1
Weight ....4.3 grams
Materials: Case ....Kovar
Cover ....Nickel
Leads ....Kovar
Finish: Case and Leads ....Gold Plated, 50 μinches minimum

ENVIRONMENTAL CHARACTERISTICS

Temperature, Storage ....— 65°C to + 150°C
Temperature, Operating ....— 65°C to + 150°C
Temperature Cycling ....Method 1051, Test Condition B
Thermal Shock ....Method 1056, Test Condition A
Humidity ....Method 1021.1, omit initial conditioning
Shock ....Method 2016.1, 5 blows each X_1, Y_1, Y_2, Z orientations, 0.5 ms pulse, 1500 G min, non-operating
Vibration Fatigue ....Method 2046, 60 Hz, 20 G min., non-operating
Vibration Variable Frequency ....Method 2056
Constant Acceleration ....Method 2006, 2000 G

ELECTRICAL SPECIFICATIONS

All specifications are at 25°C and apply to either RF port since the switch is electrically and mechanically symmetrical.

USABLE FREQUENCY RANGE ....12.4 to 18 GHz

VSWR

Switch ON ....2:1 maximum, 1.5:1 typical
Switch OFF ....High, dependent on bias current and frequency
VSWR is determined in a 50Ω system.

ISOLATION AND INSERTION LOSS

Frequency (GHz)	Insertion Loss ($I_{BIAS} = -5$ V) Max.	Typ.	Isolation ($I_{BIAS} = 100$ mA) Min.	Typ.
12.4 - 18	1.8 dB	1.5 dB	45 dB	50 dB

SWITCHING CHARACTERISTICS

The switching characteristic is measured over a dynamic range of approximately 10 dB of detected RF power. The RF OFF-to-ON time is measured between 10 dB of isolation and a point 0.45 dB above the insertion loss level of the 3531. The RF ON-to-OFF time is measured between the insertion loss plus 0.45 dB point and 10 dB of isolation. This is a 10%-90% measurement of the detected video pulse when square law detection obtains in the systems.

The measurement is made with the switch biased OFF with a forward current of 100 mA and driven ON by a voltage pulse of 50 volts having a rise and fall time of 20 nanoseconds as obtained from a pulse generator with a 50Ω source impedance, such as the Hewlett-Packard Model 214A.

TYPICAL CHARACTERISTICS

ATTENUATION. The HPA 3531 switch exhibits no fine grain attenuation structure. Typical variation of attenuation as a function of bias current is shown in Figure 1.

PHASE SHIFT. The phase shift characteristics of the switch are a function of frequency and the electrical length at a specific bias. The air equivalent electrical lengths for the two principal bias conditions are:

Switch ON..............................2.5 cm between front surfaces of the two RF ports.
Switch OFF................1.3 cm between either front surface and the internal short.

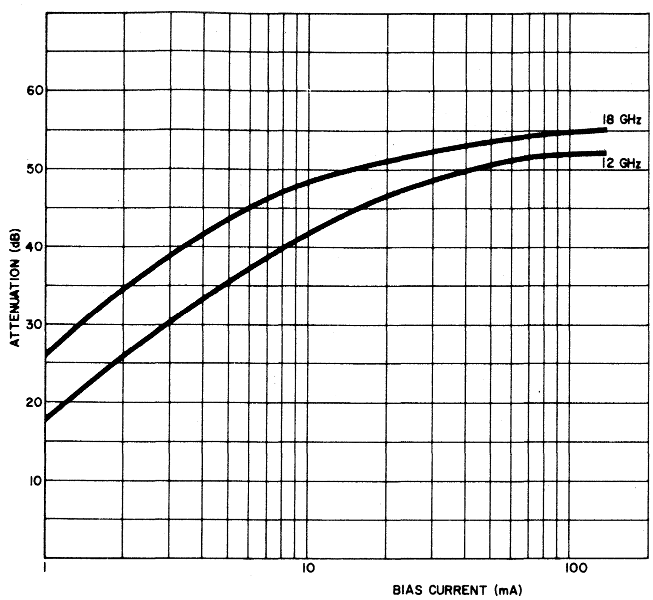
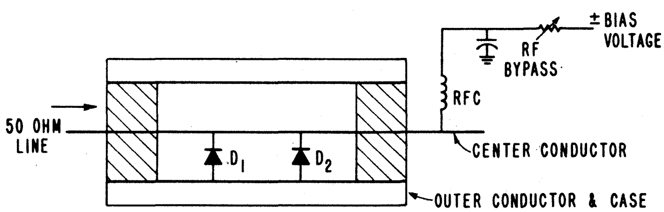


Figure 1. Typical Attenuation vs. Bias Current

APPLICATION INFORMATION

SWITCH BIASING. Proper biasing of the switch can be understood by reference to the internal circuit of the switch as represented by the following schematic diagram:



The internal compensated microwave structure is not shown since it does not affect the low frequency bias currents. Bias can be applied to either center conductor. The switch is considered to be "ON" or passing an RF signal when the bias voltage is zero or a positive value. Under this condition the diodes are in a high impedance state and the current through them is typically less than one microampere. The switch is considered to be "OFF" or blocking an RF signal when the bias voltage is negative. Under this condition the diodes are forward biased and are in a low impedance state. The individual diodes are matched and the total bias current is divided equally between them. The magnitude of the forward bias current determines the degree of attenuation provided by the switch as shown in Figure 1. Maximum attenuation, or full isolation, is obtained for the bias currents on the order of 100 mA. The forward bias current-voltage characteristic of the switch is shown in Figure 2.

BIASING FOR FAST SWITCHING. The rise and fall times of the RF envelope depend on the attenuation levels at which the switch is considered to be ON or OFF, on the magnitude of the bias current, and on the bias pulse shape. Faster switching can be obtained by operating at the lowest possible forward bias current consistent with the necessary isolation level. Faster switching may also be obtained by suitable shaping of the bias current waveform as illustrated in Figure 3.

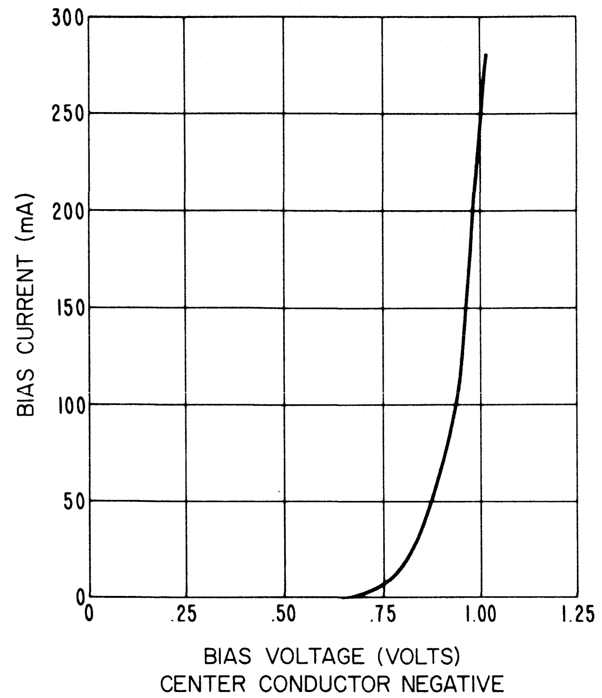


Figure 2. Typical Bias Terminal Voltage vs. Current Characteristic

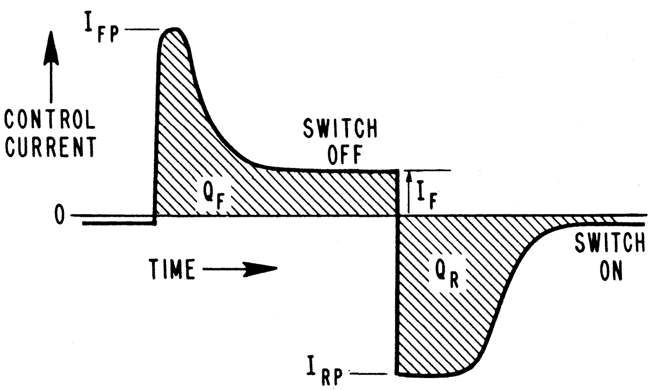


Figure 3. Control Current Pulse Shape for Fast Switching

The initially high peak turn-OFF current I_{FP} is used to effect a rapid decrease in diode impedance. I_{FP} must be reduced to I_F to assure that the stored charge Q_R, which is approximately equal to $I_F \times 10^{-7}$ coulombs, is kept to a minimum. I_F should not exceed the value necessary for the desired isolation in the OFF condition. Similarly a high peak turn-ON current I_{RP} is desirable to quickly remove the charge stored in the diodes and return them to the high impedance state. The values of I_{FP} and I_{RP} and their duration must stay within the limits by the peak bias current and the maximum power dissipation.

An elementary transistor driver suitable for obtaining 50 nanosecond rise and fall times is shown in Figure 4. No pulse shaping is used. The RF filter should not affect the bias pulse but may contain an RF by-pass such as the 45 pF capacitor used in this circuit. Fast switching silicon diodes D_1 and D_2 serve only to offset the emitter voltage so that the second transistor may turn off.

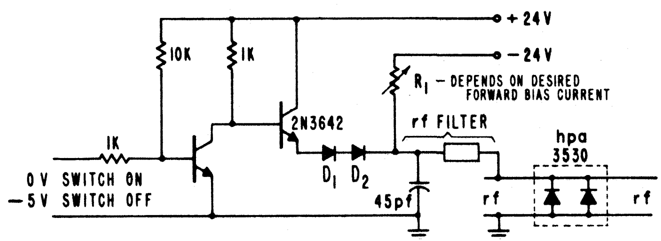


Figure 4. Example of a Transistor Switch Driver

RF POWER HANDLING CHARACTERISTICS

The incident RF power that can be safely handled by the modules is dependent on the breakdown voltage of the diodes, the maximum diode power dissipation, the bias state of the module (i.e., whether the unit is ON, OFF, or in an intermediate attenuation condition), and the frequency of the RF signals.

Maximum safe signal power handling capability of the modules as a function of attenuation and frequency are shown by Figure 5. Note that safe limits for both pulse and CW conditions are given. Under full isolation conditions the limiting factor which defines power handling capability is energy storage capacity of the diodes. Under insertion loss conditions the limiting factor which defines power handling capability is diode breakdown voltage.

The limits defined for pulse power handling assumed a one microsecond pulse at a duty factor of 1% maximum. The table below defines correction factors to be used for pulse durations of 0.5 μsec and 2.0 μsec. These factors may be used directly to modify incident power limitations read from Figure 5.

Pulse Width	3531
0.5 μsec	1.55
2.0 μsec	0.62

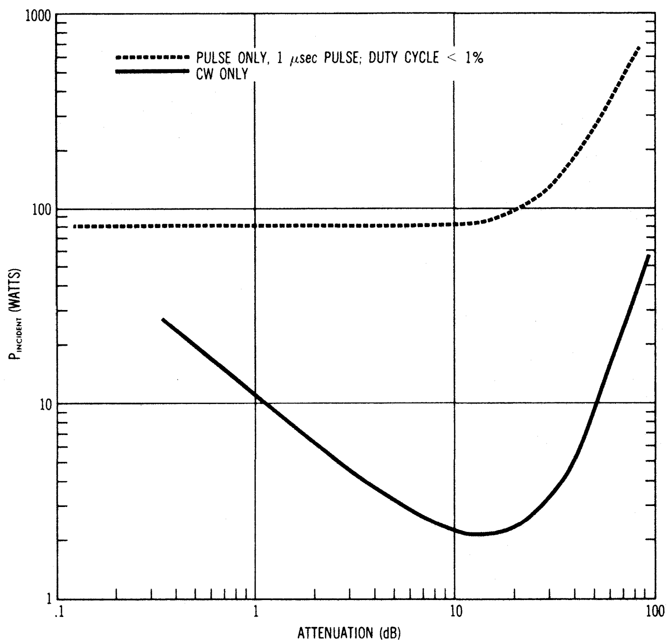


Figure 5. Maximum Allowable Incident Power as a Function of Attenuation

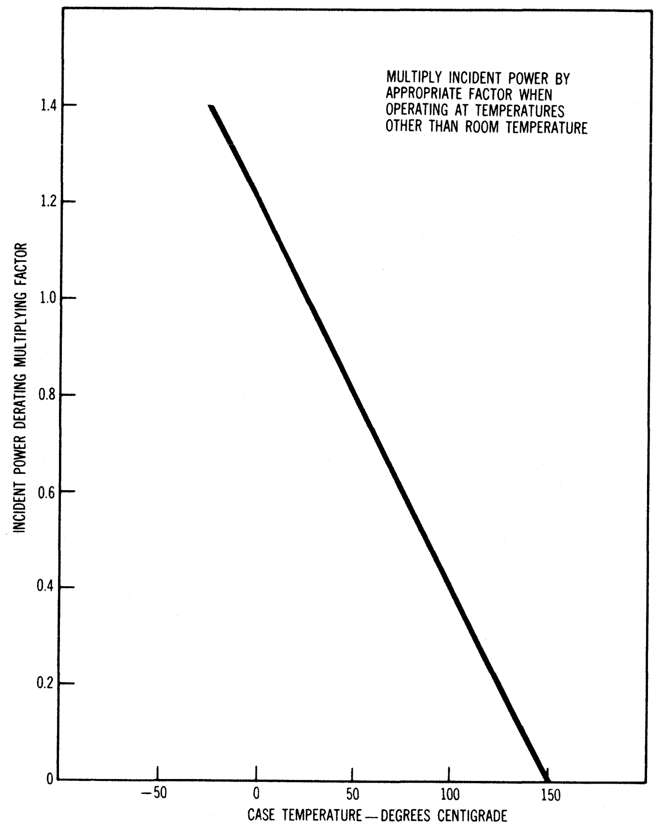


Figure 6. Derating Curve

HEWLETT hp PACKARD

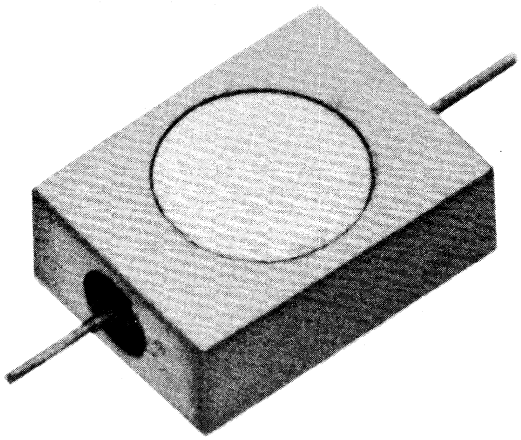
STRIPLINE MICROWAVE SWITCH

HP 33535A

BROAD BANDWIDTH--dc to 18 GHz

LOW INSERTION LOSS--0.5 to 1.5 dB

HIGH ISOLATION--25 to 50 dB



FAST SWITCHING--50 nanoseconds typical

MINIATURE SIZE--Weight 4.3 grams

HERMETICALLY SEALED

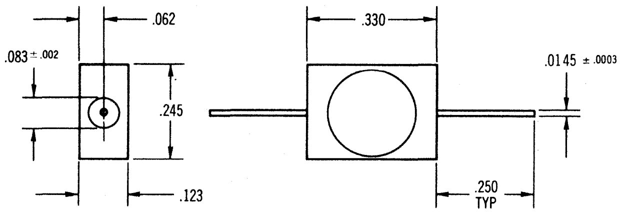
HYBRID INTEGRATED SOLID STATE

A broad-band solid-state switch or attenuator, the HP 33535A is suitable for use from dc to 18 GHz. It consists of two oxide passivated silicon PIN diodes which are functionally integrated into a broad-band 50-ohm microwave . . .

structure. The dimensions of the switch are optimized for use in 50-ohm stripline. The housing is hermetically sealed and all internal joints are welded or thermal compression bonded, using proven materials to assure reliable operation under severe environmental conditions.

APPLICATION

The HP 33535A is a versatile diode switch ideally suited for a large variety of high frequency and microwave circuits including: pulse modulators, amplitude modulators, phase shifters, multiple throw switches, phased array antennas, T-R switches, limiters, attenuators, automatic gain control circuits, power leveling circuits, redundant microwave systems, signal synthesizers, frequency synthesizers, suppressed carrier modulators, pulse shapers, and antenna lobing circuits.



All tolerances ± 0.005 inch except as noted

ELECTRICAL SPECIFICATIONS

All specifications are at 25°C and apply to either RF port since the switch is electrically and mechanically symmetrical.

USABLE FREQUENCY RANGE ....dc to 18 GHz

VSWR

Switch ON ....2 maximum
1.5 typical

Switch OFF ....High, dependent on bias current and frequency, typically 20:1

VSWR is determined in a 50Ω system.

ISOLATION AND INSERTION LOSS

	Insertion Loss ($V_R = +5V$)		Isolation ($I_{bias} = -100mA$)	
Frequency (GHz)	Max.	Typ.	Min.	Typ.
dc - 0.5	0.5 dB	0.3 dB	25 dB	28 dB
0.5 - 1.0	0.7	0.3	28	40
1.0 - 2.0	0.7	0.3	35	43
2.0 - 4.0	1.0	0.7	40	48
4.0 - 8.0	1.0	0.7	45	53
8.0 - 12.4	1.5	1.0	45	53
12.4 - 18.0	1.8	1.5	45	55

ABSOLUTE MAXIMUM RATINGS

Maximum Switch Power Dissipation ....see Figures 8 and 9

Maximum Forward Bias Voltage ....1 volt

Diode Breakdown Voltage ....100 volts

MECHANICAL CHARACTERISTICS

Size ....As shown in the Outline Drawing (Flattened leads available at no extra cost)

Weight ....4.3 grams

Materials: Case ....Kovar

Cover ....Nickel

Leads ....Kovar

Finish: Case and Leads ....Gold Plated, 50 μinches minimum

ENVIRONMENTAL CHARACTERISTICS

Temperature, Storage ....— 65° to + 150°C

Temperature, Operating ....— 65° to + 150°C

Temperature Cycling ....Method 1051, Test Condition B

Thermal Shock ....Method 1056, Test Condition A

Humidity ....Method 1021.1, omit initial conditioning

Shock ....Method 2016.1, 5 blows each X_1, Y_1, Y_2, Z orientations, 0.5 ms pulse, 1500 G min., non-operating

Vibration Fatigue ....Method 2046, 60 Hz, 20 G min., non-operating

Vibration Variable Frequency ....Method 2056

Constant Acceleration ....Method 2006, 2000 G

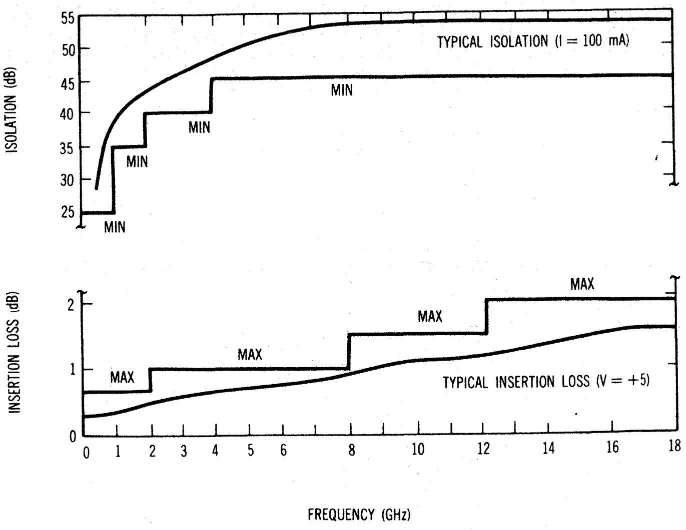


Figure 1. Isolation and insertion loss

SWITCHING CHARACTERISTIC

The switching characteristic is measured over a dynamic range of approximately 10 dB of detected RF power. The RF OFF to ON time is measured between 10 dB of isolation and a point 0.45 dB above the insertion loss level of the 33535A. The RF ON to OFF time is measured between the insertion loss plus 0.45 dB point and 10 dB of isolation. This is a 10%-90% measurement of the detected video pulse when square law detection obtains in the system.

The measurement is made with the switch biased OFF with a forward current of 100 mA and driven ON by a voltage pulse of 50 volts having a rise and fall time of 20 nanoseconds as obtained from a pulse generator with a 50-ohm source impedance, such as the Hewlett-Packard Model 214A.

SWITCHING SPECIFICATION

Rise Time, $t_{off\ to\ on}$ ....75 nsec maximum
Fall Time, $t_{on\ to\ off}$ ....50 nsec maximum

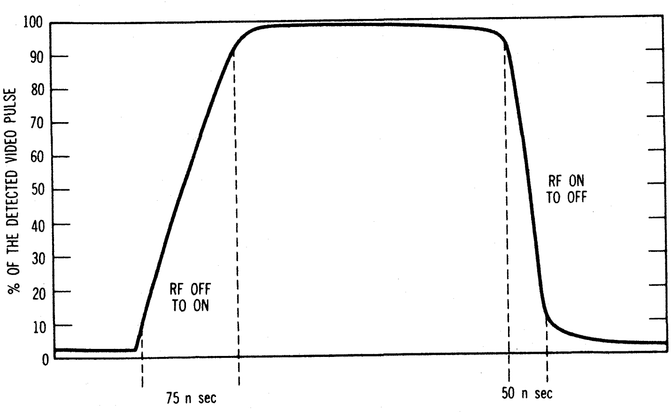


Figure 2. Typical RF switching characteristics

TYPICAL CHARACTERISTICS

Attenuation. The HP 33535A switch exhibits no fine grain attenuation structure. Typical variation of attenuation as a function of bias current, frequency and temperature are shown in Figures 3 and 4.

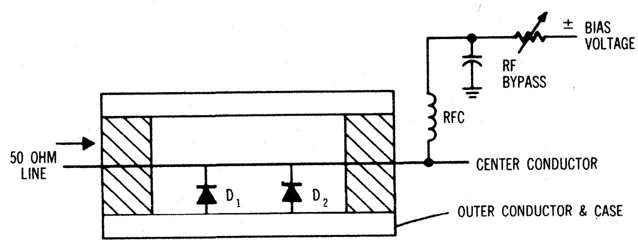
Phase Shift. The phase shift characteristics of the switch are a function of frequency and the electrical length at a specific bias. The air equivalent electrical lengths for the two principal bias conditions are:

Switch ON ....1.6-2.1 cm between front surfaces of the two RF ports, depending on frequency

Switch OFF..........0.9 cm between either front surface and the internal short

APPLICATION INFORMATION

Switch Biasing. Proper biasing of the switch can be understood by reference to the internal circuit of the switch as represented by the following schematic diagram:



The internal compensated microwave structure is not shown since it does not affect the low frequency bias currents. Bias can be applied to either center conductor. The switch is considered to be "ON" or passing an RF signal when the bias voltage is zero or a positive value. Under this condition the diodes are in a high impedance state and the current through them is typically less than one microampere. The switch is considered to be "OFF" or blocking an RF signal when the bias voltage is negative. Under this condition the diodes are forward biased and are in a low impedance state. The individual diodes are matched and the total bias current is divided equally between them. The magnitude of the forward bias current determines the degree of attenuation provided by the switch as shown in Figure 3. Maximum attenuation, or full

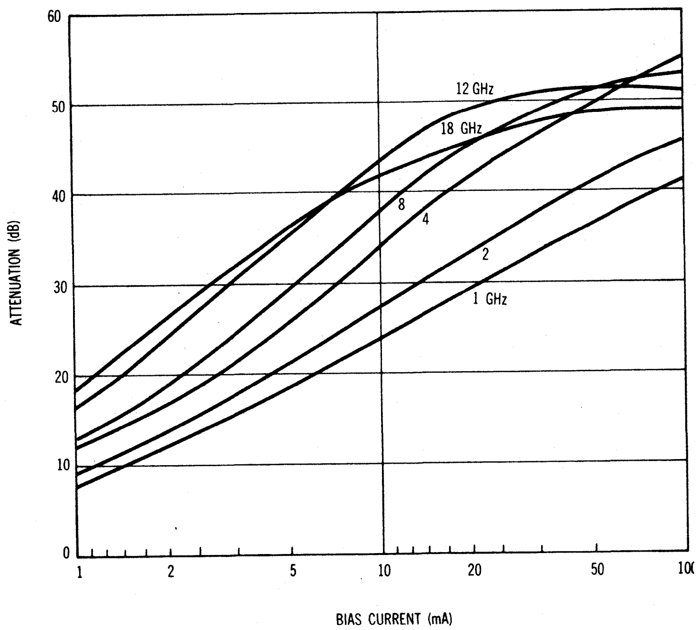


Figure 3. Typical attenuation vs. bias current

isolation, is obtained for bias currents on the order of 100 mA. The forward bias current-voltage characteristic of the switch is shown in Figure 5.

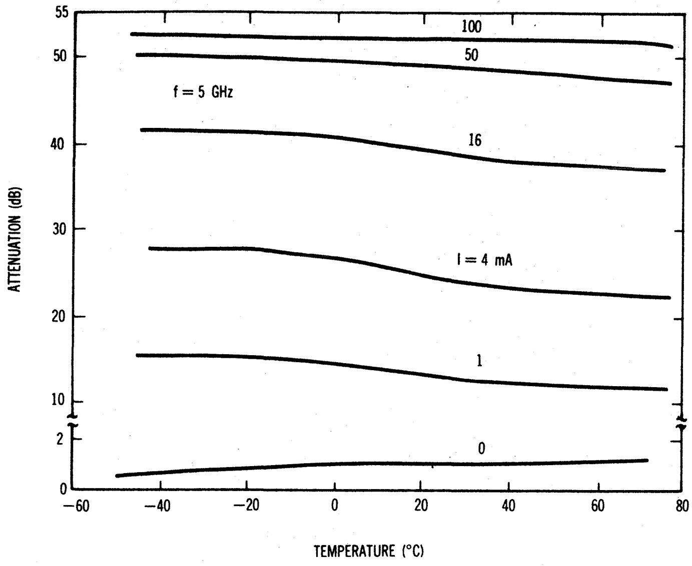


Figure 4. Typical attenuation vs. temperature and bias current

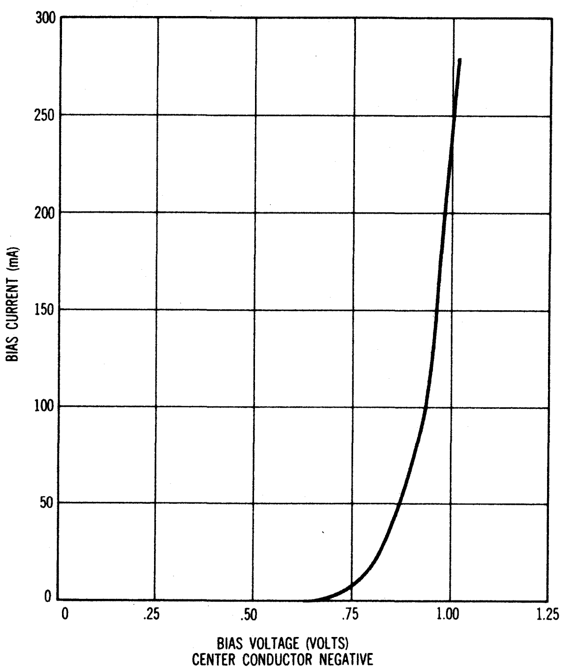


Figure 5. Typical bias terminal voltage vs. current characteristic

Biasing for Fast Switching. The rise and fall times of the RF envelope shown in Figure 2 depend on the attenuation levels at which the switch is considered to be ON or OFF, on the magnitude of the bias current, and on the bias pulse shape. Faster switching can be obtained by operating at the lowest possible forward bias current consistent with the necessary isolation level. Faster switching may also be obtained by suitable shaping of the bias current waveform as illustrated in Figure 6.

The initially high peak turn-OFF current I_{FP} is used to effect a rapid decrease in diode impedance. I_{FP} must be reduced to I_F to assure that the stored charge Q_R, which is approximately equal to $I_F \times 10^{-7}$ coulombs, is kept to a minimum. I_F should not exceed the value necessary for the desired isolation in the OFF condition. Similarly a high peak

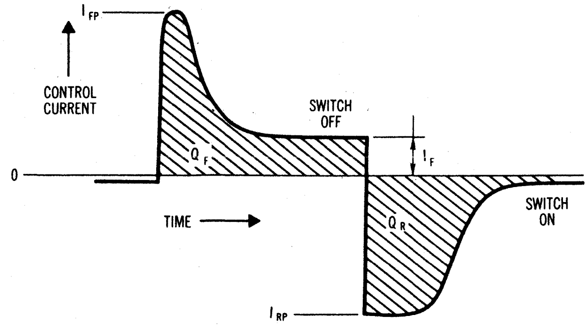


Figure 6. Control current pulse shape for fast switching

turn-ON current I_{RP} is desirable to quickly remove the charge stored in the diodes and return them to the high impedance state. The values of I_{FP} and I_{RP} and their duration must stay within the limits by the peak bias current and the maximum power dissipation.

An elementary transistor driver suitable for obtaining 50 nanosecond rise and fall times is shown in Figure 7. No pulse shaping is used. The RF filter should not affect the bias pulse but may contain an RF by-pass such as the 45 pF capacitor used in this circuit. Fast switching silicon diodes D_1 and D_2 serve only to offset the emitter voltage so that the second transistor may turn off.

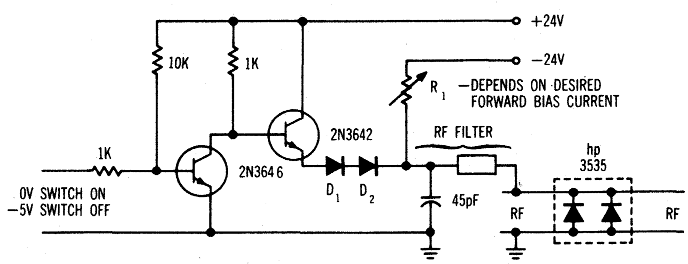


Figure 7. Example of a transistor switch driver

RF POWER HANDLING CHARACTERISTICS

The incident RF power that can be safely handled by the modules is dependent on the breakdown voltage of the diodes, the maximum diode power dissipation, the bias state of the module (i.e., whether the unit is ON, OFF, or in an intermediate attenuation condition), and the frequency of the RF signals.

Maximum safe signal power handling capability of the modules as a function of attenuation and frequency are shown by Figure 8. Note that safe limits for both pulse and CW conditions are given. Under full isolation conditions the limiting factor which defines power handling capability is energy storage capacity of the diodes. Under insertion loss conditions the limiting factor which defines power handling capability is diode breakdown voltage.

The limits defined for pulse power handling assumed a one microsecond pulse at a duty factor of 0.1% maximum. The table below defines correction factors to be used for pulse durations of 0.5 μsec and 2.0 μsec. These factors may be used directly to modify incident power limitations read from Figure 8.

Pulse Width	33535A
0.5 μsec	1.55
2.0 μsec	0.62

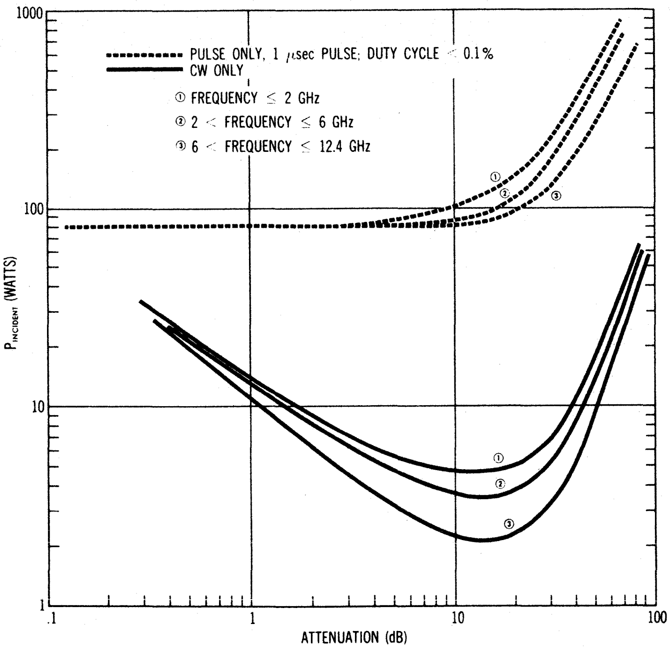


Figure 8. Maximum allowable incident power as a function of attenuation

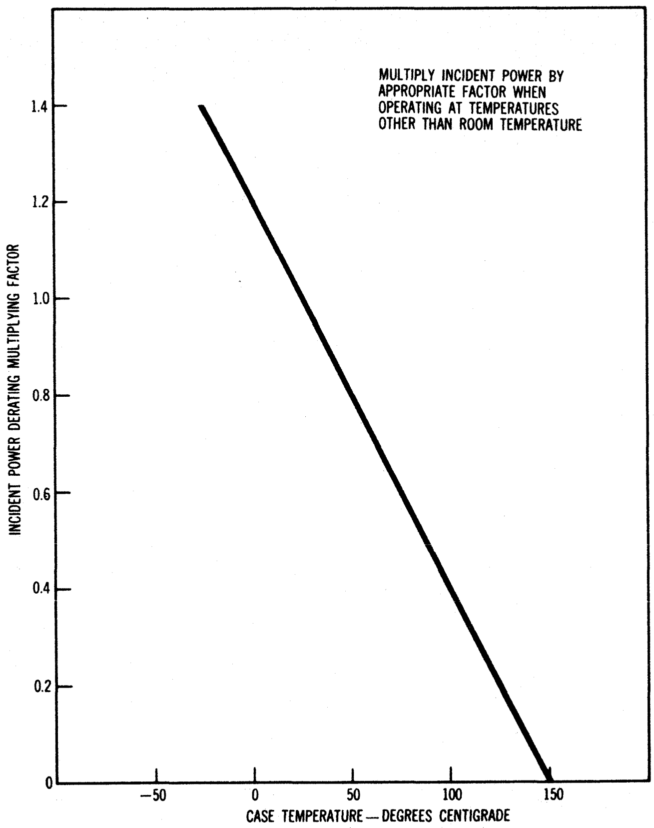


Figure 9. Derating curve

SWITCH MOUNTING

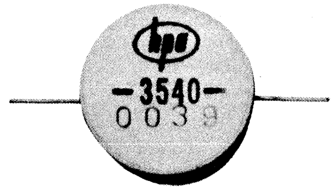
The switch may be mounted in any position.

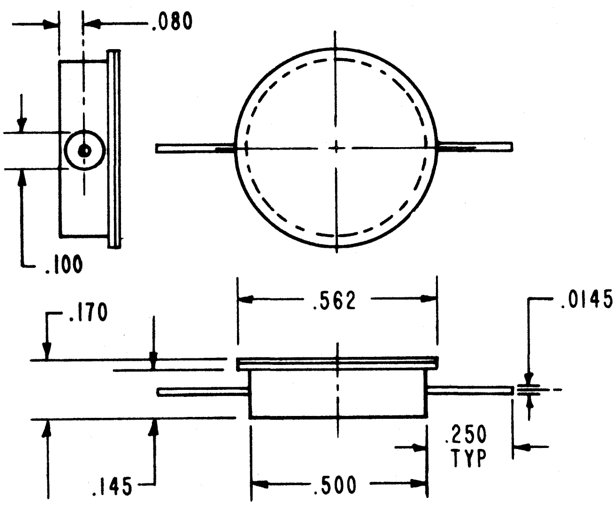
HEWLETT hp PACKARD

MICROWAVE SWITCH

HPA 3540

- BROAD BANDWIDTH
  DC to above 12.4 GHz
- LOW INSERTION LOSS
  0.5 to 2.0 dB
- HIGH ISOLATION
  20 to 45 dB
- FAST SWITCHING
  10 nanoseconds maximum
- MINIATURE SIZE
  Weight 4.3 grams
- HERMETICALLY SEALED
- ALL SOLID STATE





DESCRIPTION

The HPA 3540 is a broad-band solid-state switch suitable for use from DC to above 12 GHz. It consists of two oxide passivated silicon PIN diodes which are functionally integrated into a broad-band 50-ohm microwave structure. The dimensions of the switch are optimized for use in 50 ohms stripline. The housing is hermetically sealed and all internal joints are welded or thermal compression bonded, using proven materials to assure reliable operation under severe environmental conditions.

APPLICATION

The HPA 3540 is a versatile diode switch ideally suited for a large variety of high frequency and microwave circuits including: Pulse Modulators, Amplitude Modulators, Phase Shifters, Multiple Throw Switches, Phased Array Antennas, T-R Switches, Limiters, Attenuators, Automatic Gain Control Circuits, Power Leveling Circuits, Redundant Microwave Systems, Signal Synthesizers, Frequency Synthesizers, Suppressed Carrier Modulators, Pulse Shapers, Antenna Lobing Circuits.

ABSOLUTE MAXIMUM RATINGS

Maximum Diode Junction Temperature	150°C
Maximum Switch Power Dissipation	0.75 W @ 25°C
Maximum Diode Power Dissipation (Single Diode)	0.37 W @ 25°C
Peak Bias Current (duration less than 0.1 μsec)	500 mA
Diode Breakdown Voltage	36 volts
Thermal Resistance Junction/Case	150°C/Watt
Pulse Thermal Resistance Junction/Case	(as below)

For RF pulse lengths less than 30 microseconds the thermal resistance is dependent on the pulse duration. Its value in °C/Watt is equal to the numerical value of the pulse duration expressed in microseconds, i.e., for a 10 μsec pulse the thermal resistance is 10°C/Watt, thus the internal temperature rise is:

$T_{Junction} - T_{Case} = P \text{ X } t(\mu sec) \times$ factor of 1.5 for $t < 30\ \mu sec$

MECHANICAL CHARACTERISTICS

Size	As shown in the Outline Drawing on Page 1
Weight	4.3 grams
Materials: Case	Kovar
Cover	Nickel
Leads	Kovar
Finish: Case and Leads	Gold Plated, 50 μinches min.

ENVIRONMENTAL CHARACTERISTICS

Temperature, Storage and Operating	− 65°C to + 125°C
Shock	1,500 G, 0.5 ms duration
Vibration	20 G, 10-2000 cps
Hermeticity	Each unit is subjected to a Helium Leak Test, sensitivity 2 x 10^{-8} cm^3/sec

ELECTRICAL SPECIFICATIONS

All specifications are at 25°C and apply to either RF port since the switch is electrically and mechanically symmetrical.

USABLE FREQUENCY RANGE DC to above 12.4 GHz

VSWR

Switch ON	2 maximum, 1.5 typical
Switch OFF	High, dependent on bias current and frequency, 50:1 typical

VSWR is determined in a 50Ω stripline system.

SWITCHING CHARACTERISTIC

Both t_r and t_f are defined as the time intervals between the 10% and 90% points of the observed voltage amplitude pulse. The measurement is made with the switch biased OFF by a current of 100 mA and driven ON by a voltage pulse of 20 volts having a rise and fall of 20 nanoseconds as obtained from a pulse generator with a 50Ω source impedance, such as the Hewlett-Packard Model 214A.

SWITCHING SPECIFICATION

Rise Time, t_r	10 nsec maximum
Fall Time, t_f	10 nsec maximum

TYPICAL CHARACTERISTICS

Attenuation. The HPA 3540 switch exhibits some fine grain attenuation structure at low bias levels at low frequencies.

Phase Shift. The phase shift characteristics of the switch are a function of frequency and the electrical

ISOLATION AND INSERTION LOSS

Frequency (GHz)	Insertion Loss ($I_{bias} = 0$) Max.	Typ.	Isolation ($I_{bias} = 100$ mA) Min.	Typ.
DC - 0.5	0.5 dB	0.3 dB	20 dB	25 dB
0.5 - 1.0	0.7	0.3	25	30
1.0 - 2.0	0.7	0.3	30	35
2.0 - 4.0	1.0	0.7	35	40
4.0 - 8.0	1.5	1.0	45	49
8.0 - 12.4	2.0	1.5	45	50

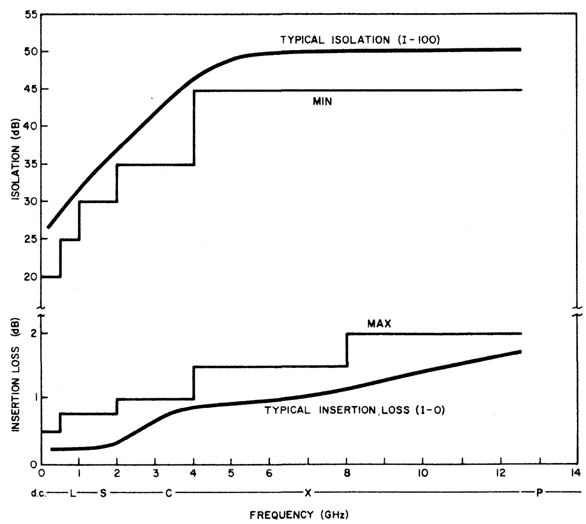


Figure 1. Isolation and Insertion Loss.

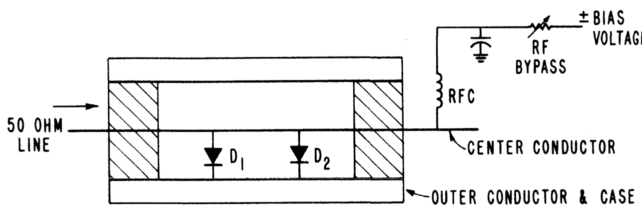
length at a specific bias. The air equivalent electrical lengths for the two principal bias conditions are approximately:

Switch ON 2.5 cm between front surfaces of the two RF ports

Switch OFF 1.3 cm between either front surface and the internal short.

APPLICATION INFORMATION

Switch Biasing. Proper biasing of the switch can be understood by reference to the internal circuit of the switch as represented by the following schematic diagram:



The internal compensated microwave structure is not shown since it does not affect the low frequency bias currents. Bias can be applied to either center conductor. The switch is considered to be "ON" or passing as RF signal when the bias voltage is zero or a negative value. Under this condition the diodes are in a high impedance state and the current through them is typically less than one microampere. The switch is considered to be "OFF" or blocking an RF signal when the bias voltage is positive. Under this condition the diodes are forward biased and are in a low impedance state. The individual diodes are matched and the total bias current is divided equally between them. The magnitude of the forward bias current determines the degree of attenuation provided by the switch. Maximum attenuation, or full isolation, is obtained for bias currents on the order of 100 mA. The forward bias current-voltage characteristics of the switch is shown in Figure 2.

SWITCH MOUNTING

The switch may be mounted in any position. An appropriate microwave structure for use with the switch is a dielectrically loaded stripline. An example of this application is shown in Figure 4.

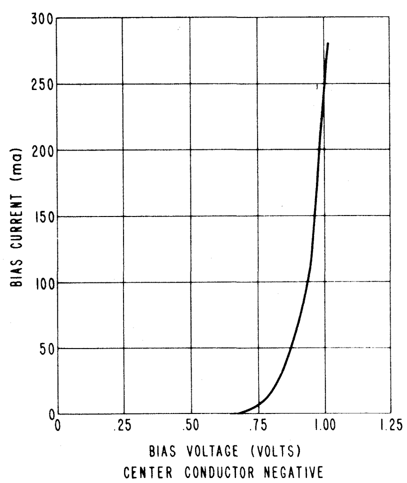


Figure 2. Typical Bias Voltage vs. Current Characteristic.

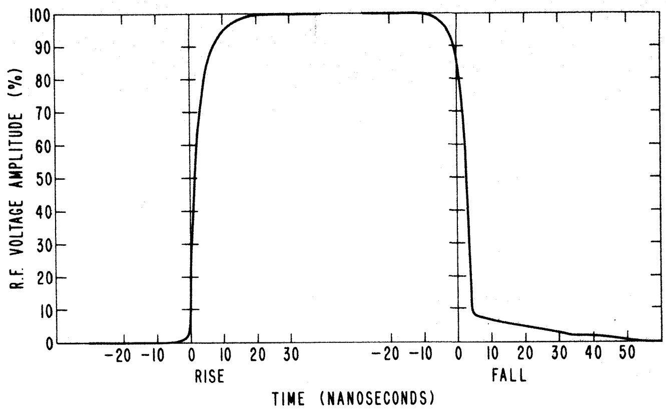


Figure 3. Typical Pulsed RF Amplitude.

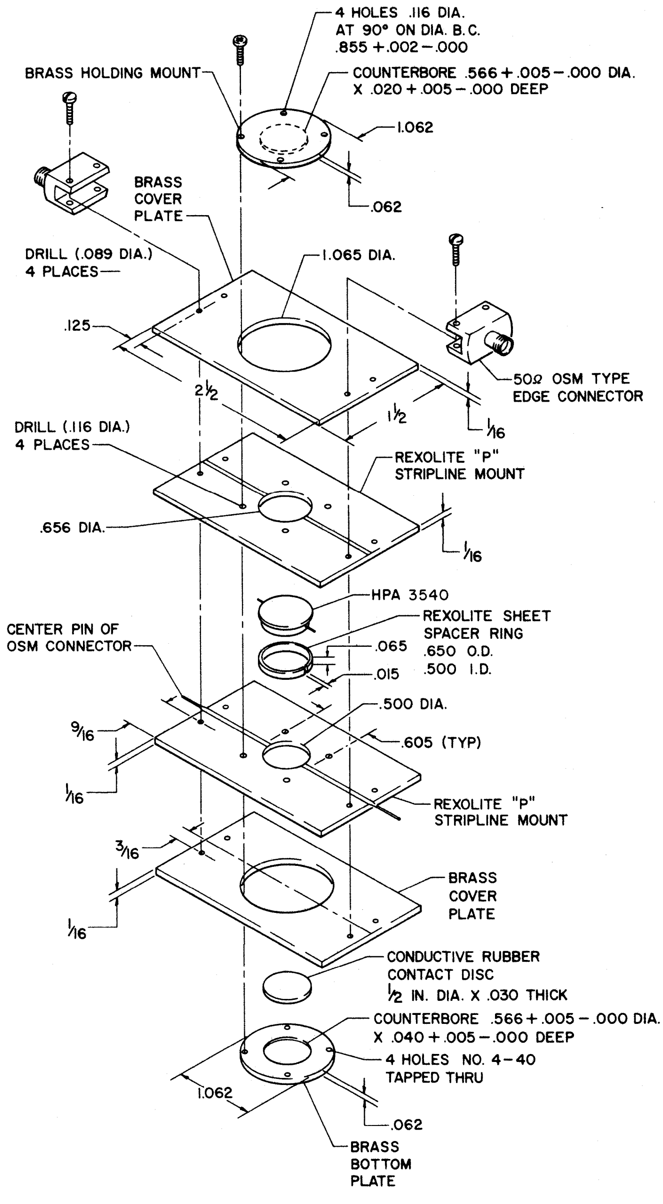


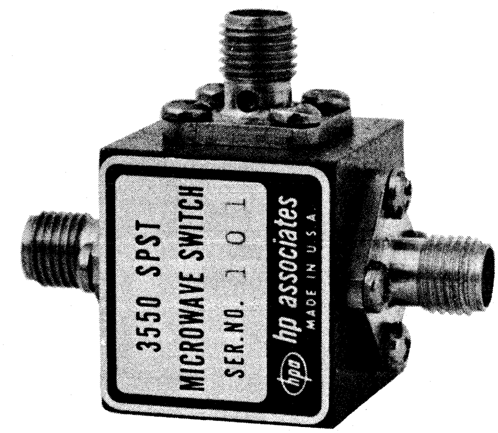
Figure 4.

HEWLETT hp PACKARD

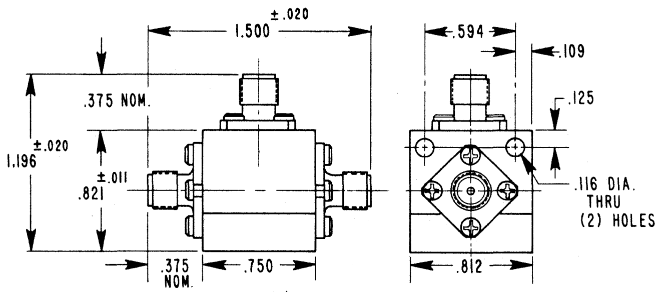
MICROWAVE SWITCH

HPA
3550
3551

- **BROAD BANDWIDTH—200 MHz to 12.4 GHz**
- **LOW INSERTION LOSS—0.5 to 1.5 dB**
- **HIGH ISOLATION—25 to 50 dB**
- **ALL SOLID STATE**



Switch No.	Bias Polarity For Switch—OFF
3550	Positive
3551	Negative



DESCRIPTION

The HPA 3550/51 are broadband solid-state switches or attenuators suitable for use from 200 MHz to 12.4 GHz. They consist of two silicon PIN diodes which are functionally integrated into a broadband 50 Ω microwave structure and bias circuit.

APPLICATION

These are versatile diode switches that are ideally suited for a large variety of high frequency and microwave circuits including: Pulse Modulators, Phase Shifters, Phased Array Antennas, T-R Switches, Limiters, Attenuators, Automatic Gain Control Circuits, Power Leveling Circuits, Redundant Microwave Systems, Signal Synthesizers, Frequency Synthesizers, Suppressed Carrier Modulators, Pulse Shapers, Antenna Lobing Circuits.

ABSOLUTE MAXIMUM RATINGS

Maximum Diode Junction Temperature	150°C
Maximum Switch Power Dissipation (Derating per Fig. 11)	1.25 W @ 25°C
Maximum Diode Power Dissipation (Single Diode)	0.7 W @ 25°C
Maximum Bias Current	200 ma
Maximum Voltage (Center Conductor to Ground)	500 volts DC at standard temperature and pressure
Minimum Diode Breakdown Voltage	65 volts
Thermal Resistance Junction/Case	100°C/watt
Pulse Thermal Resistance Junction/Case	(as below)

For RF pulse lengths less than 30 microseconds the thermal resistance is dependent on the pulse duration. Its value in °C/watt is equal to the numerical value of the pulse duration expressed in microseconds, i.e., for a 10 μsec pulse the thermal resistance is 10°C/watt, thus the internal temperature rise is:

$$T_{Junction} - T_{Case} = P \times t(\mu\text{sec}) \text{ for } t < 30\ \mu\text{sec}$$

MECHANICAL CHARACTERISTICS

Size	As shown in the Outline Drawing, Figure 1
Weight	32 grams
Mounting Position	Two 4/40 clearance holes are provided for mounting the switch. These holes may also be tapped for screws. Stainless steel screws should be used for mounting.

ENVIRONMENTAL CHARACTERISTICS

Temperature, Storage	— 65°C to + 125°C
Temperature, Operating	— 65°C to + 125°C (Derating per Fig. 11)
Temperature Cycling	MIL-STD 202C, Test method 102, Condition C
Shock	75G, 6 ms duration; MIL-STD 202C, Test method 213, Condition B
Vibration	10-2000 Hz, 15G, MIL-STD 202C, Test method 204A, Condition B
Humidity	MIL-STD 202C, Test method 103B, Condition B
Barometric Pressure	50,000 ft. MIL-STD 202C, Test method 105C, Condition B

ELECTRICAL SPECIFICATIONS AT 25°C

Frequency Range	200 MHz to 12.4 GHz.
Impedance	All specifications are for 50 Ω.
Symmetry	Specifications apply to either direction of transmission. (See Isolation at Bias Terminal for an exception to symmetrical performance.)

ISOLATION AND INSERTION LOSS: (See Figure 8)

Frequency (GHz)	Insertion Loss (V_{bias} = 20 V) Max.	Insertion Loss Typ.	Isolation (I_{bias} = 50 ma) Min.	Isolation Typ.
0.2 - 0.5	0.7 dB	0.5 dB	20 dB	25 dB
0.5 - 1.0	0.4	0.2	25	28
1.0 - 2.0	0.5	0.3	30	35
2.0 - 3.0	0.7	0.5	35	40
3.0 - 4.0	1.0	0.7	40	45
4.0 - 6.0	1.0	0.8	45	50
6.0 - 8.0	1.2	0.9	45	50
8.0 - 12.4	1.5	1.0	45	50

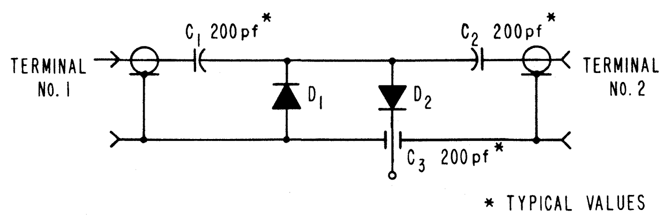


Figure 2. Switch control circuit. Diagram shown represents Model 3551

VSWR

		Frequency (GHz) 0.2 - 12.4
Switch ON	Maximum	2.0
	Typical	1.5
Switch OFF	High; dependent on bias current and frequency. 50:1 is typical VSWR.	

HARMONIC DISTORTION

Harmonics are generated by the PIN diodes in the HPA SPST switch. Harmonic output levels depend upon signal level, bias level and frequency. For frequencies above 350 MHz, generated harmonics are a minimum of 40 dB below the fundamental output level.

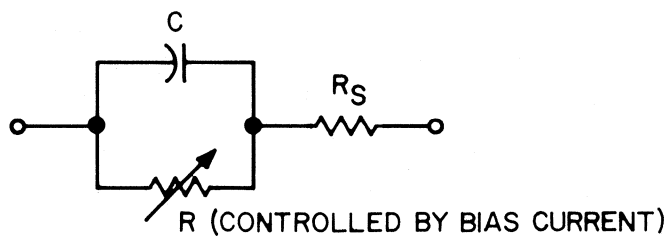


Figure 3. Typical PIN diode microwave equivalent circuit.

SWITCHING SPEED

	Maximum	Typical
Switch OFF-ON	300 ns	125 ns
Switch ON-OFF	100 ns	40 ns

CIRCUIT DIAGRAM

The control circuit of the HPA SPST switch is shown in Figure 2.

Two silicon PIN diodes shunt the RF line when forward biased and, under zero or reverse bias, are integral parts of a broadband RF network designed to provide a 50-ohm line impedance through the switch in the ON condition. The switch is ON when it is passing RF power (zero or reverse bias) and OFF when it is reflecting RF power (forward bias). A diode equivalent circuit showing typical values is given in Figure 3.

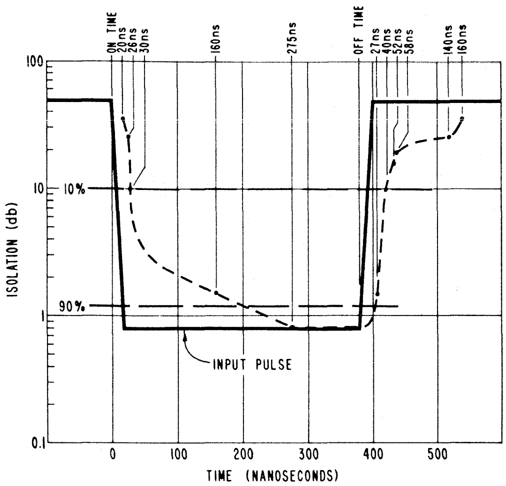


Figure 4. Typical switching speed for full operation. R_F frequency = 7.25 GHz.

SWITCHING SPEED

A typical RF pulse shape is shown by Figure 4. The rise and fall times depend on the attenuation levels at which the switch is considered to be ON or OFF. These times also depend on the magnitude of bias current and on the bias pulse shape.

Switching speed on production units is measured in the circuit shown in Figure 5.

The switching speed is read as the interval between the 10% to 90% points of the detected RF signal. Note that a high-pass filter with a DC return is provided on the input of the switch. The high-pass filter is a desirable addition to prevent drive pulse leakage onto the RF line. DC returns on both sides of the switch are necessary to achieve the rated switching speed, since complete depletion of diode stored charge is dependent upon these paths to ground. A low-pass filter for introducing the pulse and bias is also a desirable circuit feature. Typical switching speed from 50 dB of isolation to the full ON condition and the input driving pulse are shown in Figure 4.

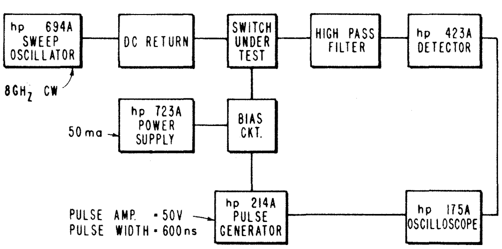


Figure 5. Block diagram of circuit used for switching speed test.

Biasing for Fast Switching. Faster switching can be obtained by operating at the lowest possible forward bias current consistent with the necessary isolation level. Faster switching may also be obtained by suitable shaping of the bias current waveform as illustrated in Figure 6.

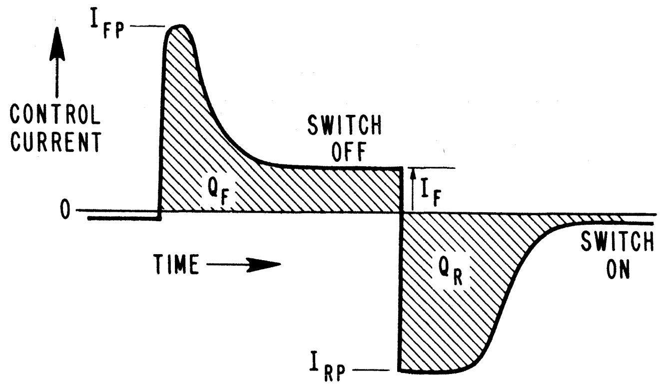


Figure 6. Control current pulse shape for fast switching.

The initially high peak turn-OFF current I_{FP} is used to effect a rapid decrease in diode impedance. I_{FP} must be reduced to I_F to assure that the stored charge Q_R, which is approximately equal to $I_F \times 10^{-7}$ coulombs, is kept to a minimum. I_F should not exceed the value necessary for the desired isolation in the OFF condition. Similarly a high peak turn-ON current I_{RP} is desirable to quickly remove the charge stored in the diodes and return them to the high impedance state. The values of I_{FP} and I_{RP} and their duration must stay within the limits of the peak bias current and the maximum power dissipation.

Typical voltage-current performance of the diodes, looking into the bias terminal is shown in Figure 7.

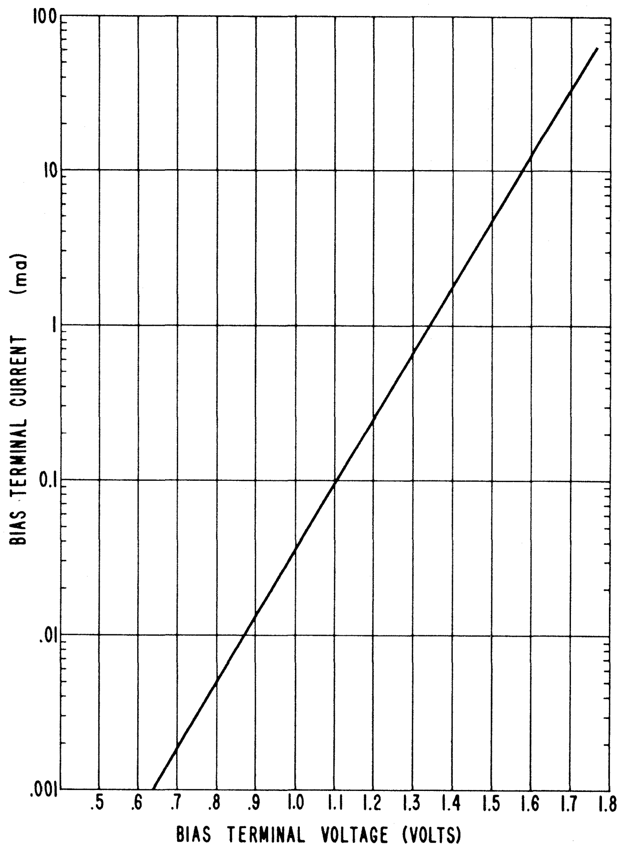


Figure 7. Voltage-current characteristics looking into bias port.

TYPICAL CHARACTERISTICS

Phase Shift. The phase shift characteristics of the switch are a function of frequency and the electrical length at a specific bias. The air equivalent electrical lengths for the two principal bias conditions are:

Switch ON ....3.25 cm face to face excluding connectors
Switch OFF ....1.625 cm face to short excluding connectors

VARIABLE ATTENUATOR CHARACTERISTICS

HPA SPST switches are useful as continuously variable, current-controlled attenuators. Although the attenuation at any particular bias current varies with RF frequency and temperature, the attenuation monotonically increases with increasing bias current, making the switch usable as an attenuator in such applications as AGC circuits, power leveling, and dynamic range extension. A typical plot of attenuation vs. bias current for various frequencies is given in Figure 9. Typical variation of attenuation as a function of bias current and frequency are shown in Figures 8 and 9. The HPA 3550/51 switch exhibits no fine grain attenuation structure.

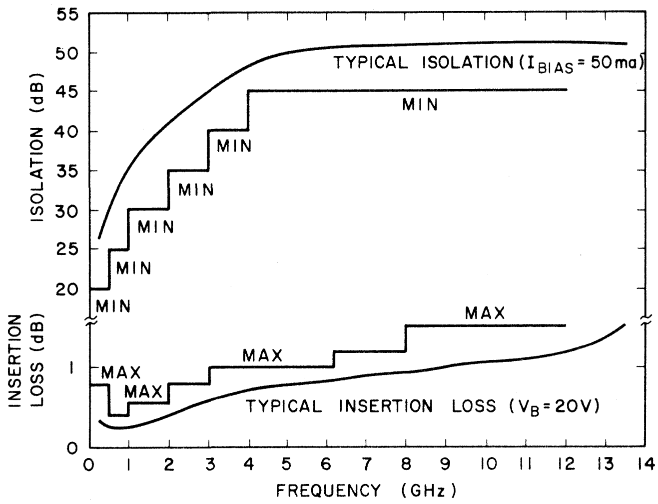


Figure 8. Isolation and insertion loss characteristics.

ISOLATION AT BIAS TERMINAL

RF leakage to the bias terminal is greater from one RF connector than from the other. This characteristic is caused by the non-symmetrical position of the bias lead with respect to the diodes (see Figure 2), and is the only exception to the symmetry of the switch. Typical isolation data is given in the table below.

TABLE I
Minimum RF Isolation at Bias Terminal

	ON	OFF
Terminal No. 1	36 dB	31 dB
Terminal No. 2	33 dB	23 dB

(Terminal No. 1 is down when the label can be read.)

The values given in Table I are the minimum isolation. Over most of the frequency range, the isolation is greater.

NOISE

HPA 3550/3551 Microwave Switches behave as thermal resistances shunted across the transmission line. Their excess noise temperature is less than 20° Kelvin. This results in noise figures essentially equal to the insertion loss at all bias levels, exceeding this value by less than 0.2 dB at the worst case, the 6-10 dB attenuation range.

RF POWER HANDLING CAPABILITY

The RF power that can be safely handled by the switch is dependent on the breakdown voltage of the diodes, the maximum diode power dissipation, the bias state of the switch, i.e., whether the switch is ON, OFF, or in an attenuation condition, and the frequency of the RF signal.

Maximum signal power handling capability of the switch as a function of attenuation and frequency are shown in the Average Power curves of Figure 10. Under pulsed signal conditions, the diode breakdown voltage limits the peak power that can be handled in the low attenuation range. This is shown in the top curves of Figure 10 for a typical 2 μsec pulse at 2% duty cycle. There are four operating conditions which are of interest and warrant additional comment.

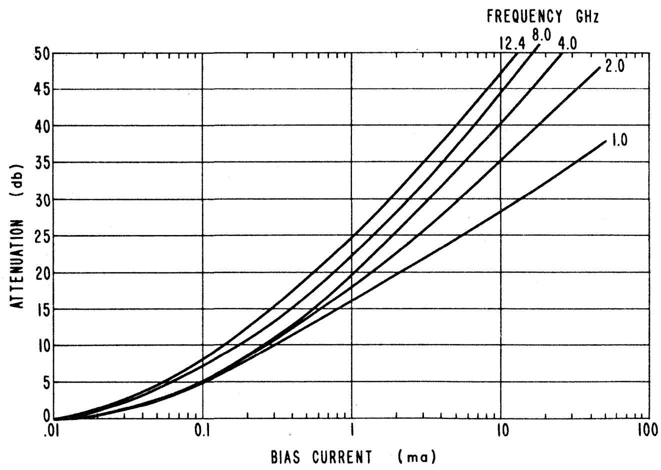


Figure 9. Typical isolation vs. bias current and frequency.

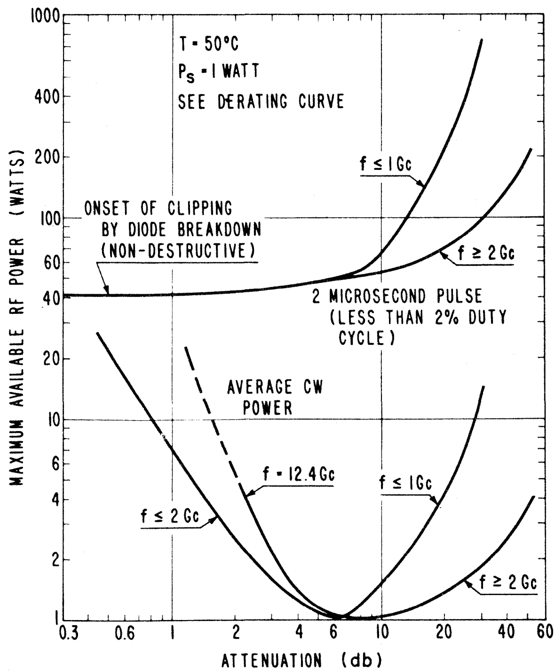


Figure 10. Power handling capabilities.

Condition	Comments
Switch ON Frequency $\leq$ 2 GHz Attenuation (α) $\leq$ 6 dB	For frequencies below 1 GHz and high power levels some modulation of insertion loss may occur because of current flow during half of the RF cycle. A reverse bias voltage $\geq$ 10% of the RF voltage will minimize this effect. Less power can be handled than at higher frequencies. The curve labeled f $\leq$ 2 GHz is the one to use for frequencies $\leq$ 2 GHz. For example, when the switch is ON (α = 1 dB) the maximum available power that can be handled at 1 GHz is 7 watts.

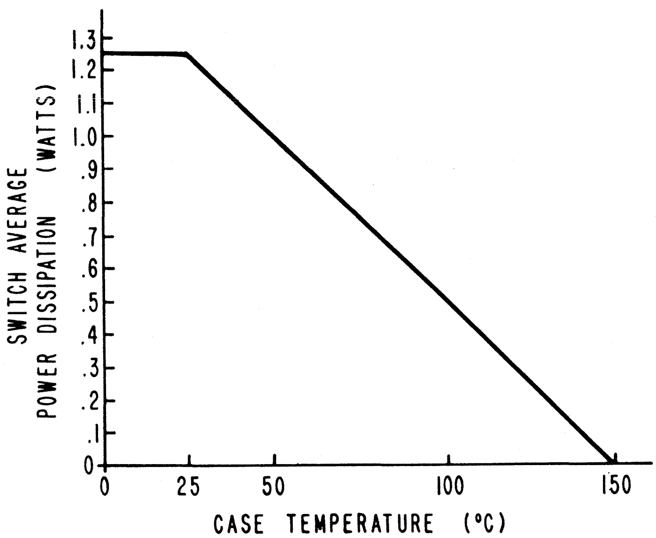


Figure 11. Temperature derating curve.

Condition	Comments
Switch ON Frequency $\geq$ 2 GHz $\alpha \leq$ 6 dB	For 0.3 dB $<\alpha<$ 1.0 dB diode breakdown voltage is the limiting factor under pulsed signal conditions. For 1.0 $<\alpha<$ 6 dB, the maximum available power for frequencies between 2 and 12.4 GHz can be found by linear interpolation between the curves labeled f $\leq$ 2 GHz and f = 12.4 GHz.
Switch OFF Frequency $\leq$ 1 GHz $\alpha \geq$ 10 dB	The curve labeled $\leq$ 1 GHz should be used. For example, an attenuation of 30 dB will permit a maximum available power of 10 watts.
Switch OFF Frequency $\geq$ 2 GHz $\alpha \geq$ 10 dB	Less maximum available power can be used than at lower frequencies. The curve labeled f $\geq$ 2 GHz should be used for frequencies $\geq$ 2 GHz. Between 1 and 2 GHz linear interpolation should be used.

In the attenuation mode the maximum power dissipation in the switch occurs for 6 dB attenuation. In this state the switch dissipates ½ of the available power. This dissipation will be divided between the two diodes equally at low frequencies, unequally at high frequencies. A conservative rating is obtained by assuming all of the dissipation to be in one diode. Therefore:

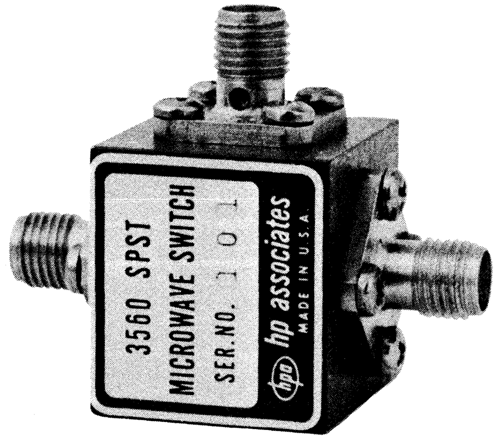
Maximum available RF power (25°C) 1.25 watts
(see derating curve, Figure 11)

HEWLETT hp PACKARD

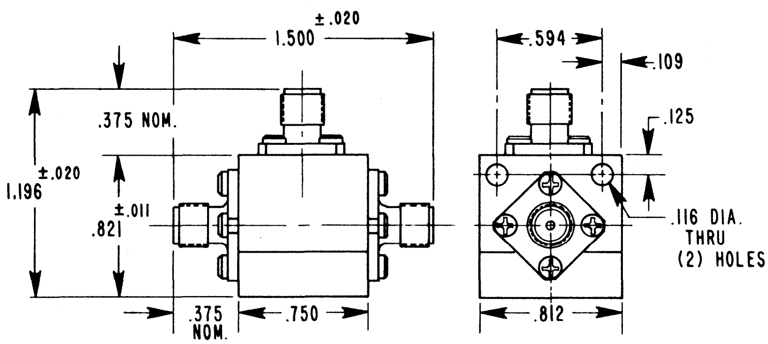
MICROWAVE SWITCH

HPA
3560
3561

BROAD BANDWIDTH - 12.4 to 18 GHz
LOW INSERTION LOSS - 1.5 dB
HIGH ISOLATION - 50 dB
ALL SOLID STATE



Switch No.	Bias Polarity for Switch—OFF
3560	Positive
3561	Negative



DESCRIPTION

The HPA 3560/61 are broadband solid-state switches or attenuators suitable for use from 12.4 to 18 GHz. They consist of two silicon PIN diodes which are functionally integrated into a broadband 50-ohm microwave structure and bias circuit.

APPLICATION

These versatile diode switches are ideally suited for a large variety of high frequency and microwave circuits including: Pulse Modulators, Phase Shifters, Phased Array Antennas, T-R Switches, Limiters, Attenuators, Automatic Gain Control Circuits, Power Leveling Circuits, Redundant Microwave Systems, Signal Synthesizers, Frequency Synthesizers, Suppressed Carrier Modulators, Pulse Shapers, Antenna Lobing Circuits.

ABSOLUTE MAXIMUM RATINGS

Maximum Diode Junction Temperature ....150°C
Maximum Switch Power Dissipation ....1.25 W @ 25°C (Derating per Fig. 11)
Maximum Diode Power Dissipation ....0.7 W @ 25°C (Single Diode)
Maximum Bias Current ....200 mA
Maximum Voltage ....500 volts DC at standard (Center Conductor to Ground) temperature and pressure
Minimum Diode Breakdown Voltage ....65 volts
Thermal Resistance Junction/Case ....100°C/watt
Pulse Thermal Resistance Junction/Case ....(as below)

For RF pulse lengths less than 30 microseconds the thermal resistance is dependent on the pulse duration. Its value in °C/watt is equal to the numerical value of the pulse duration expressed in microseconds, i.e., for a 10 μsec pulse the thermal resistance is 10°C/watt, thus the internal temperature rise is:

$$T_{JUNCTION} - T_{CASE} = P \times t(\mu\text{sec}) \text{ for } t < 30\ \mu\text{sec}$$

MECHANICAL CHARACTERISTICS

Size ....As shown in the Outline Drawing, Figure 1
Weight ....32 grams
Mounting Position ....Two 4/40 clearance holes are provided for mounting the switch. These holes may also be tapped for 6/30 screws. Stainless steel screws should be used for mounting.

ENVIRONMENTAL CHARACTERISTICS

Temperature, Storage ....— 65°C to + 125°C
Temperature, Operating ....— 65°C to + 125°C (Derating per Fig. 11)
Temperature Cycling ....MIL-STD 202C, Test Method 102, Condition C
Shock ....75G, 6 ms duration; MIL-STD 202C, Test Method 213, Condition B
Vibration ....10-2000 Hz, 15G, MIL-STD 202C, Test Method 204A, Condition B
Humidity ....MIL-STD 202C, Test Method 103B, Condition B
Barometric Pressure ....50,000 ft. MIL-STD 202C, Test Method 105C, Condition B

ELECTRICAL SPECIFICATIONS AT 25°C

Frequency Range ....12.4 GHz to 18 GHz
Impedance ....All specifications are for 50 Ω
Symmetry ....Specifications apply to either direction of transmission. (See Isolation at Bias Terminal for an exception to symmetrical performance.)

ISOLATION AND INSERTION LOSS: (See Figure 9)

Frequency (GHz)	Insertion Loss (V_{BIAS} = 20 V) Max.	Insertion Loss (V_{BIAS} = 20 V) Typ.	Isolation (I_{BIAS} = 50 mA) Min.	Isolation (I_{BIAS} = 50 mA) Typ.
12.4 - 18.0	2.0 dB	1.5 dB	45 dB	50 dB

VSWR

		Frequency 12.4-18 GHz
Switch ON	Maximum	2.0
	Typical	1.6

Switch OFF ....High; dependent on bias current and frequency: 5:1 is typical VSWR

HARMONIC DISTORTION

Harmonics are generated by the PIN diodes in the HPA SPST switch. Harmonic output levels depend upon signal level, bias level, and frequency. Generated harmonics are a minimum of 40 dB below the fundamental output level.

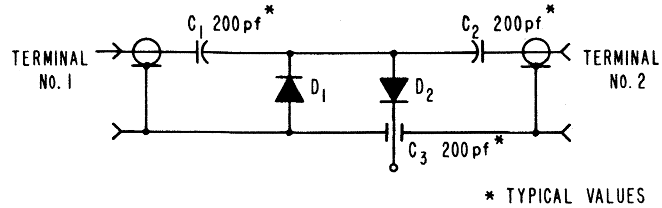


Figure 2. Switch Control Circuit. Diagram Shown Represents Model 3561.

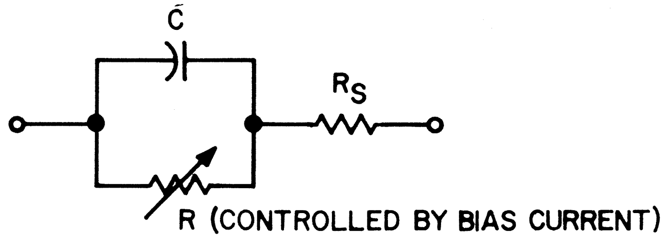


Figure 3. Typical PIN Diode Microwave Equivalent Circuit.

SWITCHING SPEED

	Maximum	Typical
Switch OFF-ON	300 ns	125 ns
Switch ON-OFF	100 ns	40 ns

CIRCUIT DIAGRAM

The control circuit of the HPA SPST switch is shown in Figure 2.

Two silicon PIN diodes shunt the RF line when forward biased and, under zero or reverse bias, are integral parts of a broadband RF network designed to provide a 50-ohm line impedance through the switch in the ON condition. The switch is ON when it is passing RF power (zero or reverse bias) and OFF when it is reflecting RF power (forward bias). A diode equivalent circuit showing typical values is given in Figure 3.

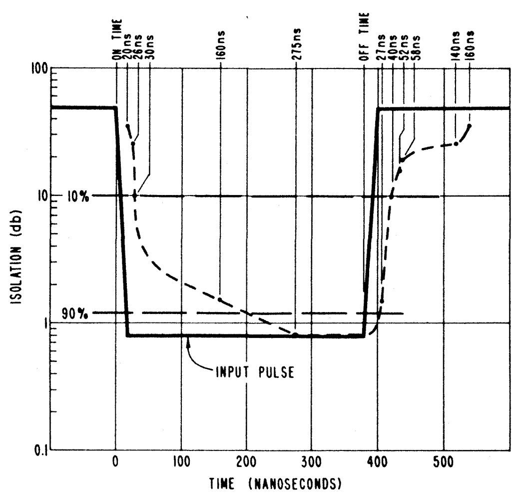


Figure 4. Typical Switching Speed for Full Operation. R_F frequency = 12.4 GHz.

SWITCHING SPEED

A typical RF pulse shape is shown by Figure 4. The rise and fall times depend on the attenuation levels at which the switch is considered to be ON or OFF. These times also depend on the magnitude of bias current and on the bias pulse shape.

Switching speed on production units is measured in the circuit shown in Figure 5.

The switching speed is read as the interval between the 10% to 90% points of the detected RF signal. Note that a high-pass filter with a DC return is provided on the input of the switch. The high-pass filter is a desirable addition to prevent drive pulse leakage onto the RF line. DC returns on both sides of the switch are necessary to achieve the rated switching speed, since complete depletion of diode stored charge is dependent upon these paths to ground. A low-pass filter for introducing the pulse and bias is also a desirable circuit feature. Typical switching speed from 50 dB of isolation to the full ON condition and the input driving pulse are shown in Figure 4.

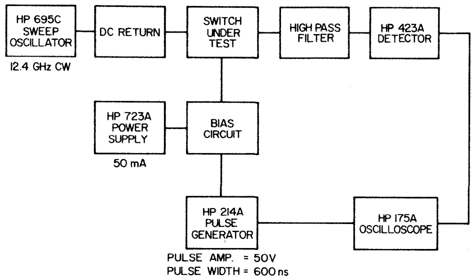


Figure 5. Block Diagram of Circuit Used for Switching Speed Test.

Biasing for Fast Switching. Faster switching can be obtained by operating at the lowest possible forward bias current consistent with the necessary isolation level. Faster switching may also be obtained by suitable shaping of the bias current waveform as illustrated in Figure 6.

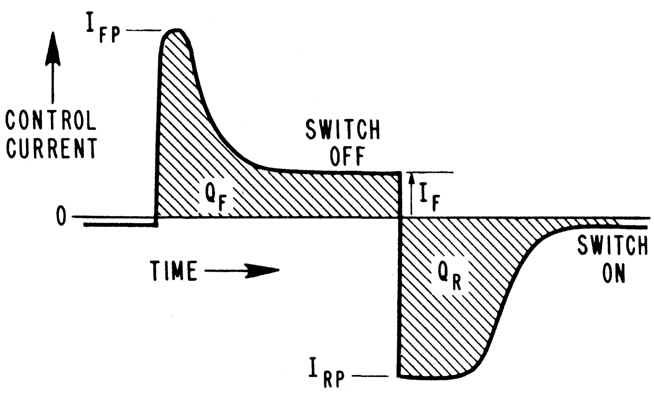


Figure 6. Control Current Pulse Shape for Fast Switching.

The initially high peak turn-OFF current I_{FP} is used to effect a rapid decrease in diode impedance. I_{FP} must be reduced to I_F to assure that the stored charge Q_R, which is approximately equal to I_F, should not exceed the value necessary for the desired isolation in the OFF condition. Similarly a high peak turn-ON current I_{RP} is desirable to quickly remove the charge stored in the diodes and return them to the high impedance state. The values of I_{FP} and I_{RP} and their duration must stay within the limits of the peak bias current and the maximum power dissipation.

Typical voltage-current performance of the diodes, looking into the bias terminal, is shown in Figure 7.

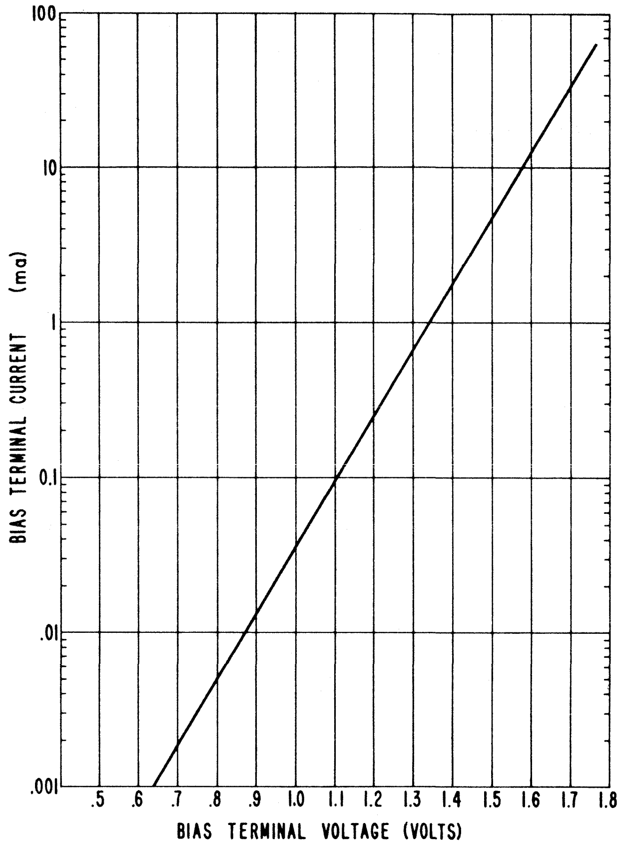


Figure 7. Voltage-current Characteristics Looking Into Bias Port.

TYPICAL CHARACTERISTICS

Phase Shift. The phase shift characteristics of the switch are a function of frequency and the electrical length at a specific bias. The air equivalent electrical lengths for the two principal bias conditions are:

Switch ON ....3.25 cm face to face excluding connectors
Switch OFF....1.625 cm face to short excluding connectors

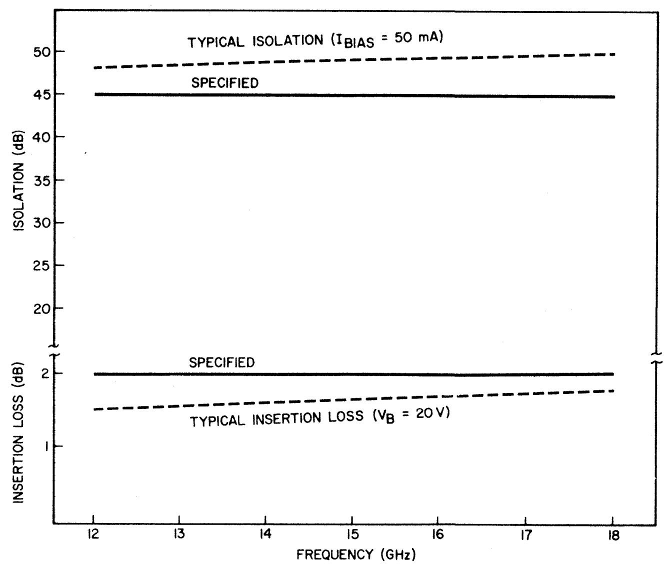


Figure 8. Isolation and Insertion Loss Characteristics.

VARIABLE ATTENUATOR CHARACTERISTICS

HPA SPST switches are useful as continuously variable, current-controlled attenuators. Although the attenuation at any particular bias current varies with RF frequency and temperature, the attenuation monotonically increases with increasing bias current, making the switch usable as an attenuator in such applications as AGC circuits, power leveling, and dynamic range extension. A typical plot of attenuation vs. bias current is given in Figure 9. The HPA 3560/61 switch exhibits no fine grain attenuation structure.

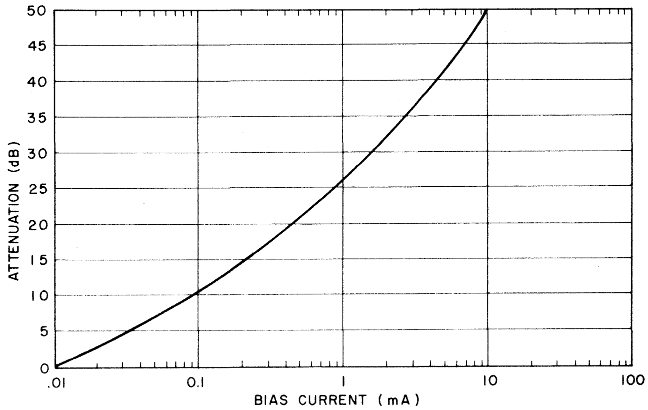


Figure 9. Typical Isolation vs. Bias Current and Frequency.

ISOLATION AT BIAS TERMINAL

RF leakage to the bias terminal is greater from one RF connector than from the other. This characteristic is caused by the non-symmetrical position of the bias lead with respect to the diodes (see Figure 2), and is the only exception to the symmetry of the switch. Typical isolation data is given in the table below.

TABLE I
Minimum RF Isolation at Bias Terminal

	ON	OFF
Terminal No. 1	36 dB	31 dB
Terminal No. 2	33 dB	23 dB

The values given in Table I are the minimum isolation. Over most of the frequency range the isolation is greater.

NOISE GENERATION

HPA 3560/3561 Microwave Switches behave as thermal resistances shunted across the transmission line. Their excess noise temperature is less than 20° Kelvin. This results in noise figures essentially equal to the insertion loss at all bias levels, exceeding this value by less than 0.2 dB at the worst case, the 6-10 dB attenuation range.

RF POWER HANDLING CAPABILITY

The RF power that can be safely handled by the switch is dependent on the breakdown voltage of the diodes, the maximum diode power dissipation, the bias state of the switch, i.e., whether the switch is ON, OFF, or in an attenuation condition, and the frequency of the RF signal.

Maximum signal power handling capability of the switch as a function of attenuation and frequency is shown in the Average Power curves of Figure 10. Under pulsed signal conditions, the diode breakdown voltage limits the peak power that can be handled in the low attenuation range. This is shown in the top curves of Figure 10 for a typical 2 μsec pulse at 2% duty cycle. There are two operating conditions which are of interest and warrant additional comment.

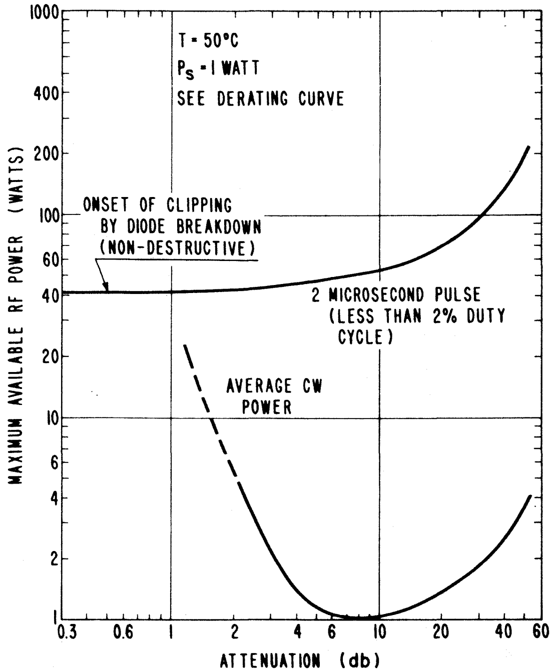


Figure 10. Power Handling Capabilities.

Condition	Comments
Switch ON $\alpha \leq 6$ dB	For 0.3 dB $< \alpha <$ 1.0 dB diode breakdown voltage is the limiting factor under pulsed signal conditions. For 1.0 $< \alpha <$ 6 dB, the maximum available power may be read from Figure 10.
Switch OFF Frequency $\leq$ 2 GHz $\alpha \geq 6$ dB	Refer to Figure 10 for maximum available power vs. attenuation.

In the attenuation mode the maximum power dissipation in the switch occurs for 6 dB attenuation. In this state the switch dissipates ½ of the available power. This dissipation will be divided between the two diodes equally at low frequencies, unequally at high frequencies. A conservative rating is obtained by assuming all of the dissipation to be in one diode. Therefore:

Maximum available RF power (25°C) 1.25 watts
(see derating curve, Figure 11)

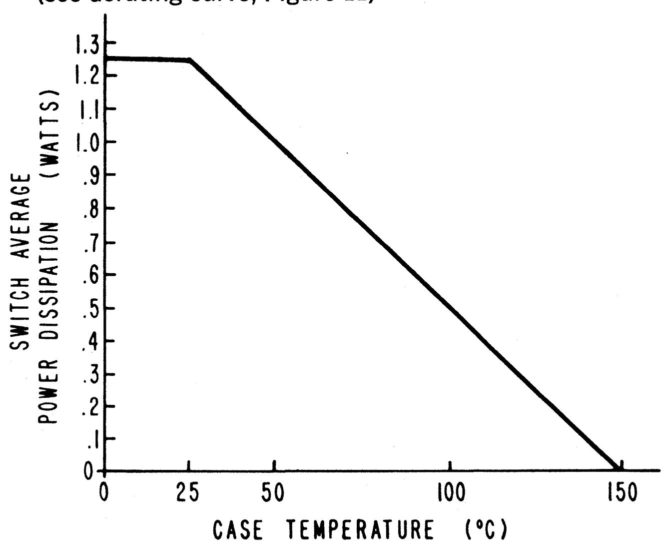


Figure 11. Temperature Derating Curve.

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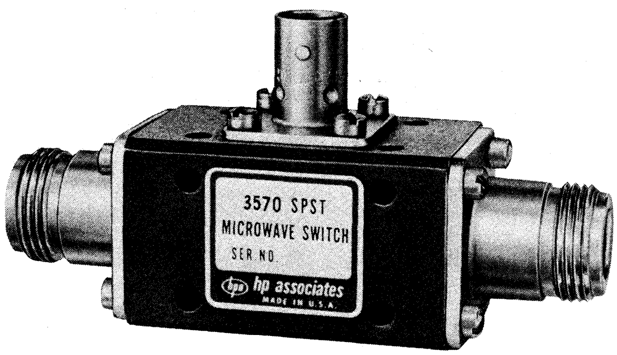
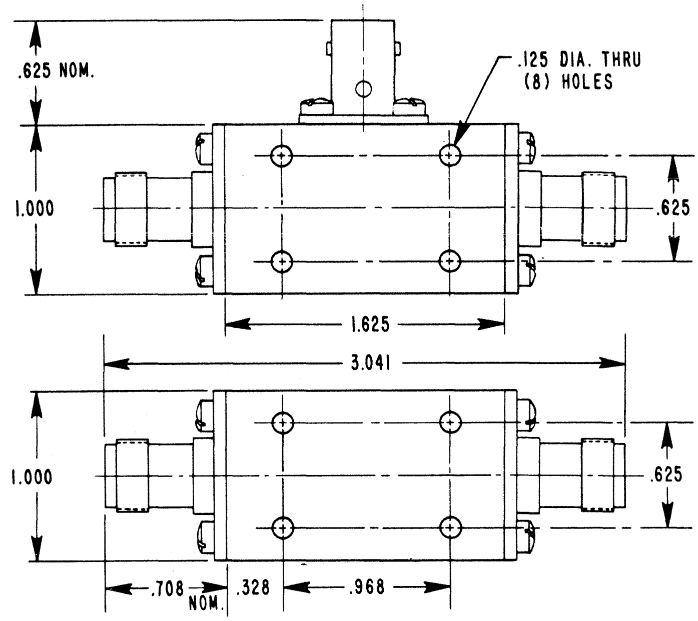
SPST MICROWAVE SWITCH

HPA 3570 3571



π filter
this end



TNC RF Connector—3570
N RF Connector—3571

TNC RF Connector—3570
N RF Connector—3571

DESCRIPTION

The HPA 3570 diode switch uses modular construction, fast diodes, and internal filtering to obtain high performance and high speed over an extended frequency range. The diodes are hermetically protected against the environment and the switch body itself is tightly closed to permit operation in severe environments. A special diode is used which provides a limited amount of pulse sharpening so that rise times are not critically dependent on pulse shape. Thus the rise times shown are compatible with the 13 ns rise time of the Hewlett-Packard Model 214A Pulse Generator used to drive the switch.

Because fast diodes are used in the switch, it will generate harmonics and mixing products if the signal currents are comparable to the diode bias current. Therefore the bias must overcome the signal amplitude if such distortion is not tolerable. The bias can easily overcome the signal effects except in the case of a variable attenuator application. If an unbalanced switch like the 3570 is to be used in a high-speed continuous control application, these nonlinear effects must be eliminated by filtering or must be tolerable in the application.

The filtering of the video pulse from the RF lines is such that the switch provides a dc open circuit at one RF port and a dc short or return path at the other RF port. It may thus be used with other solid state components requiring one or the other without the need for an additional RF component.

RATINGS—ABSOLUTE MAXIMUM

Maximum Bias Current	100 mA DC steady state
Maximum Bias Voltage	36 volts
Maximum Voltage (DC) center conductor to ground	T end, 200 V
Maximum Current (DC) center conductor to ground	π end, 100 mA
Storage and Operating Temperatures	$-55°C$ to $+125°C$
Shock	30 G, 3 ms duration
Vibration	10 G, 10-100 Hz
Mounting Position	Any
Maximum Power Handling @ 25°C (for 100 mA bias OFF and 11 v bias ON)	1 watt CW
Bias Polarity for "OFF"	Positive

MAXIMUM AND MINIMUM ELECTRICAL CHARACTERISTICS AT 25°C

Frequency (GHz)	Insertion Loss @ 20 V Bias		Isolation @ + 100 mA Bias		VSWR @ − 20 V Bias	
	Typical	Maximum	Typical	Minimum	Typical	Maximum
1-2	0.6	1.0	31	27 dB	1.5:1	2:1
2-4	0.8	1.2	36	33 dB	1.5:1	2:1
4-8	1.2	1.5	42	38 dB	1.8:1	2.5:1
8-12.4	1.6	2.0	45	40 dB	1.8:1	2.5:1

Switching speed @ 25°C* (10%-90% RF Voltage)		Maximum	Typical
	RF ON:	15	9
	RF OFF:	10	6

* **Note:** Switching speed is slightly affected by ambient temperature, nature of bias circuit, and VSWR in RF lines. Rise and fall times of switch driver must be consistent with switching time desired.

Video leakage—with 100 mA and 11 V pulse
going on < 0.4 mW for < 25 ns, < 1 volt peak
going on < 0.1 mW for < 10 ns, < 1 volt peak

► Indicates change from prior specifications

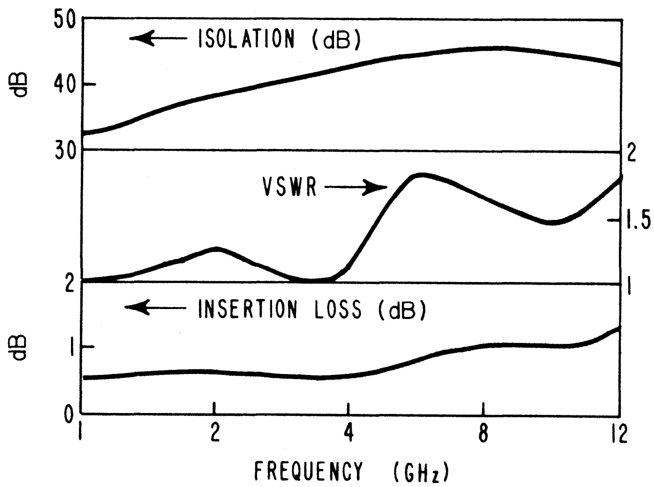


Figure 2. Isolation, Insertion Loss and VSWR, Typical.

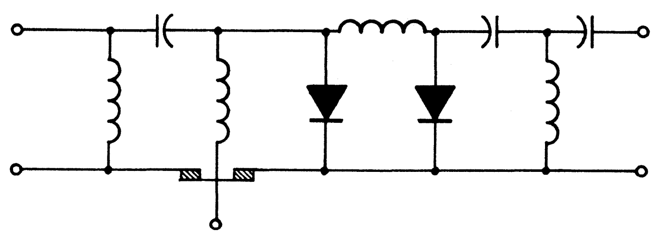


Figure 4. Switch Circuit Diagram. Note external orientation of π filter on picture.

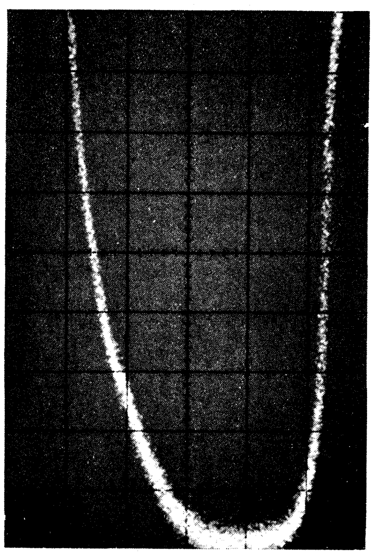


Figure 3. Typical RF Waveform @ 8 GHz (25°C Ambient) with HP 214A Pulse Generator as Switch Driver. Scale 5 ns/cm.

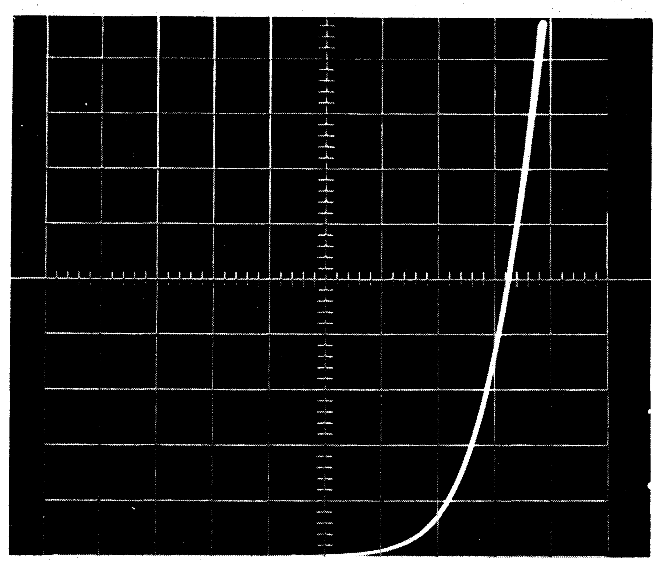


Figure 5. V-I Characteristic at Bias Port (Scale 0.1 V/div. and 10 mA/div.)

HEWLETT hp PACKARD

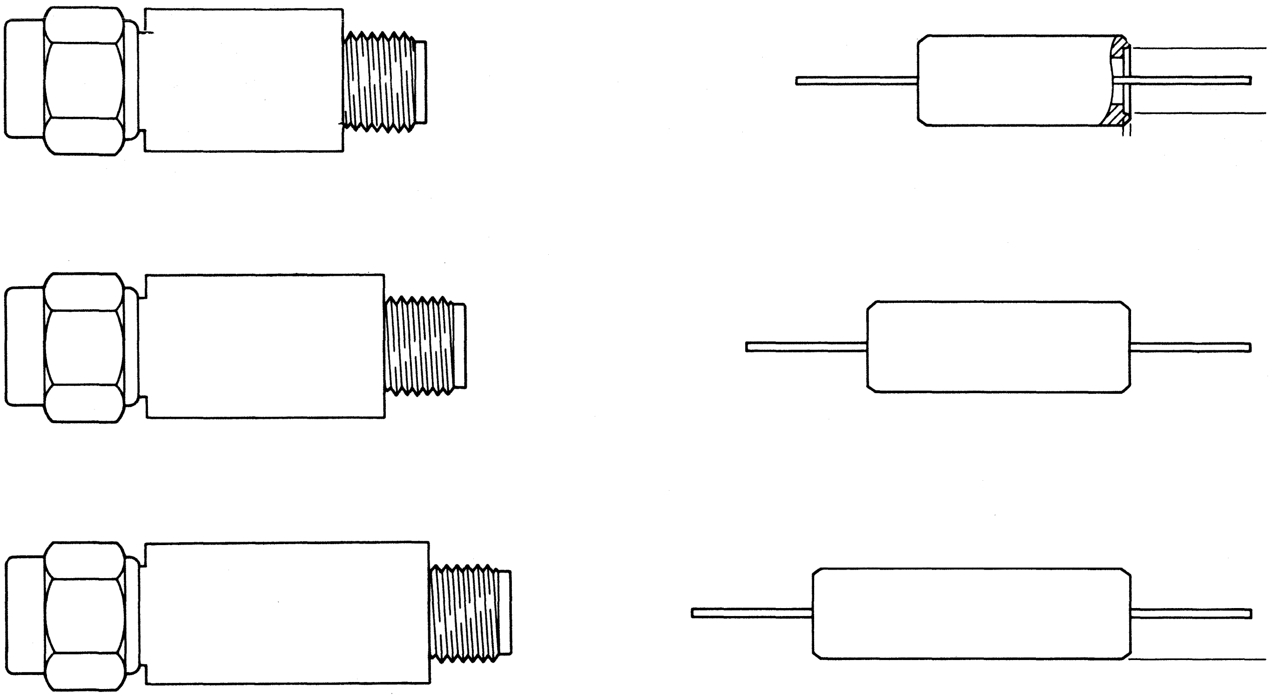
PIN Diode Modular Switches

HP 33600 series

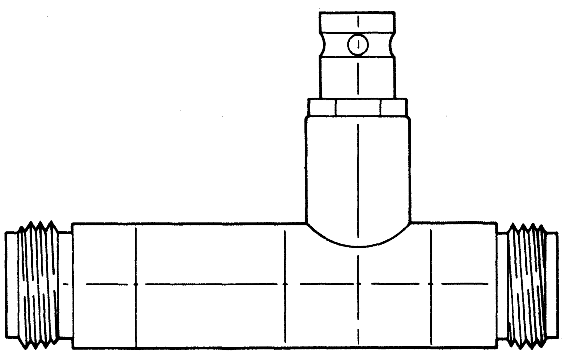
BROAD BANDWIDTH—DC to 18 GHz ■ LOW INSERTION LOSS—0.5 to 2.2 dB

HIGH ISOLATION—40 to 80 dB, three series ■ FAST SWITCHING—2 series, 10 and 50 nsec

MINIATURE SIZE ■ HERMETICALLY SEALED ■ ALL SOLID STATE



MODULAR OCTAVE BANDWIDTH SPST SWITCHES



Low Cost Modular Design

Octave Bandwidths, 1 to 18 GHz

Bias Port

DC Isolation from RF Line

Type N or 3 mm RF Connectors

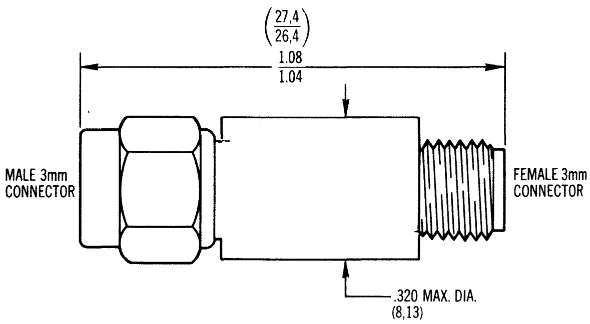
Environmentally Rugged

DESCRIPTION

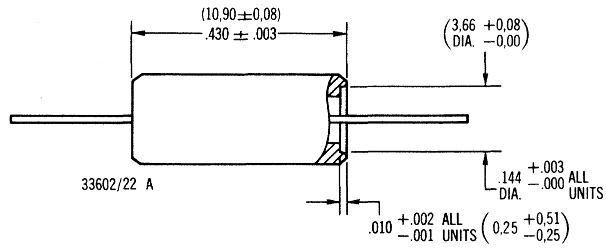
HP series 33600 are broadband solid-state switches or attenuators for use from dc to 18 GHz. They consist of two or more oxide passivated silicon PIN or fast-switching diodes which are functionally integrated into 50-ohm miniature coaxial transmission line. Dimensions of the A series match both 0.141-inch O.D. and 0.188-inch O.D. miniature semi-rigid coaxial cable, and are readily adaptable to 0.276-inch O.D. line. Module housings are hermetically sealed and all internal joints are welded or thermal compression bonded, using proven materials to assure reliable operation under severe environmental conditions. The B series incorporates one male and one female 3 mm miniature RF connector with the module to facilitate applications where connectors are desired.

APPLICATION

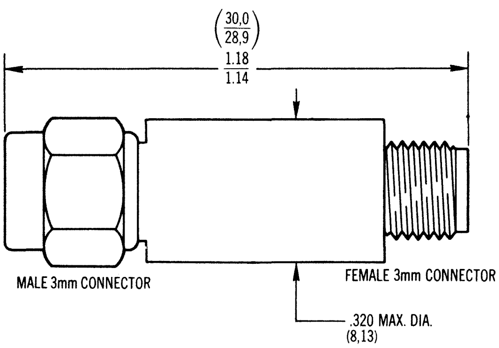
HP 33600 A/B series are versatile, electrically actuated control elements that are ideally suited for a large variety of high frequency and microwave circuits including: Pulse Modulators, Amplitude Modulators, Phase Shifters, Multiple Throw Switches, Phased Array Antennas, T-R Switches, Limiters, Attenuators, Automatic Gain Control Circuits, Power Leveling Circuits, Redundant Microwave Systems, Signal Synthesizers, Frequency Synthesizers, Suppressed Carrier Modulators, Pulse Shapers, Antenna Lobing Circuits.



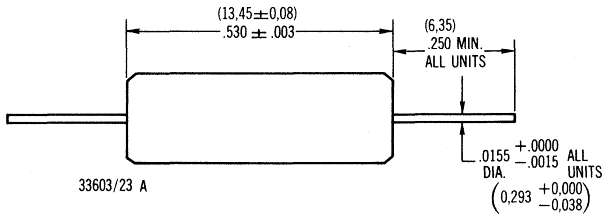
33602 B / 33622 B



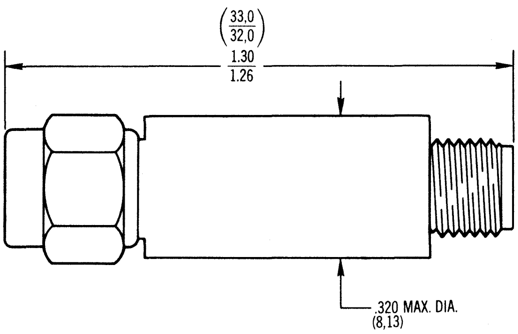
33602/22 A



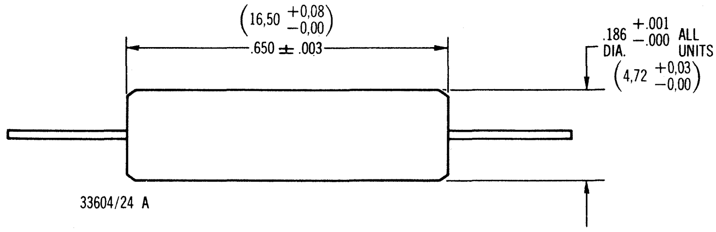
33603 B / 33623 B



33603/23 A



33604 B / 33624 B



33604/24 A

ABSOLUTE MAXIMUM RATINGS (All Modules & Options)
Maximum Forward Bias Voltage (all units)............1.0 volt
Maximum Reverse Diode Breakdown Voltage
33602/3/4 A and B ....100 volts
33622/3/4 A and B ....40 volts
Maximum Incident Power........See power handling curves and derating curve

MECHANICAL CHARACTERISTICS (Modules Only)
Size ....As shown in the outline drawing
Weight
A Versions ....One gram maximum, all units
B Versions ....Ten grams maximum, all units
Materials ....Case, Cover, and Leads: Kovar
Finish ....Case, Cover, and Leads or Connectors: Gold plated, 50 μ inches, minimum

ELECTRICAL SPECIFICATIONS
All specifications are at 25°C and apply to either RF port since all units are electrically and mechanically symmetrical.

USABLE FREQUENCY RANGE ....dc to 12.4 GHz (33604 A/B, 33624 A/B)
dc to 15 GHz (33622 A/B, 33623 A/B)
dc to 18 GHz (33602 A/B, 33603 A/B)

DESIGN CHARACTERISTICS (A Modules Only)
Temperature, Storage ....– 65° to + 150°C
Temperature, Operating ....– 65° to + 150°C

MIL-STD-750 reference and conditions
Temperature Cycling ....Method 1051, Test Condition B
Thermal Shock ....Method 1056, Test Condition A
Humidity ....Method 1021.1, omit initial conditioning
Shock ....Method 2016.1, 5 blows each X_1, Y_1, Y_2, Z orientations, 0.5 Ms pulse, 1500 G min., non-operating
Vibration Variable Frequency ....Method 2056
Constant Acceleration ....Method 2006, 2000 G

VSWR ....Switch ON: Refer to Table I
Switch OFF: High, dependent on bias and frequency, typically 20-40:1
VSWR is determined in a 50 Ω coaxial cable system.

TABLE I
VSWR, ISOLATION, AND INSERTION LOSS CHARACTERISTICS
Specifications and Typical Performance (Modules Only)

Type No.	Parameter— Test Condition	dc-0.1 GHz Spec.	Typ.	0.1-1.0 GHz Spec.	Typ.	1-2 GHz Spec.	Typ.	2-4 GHz Spec.	Typ.	4-8 GHz Spec.	Typ.	8-12 GHz Spec.	Typ.	12-18 GHz Spec.	Typ.
33602 A/B	VSWR (0 bias)	1.5:1 max.	1.3:1	1.5:1 max.	1.3:1	1.5:1 max.	1.3:1	1.5:1 max.	1.3:1	2.0:1 max.	1.5:1	2.0:1 max.	1.5:1	2.2:1 max.	1.5:1
	Isol. (I_{BIAS} = 100mA)	30 dB min.	34 dB	33 dB min.	38 dB	35 dB min.	40 dB	40 dB min.	45 dB	45 dB min.	50 dB	45 dB min.	50 dB	45 dB min.	50 dB
	Insert. Loss (0 bias)	0.2 dB max.	0.1 dB	0.5 dB max.	0.3 dB	0.5 dB max.	0.3 dB	0.7 dB max.	0.5 dB	1.2 dB max.	1.0 dB	1.5 dB max.	1.0 dB	2.0 dB max.	1.5 dB
33603 A/B	VSWR (0 bias)	1.5:1 max.	1.3:1	1.5:1 max.	1.3:1	1.7:1 max.	1.5:1	2.0:1 max.	1.8:1	2.0:1 max.	1.8:1	2.0:1 max.	1.8:1	2.4:1 max.	2.1:1
	Isol. (I_{BIAS} = 150mA)	35 dB min.	37 dB	38 dB min.	40 dB	55 dB min.	60 dB	60 dB min.	65 dB	60 dB min.	70 dB	60 dB min.	70 dB	60 dB min.	70 dB
	Insert. Loss (0 bias)	0.2 dB max.	0.1 dB	0.3 dB max.	0.2 dB	0.8 dB max.	0.6 dB	0.8 dB max.	0.6 dB	1.5 dB max.	1.0 dB	1.5 dB max.	1.0 dB	2.3 dB max.	1.8 dB
33604 A/B	VSWR (0 bias)	1.5:1 max.	1.2:1	1.5:1 max.	1.2:1	1.6:1 max.	1.4:1	1.7:1 max.	1.5:1	1.7:1 max.	1.5:1	1.7:1 max.	1.5:1		
	Isol. (I_{BIAS} = 200mA)	43 dB min.	45 dB	45 dB min.	50 dB	65 dB min.	70 dB	80 dB min.	87 dB	80 dB min.	87 dB	80 dB min.	87 dB		
	Insert. Loss (0 bias)	0.3 dB max.	0.2 dB	0.4 dB max.	0.3 dB	0.8 dB max.	0.6 dB	1.0 dB max.	0.8 dB	1.3 dB max.	1.0 dB	1.5 dB max.	1.3 dB		
33622 A/B	VSWR (B_{BIAS} = – 10V)	1.5:1 max.	1.3:1	1.5:1 max.	1.3:1	1.5:1 max.	1.3:1	2.0:1 max.	1.5:1	2.0:1 max.	1.5:1	2.0:1 max.	1.5:1	**12-15 GHz** 2.2:1 max.	1.7:1
	Isol. (I_{BIAS} = 100mA)	25 dB min.	28 dB	28 dB min.	30 dB	28 dB min.	31 dB	33 dB min.	36 dB	39 dB min.	43 dB	45 dB min.	48 dB	45 dB min.	48 dB
	Insert. Loss (V_{BIAS} = – 10V)	0.2 dB max.	0.1 dB	0.5 dB max.	0.3 dB	0.5 dB max.	0.3 dB	0.7 dB max.	0.5 dB	1.2 dB max.	1.0 dB	1.5 dB max.	1.0 dB	2.0 dB max.	1.5 dB
33623 A/B	VSWR (V_{BIAS} = – 10V)	1.5:1 max.	1.2:1	1.5:1 max.	1.2:1	1.5:1 max.	1.2:1	1.5:1 max.	1.2:1	1.7:1 max.	1.4:1	2.0:1 max.	1.5:1	2.0:1 max.	1.7:1
	Isol. (I_{BIAS} = 150mA)	28 dB min.	31 dB	30 dB min.	33 dB	35 dB min.	40 dB	45 dB min.	50 dB	55 dB min.	60 dB	60 dB min.	65 dB	60 dB min.	65 dB
	Insert. Loss (V_{BIAS} = – 10V)	0.2 dB max.	0.1 dB	0.3 dB max.	0.2 dB	0.5 dB max.	0.3 dB	0.7 dB max.	0.5 dB	0.9 dB max.	0.7 dB	1.5 dB max.	1.3 dB	2.0 dB max.	1.6 dB
33624 A/B	VSWR (V_{BIAS} = – 10V)	1.5:1 max.	1.2:1	1.5:1 max.	1.2:1	1.5:1 max.	1.2:1	1.5:1 max.	1.2:1	1.7:1 max.	1.4:1	2.3:1 max.	2.0:1		
	Isol. (I_{BIAS} = 200mA)	30 dB min.	32 dB	32 dB min.	35 dB	45 dB min.	50 dB	60 dB min.	65 dB	75 dB min.	80 dB	80 dB min.	85 dB		
	Insert. Loss (V_{BIAS} = – 10V)	0.2 dB max.	0.1 dB	0.3 dB max.	0.2 dB	0.5 dB max.	0.3 dB	0.6 dB max.	0.4 dB	1.1 dB max.	0.8 dB	2.0 dB max.	1.7 dB		

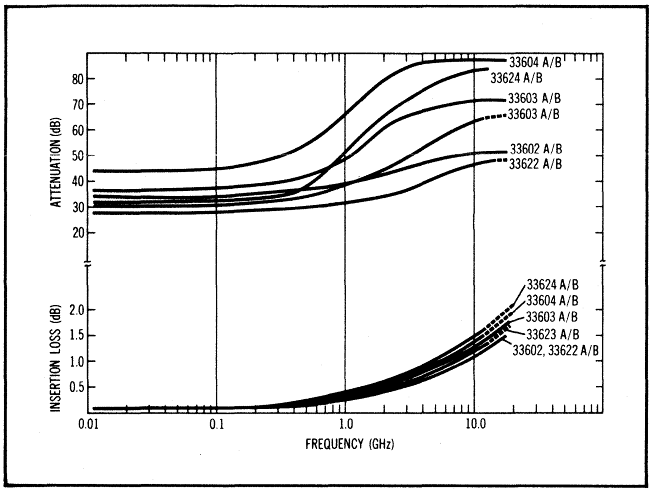


Figure 1. Typical Attenuation and Insertion Loss vs. Frequency.

SWITCHING CHARACTERISTICS

The switching characteristic is measured over a dynamic range of approximately 10 dB of detected RF power. The RF "OFF" to "ON" time is measured between 10 dB of isolation and a point 0.45 dB above the insertion loss of any module. The RF "ON" to "OFF" time is measured between a point 0.45 dB above the insertion loss and 10 dB of isolation of any module. This is a 10%-90% measurement of the detected video pulse when square law detection obtains in the system.

The measurement is made with a module biased "OFF" with forward current as follows:

	Forward Current
33602, 33622 A/B	100 mA
33603, 33623 A/B	150 mA
33604, 33624 A/B	200 mA

The modules are driven "ON" by a voltage pulse of 40 volts for 33622/23/24, and 50 volts for 33602/03/04 having rise and fall times of 20 nanoseconds as obtained from a pulse generator with a 50-ohm source impedance, such as the Hewlett-Packard Model 214A.

TABLE II
Switching Speed—nanoseconds
Specifications and Typical Performance

	Speed "OFF" to "ON"		Speed "ON" to "OFF"	
Type No.	**Max.**	**Typ.**	**Max.**	**Typ.**
33602 A/B	50 ns	45 ns	50 ns	40 ns
33603 A/B	75 ns	50 ns	50 ns	40 ns
33604 A/B	100 ns	75 ns	50 ns	40 ns
33622 A/B	10 ns	7 ns	10 ns	8 ns
33623 A/B	15 ns	10 ns	10 ns	8 ns
33624 A/B	25 ns	20 ns	15 ns	10 ns

RF POWER HANDLING CHARACTERISTICS

The incident RF power that can be safely handled by the modules is dependent on the breakdown voltage of the diodes, the maximum diode power dissipation, the bias state of the module (i.e., whether the unit is ON, OFF, or in an intermediate attenuation condition), and the frequency of the RF signals.

Maximum safe signal power handling capability of the modules as a function of attenuation and frequency is shown by Figures 2, 3, and 4. Note that safe limits for both pulse and CW conditions are given. Under full isolation conditions the limiting factor which defines power handling capability is energy storage capacity of the diodes. Under insertion loss conditions the limiting factor which defines power handling capability is diode breakdown voltage.

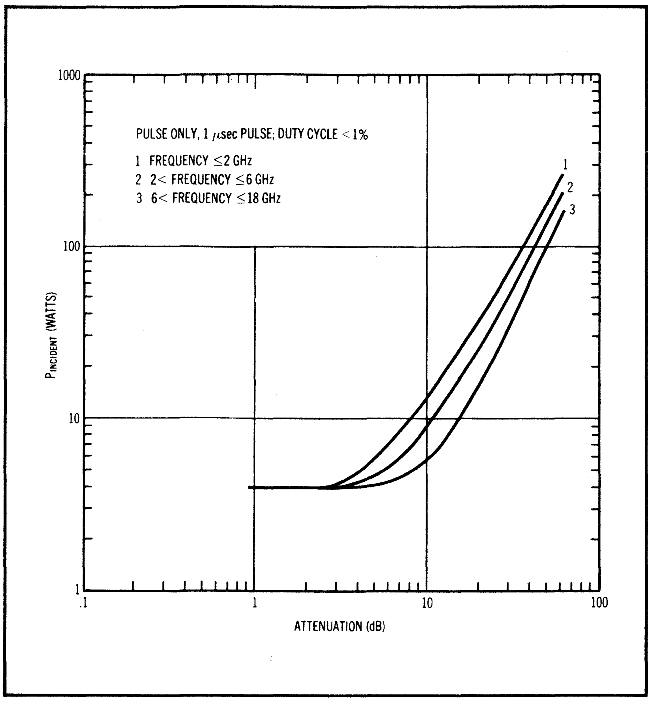


Figure 2. Incident Power Ratings at 25°C for the 33622, 33623, and 33624 A and B Versions for Pulse Operation.

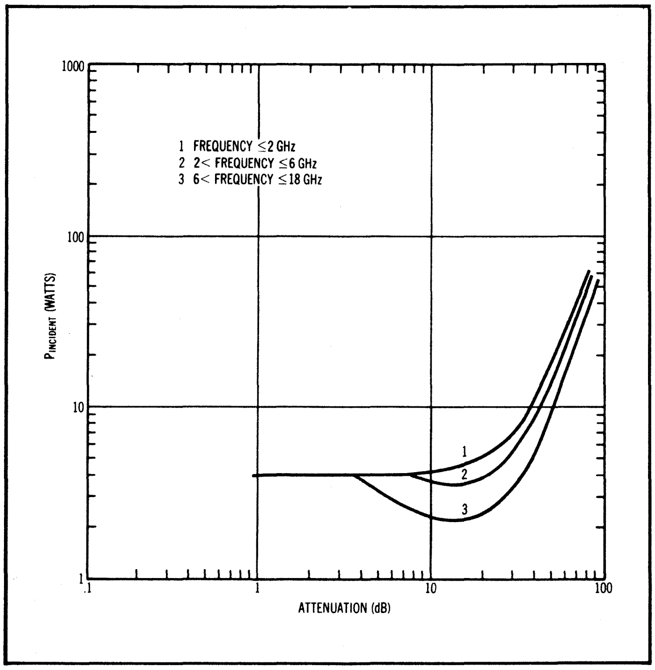


Figure 3. Incident Power Ratings at 25°C for the 33622, 33623, and 33624 A and B Versions for CW Operation.

The limits defined for pulse power handling assumed a one microsecond pulse at a duty factor of 0.1% maximum. Table III defines correction factors to be used for pulse durations of 0.5 μsec and 2.0 μsec. These factors may be used directly to modify incident power limitations read from Figures 2 and 4.

TABLE III

Pulse Width	33602, 33603, 33604 A/B	33622, 33623, 33624 A/B
0.5 μsec	1.55	1.52
2.0 μsec	0.62	0.7

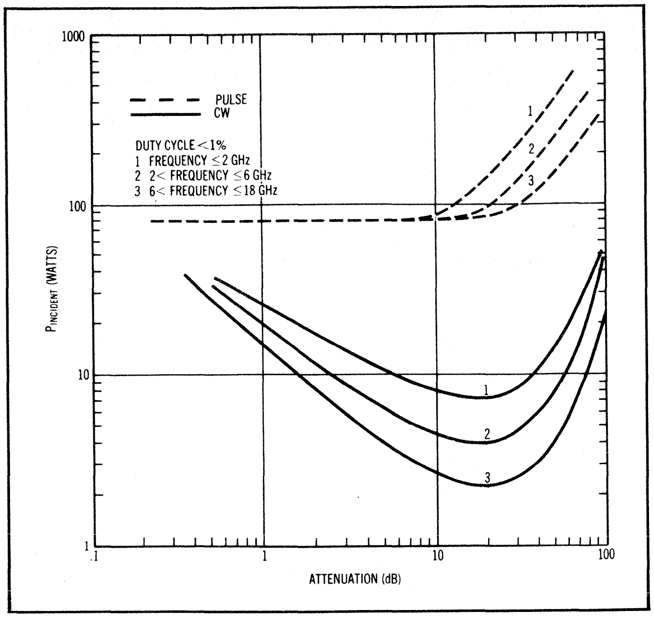


Figure 4. Incident Power Ratings at 25°C for the 33602, 33603, and 33604 Pulse and CW Operation.

Figures 2, 3, and 4 are valid for operation at 25°C only. The derating curve of Figure 5 defines the temperature derating factors which apply over the operating temperature range, and which can be used with power handling limits derived from Figures 2, 3, and 4 to completely define the power capability of any module.

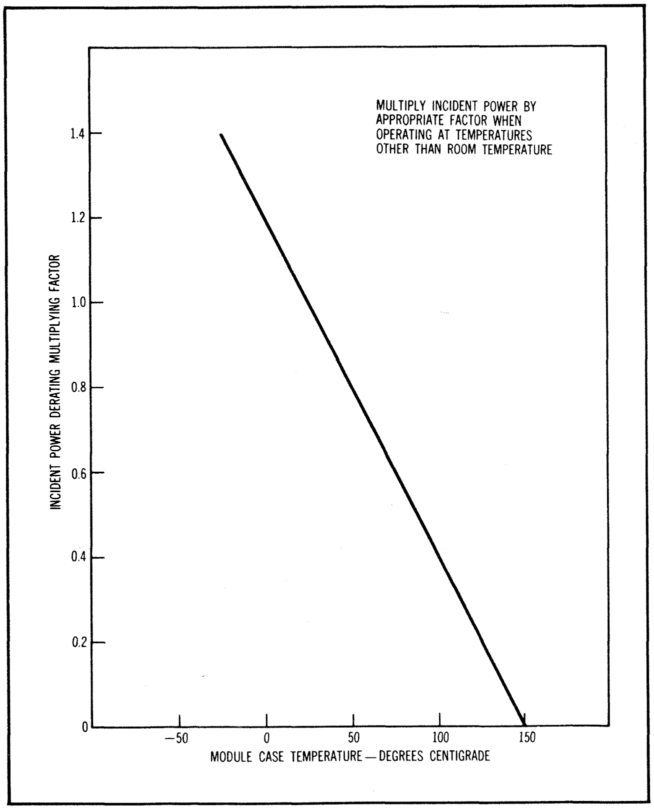


Figure 5. Temperature Derating of Incident Power.

TYPICAL CHARACTERISTICS

ATTENUATION. HP Switching Modules exhibit negligible fine grain attenuation characteristics. Typical variations of attenuation as a function of bias current, frequency, and temperature are shown in Figures 6, 7, 8, 9, 10, 11, and 12.

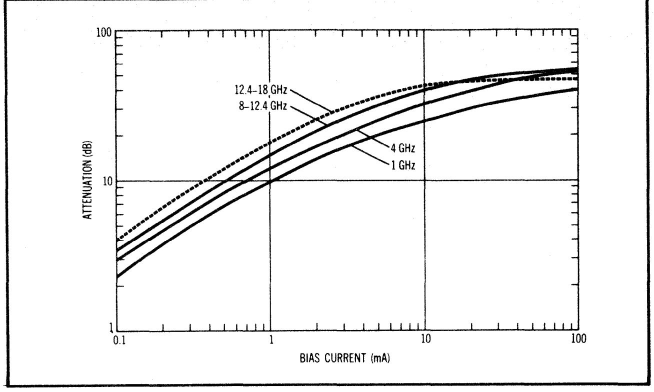


Figure 6. Attenuation of the 33602 A/B Module as a Function of Bias Current with Frequency as a Parameter.

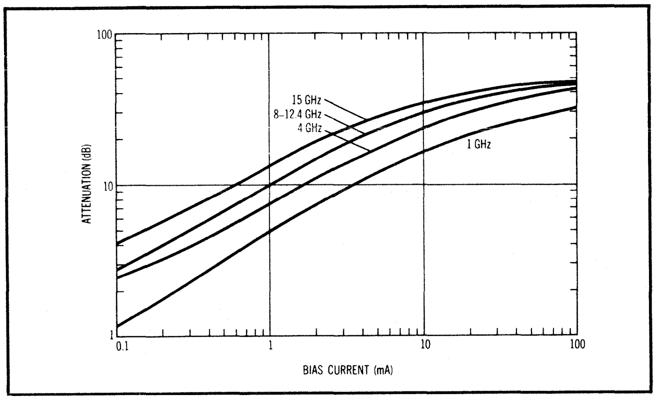


Figure 7. Attenuation of the 33622 A/B Module as a Function of Bias Current with Frequency as a Parameter.

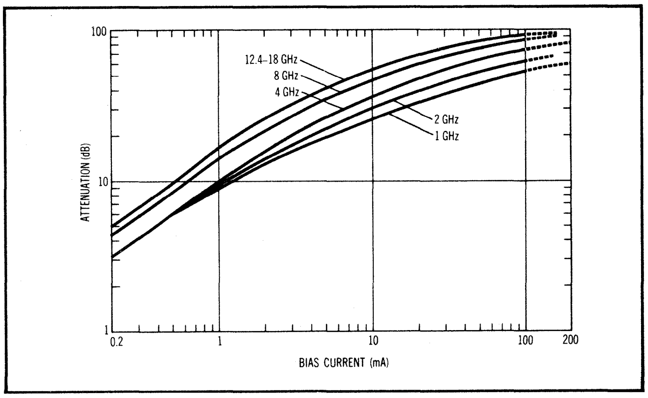


Figure 8. Attenuation of the 33603 A/B Module as a Function of Bias Current with Frequency as a Parameter.

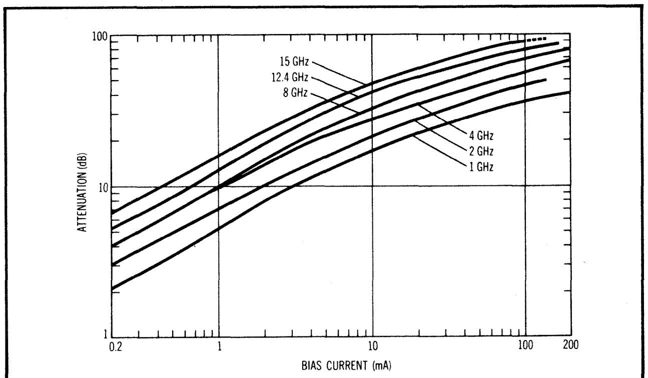


Figure 9. Attenuation of the 33623 A/B Module as a Function of Bias Current with Frequency as a Parameter.

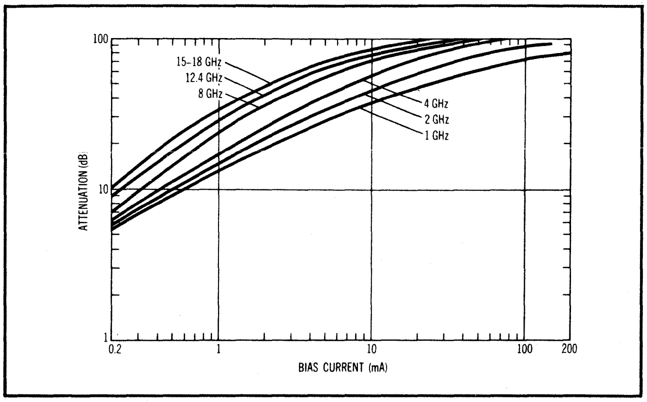


Figure 10. Attenuation of the 33604 A/B Module as a Function of Bias Current with Frequency as a Parameter.

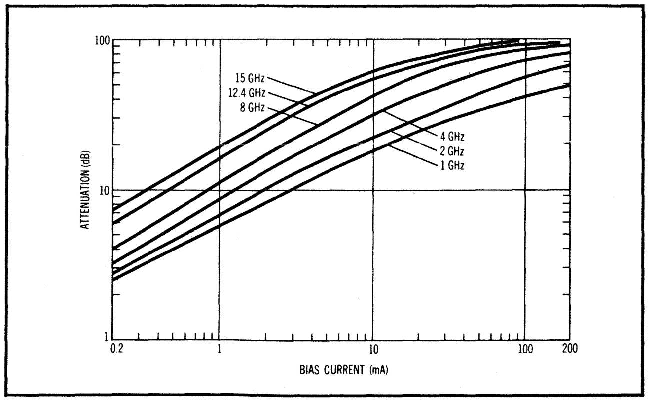


Figure 11. Attenuation of the 33624 A/B Module as a Function of Bias Current with Frequency as a Parameter.

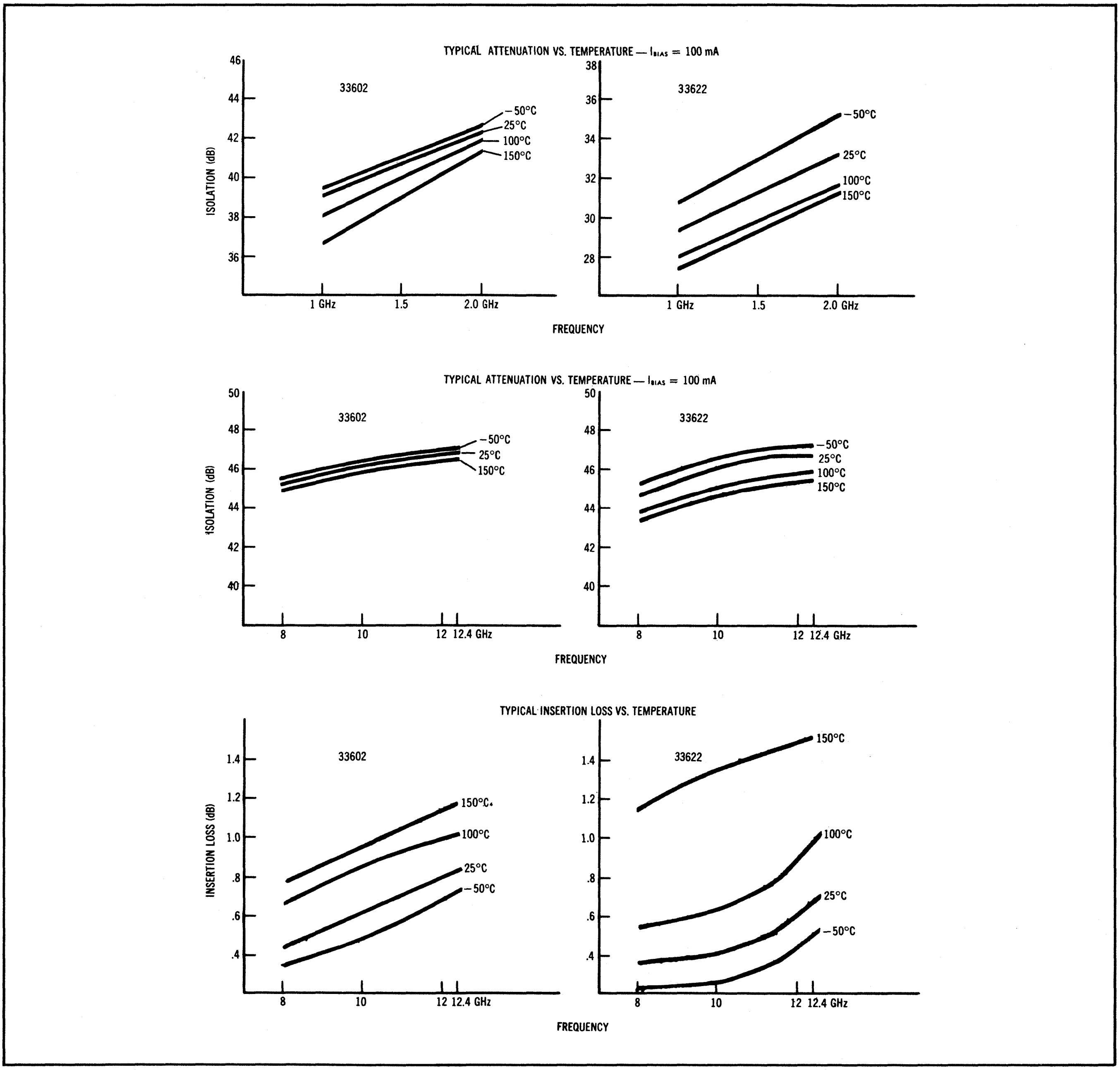


Figure 12. Typical Attenuation and Insertion Loss vs. Temperature (1-2 GHz, 8-12.4 GHz).

NOISE, HARMONICS and SPURIOUS SIGNALS. HP Switching Modules behave as thermal resistances shunted across the transmission line. Their excess noise temperature is less than 20° Kelvin, resulting in noise figures essentially equal to the insertion loss at all bias levels, exceeding this value by less than 0.2 dB at the worst case, the 6-10 dB attenuation range.

Harmonic distortion products; generated internally by 33602, 33603, and 33604 modules, are at least 40 dB below fundamental output levels for signal frequencies above 350 MHz. For 33622, 33623, and 33624 modules, the 40 dB down ratio holds for signal frequencies above 4 GHz, at full isolation level, or at insertion loss level for power inputs less than ½ watt.

Feed-through of RF signals into video control circuits and feed-through of video control signals into RF lines are functions of bias circuit and filter designs. Isolation of control pulses from the RF line of ≈ 30 dB and isolation of RF signal from the control circuit of ≈ 70 dB have been achieved at HP.

PHASE SHIFT. The phase shift characteristics of the modules are virtually identical to those of a length of coaxial cable when zero or reverse biased ON. Typical air equivalent electrical lengths for the two principal bias conditions are:

	33602/33622A	33603/33623A	33604/33624A
Module ON	1.8 cm	2.0 cm	2.3 cm
	Between front surfaces of the module.		
Module OFF	0.7 cm	0.7 cm	0.7 cm
	Between either front surface of the module and the internal short.		

The typical transmission phase shift relative to the ON condition vs. isolation is shown in Figure 13 for both two-diode and both four-diode modules.

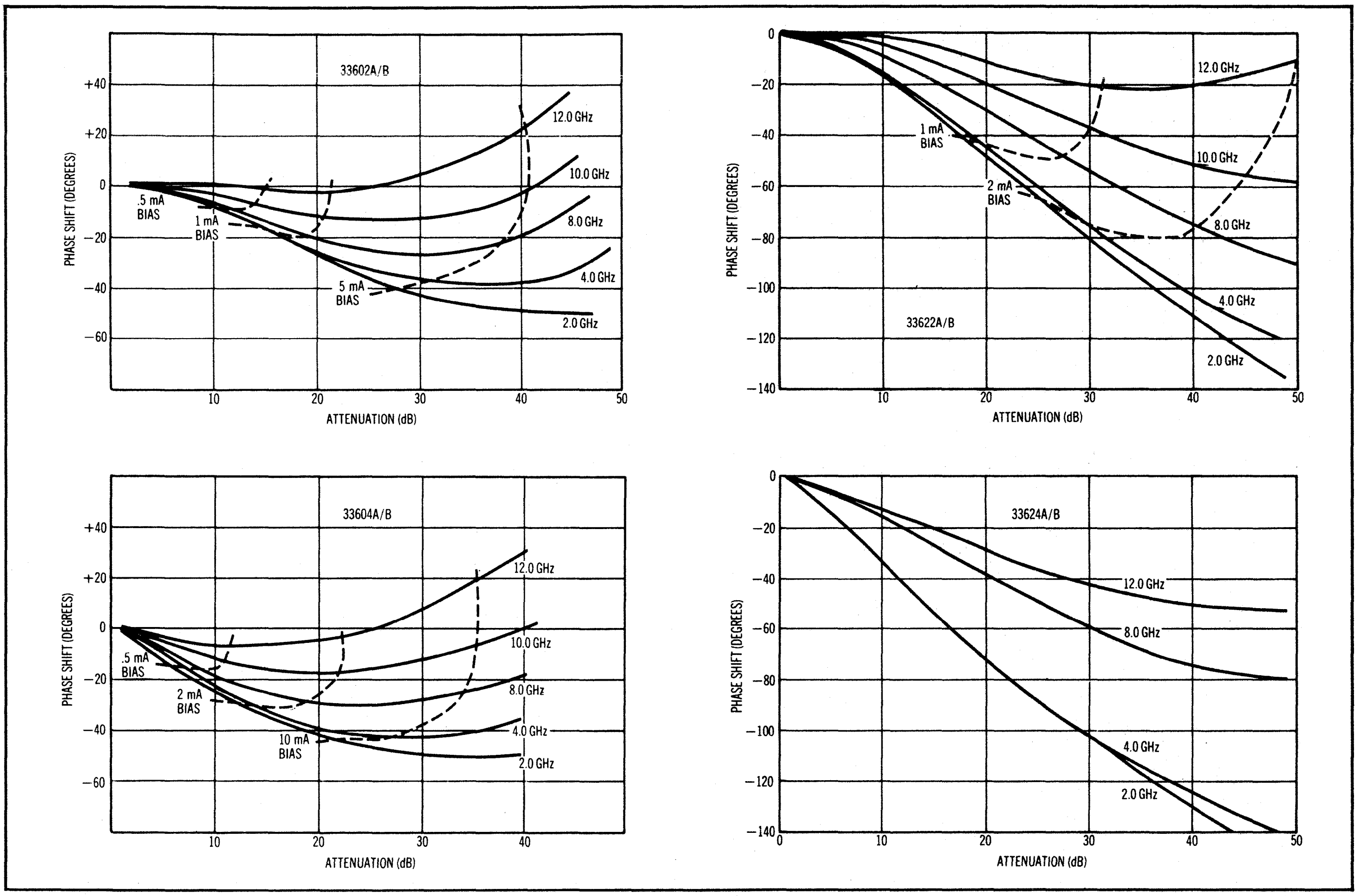


Figure 13. Typical Relative Transmission Phase Shift vs. Attenuation for 33602 A/B, 33604 A/B, 33622 A/B, and 33624 A/B. (Negative phase shift is equivalent to longer line length.)

SWITCH BIASING APPLICATION INFORMATION

Proper biasing of the switch can be understood from the following schematic diagrams, Figures 14 and 15.

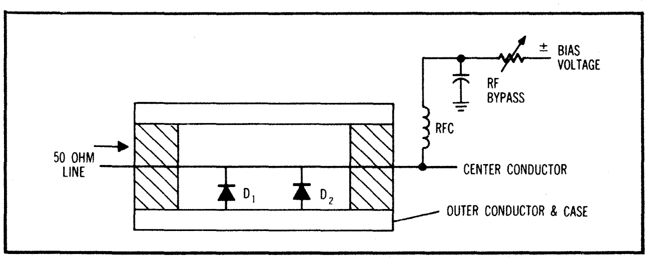


Figure 14. 33602 Module Schematic Diagram.

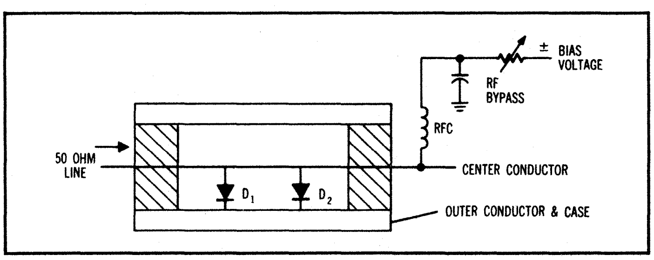


Figure 15. 33622 Module Schematic Diagram.

Bias can be applied to either port center conductor. The switch is "ON" or passing an RF signal when the bias voltage is zero or a positive value for 33602/3/4 modules, zero or negative for 33622/3/4 modules. Under this condition the diodes are a high impedance and the current through them is typically less than one microampere. The switch is "OFF" or blocking an RF signal when the bias voltage is negative for the 33602/3/4 modules and positive for the 33622/3/4 modules. Under this condition the diodes are forward biased to a low impedance. The individual diodes are matched and the total bias current is divided equally between them. The magnitude of the forward bias current determines the degree of attenuation provided by the switch.

The forward bias current-voltage characteristics of the modules are shown in the following table:

TABLE IV
TYPICAL CURRENT @ 1 VOLT

Module	Current @ 1 Volt Forward Bias
33602	450 mA
33603	675 mA
33604	900 mA
33622	300 mA
33623	450 mA
33624	600 mA

MOUNTING AND BIASING INSTRUCTIONS

MOUNTING. Since the modular switch is a short section of coaxial transmission line, mounting joins the switch with other sections of transmission line so that the whole appears as a single transmission line of uniform impedance.

The most critical concern in the mounting of the outer conductor of the module is prevention of RF leakage. Very small gaps may act as resonant sections of transmission line, exhibiting path attenuation up to 20 dB less than that of the switch. For this reason, the contact between the switch and the outer conductor of the transmission line must be made gap-free, either with positive mechanical contact or through the use of conductive compounds such as silver loaded epoxy.

The two basic methods of mounting the outer conductor are: (1) contact with the ends of the module; and (2) contacting the outer diameter. For simple designs, the end contacting method is limited to lines with an I.D. of less than 0.187 inch, while diameter contacting is limited to lines with an I.D. of 0.187 inch or greater.

An example of end contacting is shown in Figure 16. Mechanical pressure maintains a zero gap at the contacting surfaces.

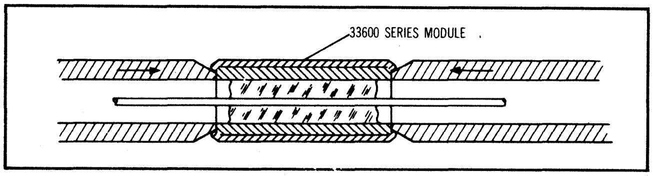


Figure 16. End Contacting Modules.

Mounting the switch by contacting the outside diameter is the simplest method mechanically, but is also most prone to RF leakage. Because the dimensional tolerance on the module diameter is +0.001/−0.000 inch, a coaxial line bored for a line fit with a maximum diameter unit will have a 0.001 inch gap with a minimum tolerance unit. This may result in a leakage path, particularly at frequencies where the length of the switch is ½ wavelength. Also, a loose fit will not ensure a good dc contact, a requirement for proper operation.

There are many techniques which will eliminate this leakage problem:

(1) The switch can be sealed with a conductive epoxy. The compound must have excellent conductivity since any resistance will appear in series with the diode resistance and reduce the switch isolation. Several compounds satisfying these requirements are commercially available.

(2) Conductive O-rings, of rubber or soft metal, or metal mesh may be used to seal leakage paths and ensure a good dc contact. If more than one of these seals are used, best results will be obtained when they are placed ¼ wavelength apart. See Figure 17.

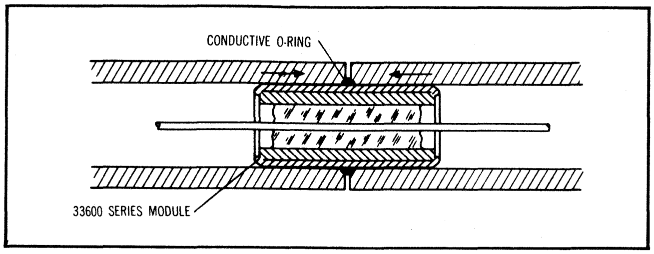


Figure 17a. Module Mounting with "O" Rings.

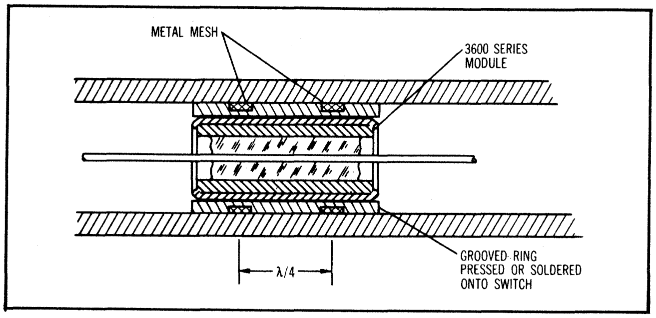


Figure 17b. Module Mounting with Metal Mesh Rings.

Mounting the center conductor of the line to the switch consists of making an electrical/mechanical contact that is properly matched to the line impedance. Soldering or finger contacts with tapered or "stepped" pins will accomplish this. Two typical examples are shown, with pertinent dimensions, in Figure 18.

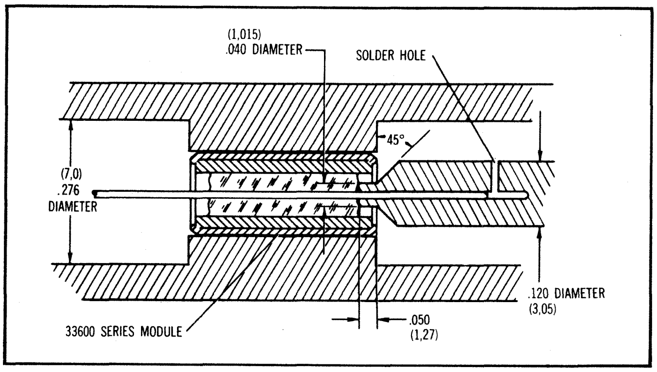


Figure 18a. Center Pin Contact.

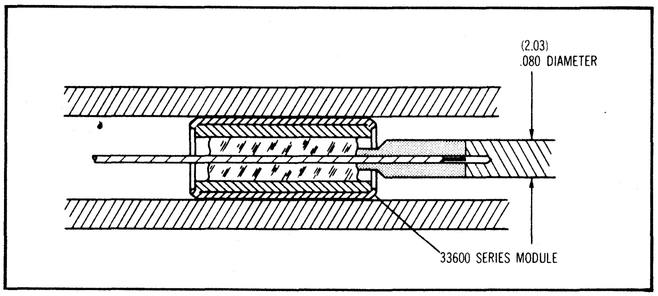


Figure 18b. Center Pin Contact.

In attaching connectors to the coaxial line, standard RF design practices should be followed. Since the center conductors of the switch are 0.014 inch in diameter, connectors with captured center conductors should be used if rough handling might be encountered.

BIASING. Since the diodes in the modules shunt the transmission line, the dc bias must be applied across the terminals of the line. This requires a shunt dc connection to the center conductor that appears as a high impedance to the RF signal. Several ways to accomplish this are shown below.

(1) A ¼ wavelength shunt transmission line can be used, as shown in Figure 19. The impedance of the shunt line should be high for maximum bandwidth. Reasonable impedance values give a good match over greater than one octave. The ¼ wavelength line must be terminated by an RF short, which can be achieved by a large lumped capacitance or a ¼ wavelength section of open circuited low impedance line. Excessively large values of bypass capacitance, which increase the isolation of RF from the bias port, also may slow the switching speed.

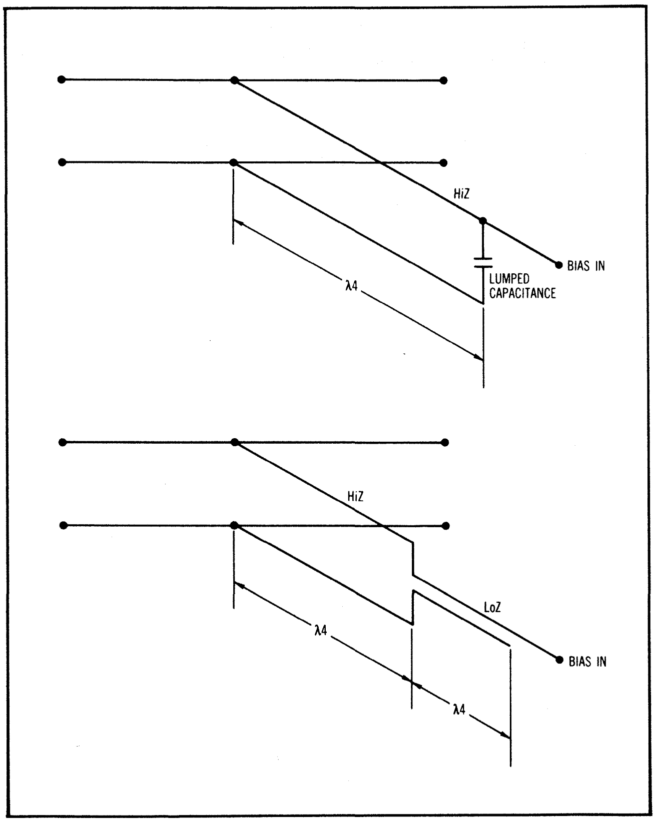


Figure 19. Quarter-wave Bias Lines.

(2) A variation of the above is the use of a ¼ wavelength section of helical transmission line, fabricated from a small coil spring. The impedance of such a device is generally high, while the physical length is typically several times smaller than a normal transmission line of equivalent electrical length. See Figure 20.

(3) Lumped element high pass filters may also be used. They have an added advantage of excellent suppression of the switching pulse from the RF line.

(4) Other system components may be adapted to introduce bias to the switch. One example is using accessible center conductors on terminations of circulators; another is utilizing a small wire connected to the probe of a waveguide to coax transition. Mounted at right angles to the electric field, such a device does not disturb the transition.

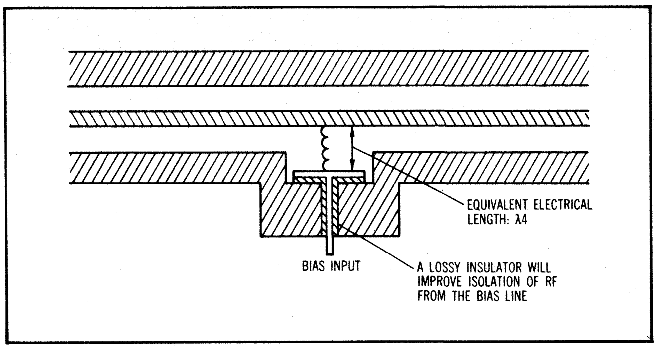


Figure 20. Helical Spring Bias Line Detail.

The presence of other components in the system, such as detectors, mixers, other switches, etc., often requires isolating the dc bias from the rest of the RF circuit. Other components such as couplers, filters, and waveguide fulfill this requirement. However, in many cases a blocking circuit must be constructed.

(1) Figure 21 shows a ¼ wavelength open line in series with the line center conductor. High values of dielectric constant will decrease both the device length and the impedance, the latter required for wide bandwidth. If the ¼ wavelength shunt line is used for bias insertion, locating these two lines at the same point will further increase the bandwidth.

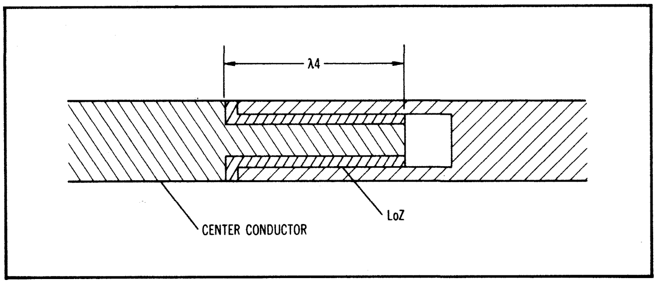


Figure 21. Bias Blocking Detail.

(2) Another useful blocker is a lumped capacitor. A thin wafer of a high dielectric ceramic can be metalized and soldered to one half of a split center conductor. The other half of the center conductor contacts the capacitor with a bellows or spring-loaded button. An example is shown in Figure 22.

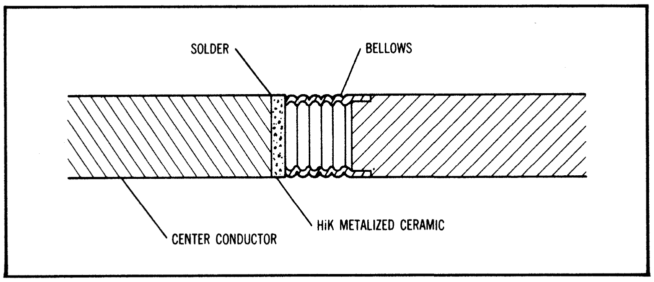


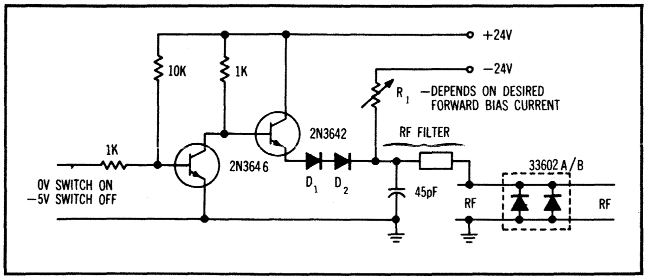
Figure 22. Bias Blocking Detail.

(3) Lumped element high pass filters can be used. These devices also have excellent suppression of the switching pulse from the line.

MODULE DRIVE CIRCUITS

A complete description of circuitry for switch driver applications of the modules is given in HP Application Note 914. This note describes required video driving waveforms, and means of generating these waveforms. Emphasis is given to methods of achieving very fast switching speeds or high modulation frequencies. The note also discusses charge storage behavior of PIN switching diodes, drive waveform requirements, suggested forms of drive circuits, pulse leakage into the RF system, test and measurement methods, and precautions for high-speed circuits.

An elementary transistor driver suitable for obtaining 50 nanosecond rise and fall times is shown below. No pulse shaping is used. The RF filter should not affect the bias pulse but may contain an RF by-pass such as the 45 pF capacitor used in this circuit. Fast switching silicon diodes D_1 and D_2 serve only to offset the emitter voltage so that the second transistor may turn off.



Example of a Transistor Driver.

DESIGN CHARACTERISTICS

(Modular Octave Switches and B Version Modules)

Temperature, Storage	−65°C to +125°C
Temperature, Operating	−65°C to +125°C

MIL-STD-202 Reference and Conditions

Temperature Cycling	—Method 102A, Condition C	−65°C to +125°C
Altitude	—Method 105C, Condition B	50,000 feet
Humidity	—Method 103B, Condition A	40°C, 90-95% RH, 240 hours
Vibration	—Method 204A, Condition B	10-2000 Hz, ±15 G
Shock	—Method 213, Condition B	75 G, 6 msec pulse
Salt Atmosphere	—Method 101B, Condition A	Fog at 35°C, 96 hr

MODULAR OCTAVE BANDWIDTH SPST SWITCHES

DESCRIPTION

A series of standard octave bandwidth microwave coaxial reflective SPST switches covering the frequency range from 1 to 18 GHz has been developed around the 33600A modules. These switches are complete with coaxial connectors at the RF and bias ports, dc blocking capacitors, bias choke, and bypass capacitor. Fifty-six switches are available as options to the 33600A modules, with Type N or 3 mm RF connectors, and BNC or 3 mm bias connectors. A wide range of performance is available: frequency coverage from 1 GHz to 18 GHz, from 30 to 80 dB isolation, 0.7 to 2.8 dB insertion loss, and 10 nanosecond to 100 nanosecond switching speeds. Due to the modularity of the design, this flexibility is obtained at low cost to the user, while providing a rugged, reliable product.

Other connector options and/or non-standard frequency octaves are available on special order. The mechanical dimensions of the switches vary depending on the module used.

APPLICATION

This line of low-cost SPST reflective coaxial PIN diode switches is ideally suited for a wide variety of low and medium power applications in high frequency and microwave circuits. These include: Pulse Modulators, Amplitude Modulators, Phase Shifters, T-R Switches, Limiters, Attenuators, Levelers, AGC Circuits, and many others. The low cost of these PIN diode switches permits the replacement of electromechanical switches where the advantages of solid-state reliability and nanosecond switching speeds are beneficial.

MODULAR OCTAVE SPST SWITCHES

The electrical properties of each switch type are related to the specific 33600A module employed, and the option number indicates the connector types and the octave band covered. Table V gives the electrical performance specifications of the switches employing each module type. Table VI shows the connector and frequency band for each option. Figure 23 shows the mechanical outline of the switch as a function of the module length, and the general construction details. The absolute maximum ratings are determined by the module used (see page 1).

TABLE VI

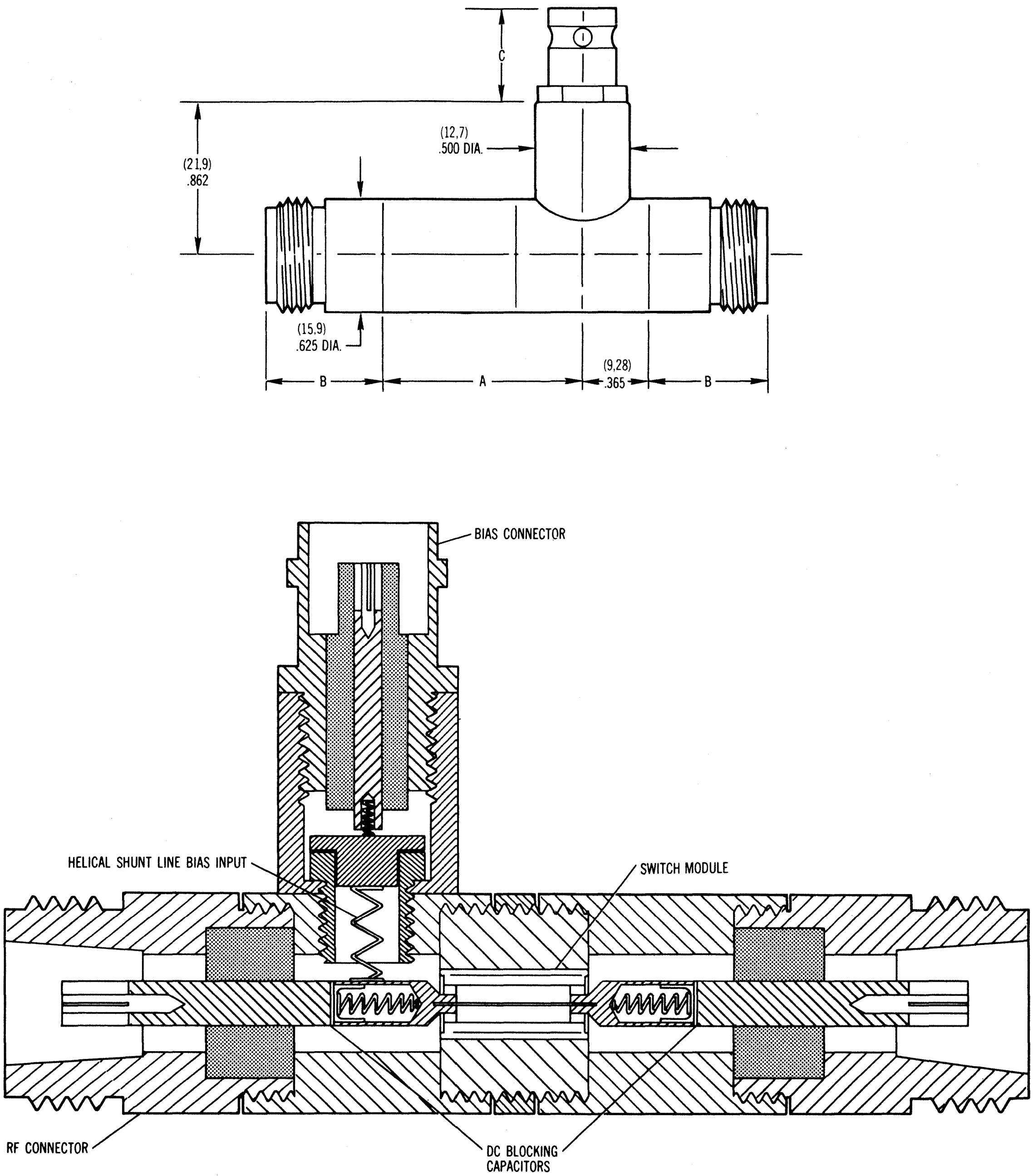
Option No.	Frequency (GHz)	RF Connectors (Female)	Bias Connectors (Female)
C02	1 - 2	N	BNC
C03	2 - 4	N	BNC
C04	4 - 8	N	BNC
C05	8 - 12	N	BNC
C18	1 - 2	3 mm	3 mm
C19	2 - 4	3 mm	3 mm
C20	4 - 8	3 mm	3 mm
C21*	8 - 18	3 mm	3 mm
C65	8 - 12	3 mm	3 mm
C66*	12 - 18	3 mm	3 mm

* Available only on 33602A and 33603A, and to only 15 GHz on 33622A and 33623A.

TABLE V
33600A Option CXX
SPST SWITCH PERFORMANCE TABLE

Type No.	Option Number / Parameter—Test Condition	C02/C18 1-2 GHz	C03/C19 2-4 GHz	C04/C20 4-8 GHz	C21: C05/C65 8-12 GHz	C21: C66 12-18 GHz*
33602A Option CXX	VSWR (0 bias)	2 max.	2 max.	2 max.	2 max.	2.5 max.
	Isol. (dB) (bias = 100 mA)	35 min.	40 min.	45 min.	45 min.	45 min.
	Insert. Loss (dB) (0 bias)	0.7 max.	1.0 max.	1.6 max.	2.0 max.	2.5 max.
33603A Option CXX	VSWR (0 bias)	2 max.	2 max.	2 max.	2 max.	2.5 max.
	Isol. (dB) (bias = 150 mA)	55 min.	60 min.	60 min.	60 min.	60 min.
	Insert. Loss (dB) (0 bias)	1.0 max.	1.1 max.	1.9 max.	2.0 max.	2.8 max.
33604A Option CXX	VSWR (0 bias)	2 max.	2 max.	2 max.	2 max.	
	Isol. (dB) (bias = 200 mA)	65 min.	80 min.	80 min.	80 min.	
	Insert. Loss (dB) (0 bias)	1.0 max.	1.3 max.	1.7 max.	2.0 max.	
33622A Option CXX						12-15 GHz*
	VSWR (—10 V bias)	2 max.	2 max.	2 max.	2 max.	2.5 max.
	Isol. (dB) (bias = 100 mA)	28 min.	33 min.	39 min.	45 min.	45 min.
	Insert. Loss (dB) (—10 V bias)	0.7 max.	1.0 max.	1.6 max.	2.0 max.	2.5 max.
33623A Option CXX	VSWR (—10 V bias)	2 max.	2 max.	2 max.	2 max.	2.5 max.
	Isol. (dB) (bias = 150 mA)	35 min.	45 min.	55 min.	60 min.	60 min.
	Insert. Loss (dB) (—10 V bias)	0.7 max.	1.0 max.	1.3 max.	2.0 max.	2.5 max.
33624A Option CXX	VSWR (—10 V bias)	2 max.	2 max.	2 max.	2 max.	
	Isol. (dB) (bias = 200 mA)	45 min.	60 min.	75 min.	80 min.	
	Insert. Loss (dB) (—10 V bias)	0.7 max.	0.9 max.	1.5 max.	2.5 max.	

* 3 mm Connectors Only.



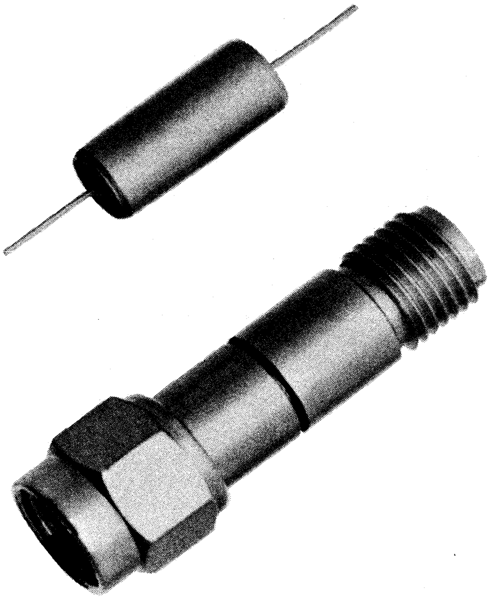
Module Type	A*		Connector	B*		C*	
	Inches	mm		Inches	mm	Inches	mm
33622/33602	1.2	30,5	Type "N" Female	0.64	16,25	——	——
33623/33603	1.3	33,0	3 mm Female	0.31	7,9	0.39	9,9
33624/33604	1.4	35,6	BNC Female	——	——	0.50	12,7

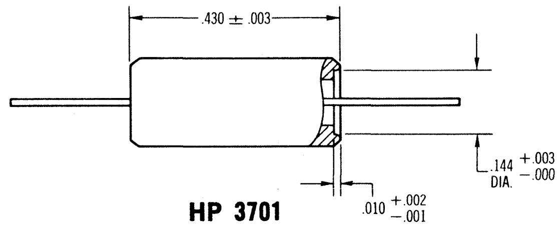
* Nominal dimensions.

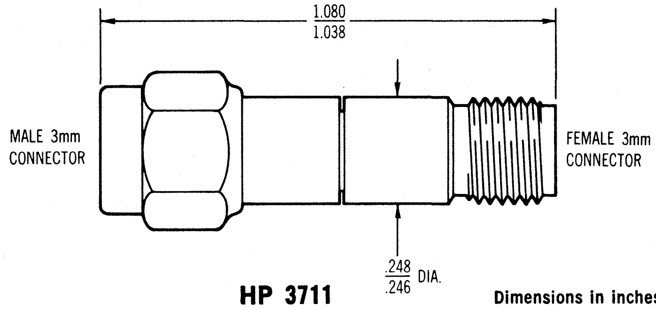
Figure 23

COAXIAL MICROWAVE PASSIVE LIMITER MODULES

HP 3701 3711







Dimensions in inches

HIGH POWER -- 75 Watts Peak Pulse
BROAD BANDWIDTH -- 400 MHz to 12.4 GHz
LOW INSERTION LOSS -- 0.4 to 1.9 dB
NEGLIGIBLE SPIKE LEAKAGE -- 0.1 erg
FAST RECOVERY -- 20 nsec
MINIATURE SIZE
HERMETICALLY SEALED
ALL SOLID STATE -- HYBRID INTEGRATED

DESCRIPTION

HP series 3700 are broadband solid-state passive limiters for use from 400 MHz to 12.4 GHz. They consist of two oxide passivated silicon PIN diodes which are functionally integrated into 50-ohm miniature coaxial transmission line. Dimensions of the 3700 series match both 0.141 inch O.D. and 0.188 inch O.D. miniature semi-rigid coaxial cable, and are readily adaptable to 0.276 inch O.D. line. Module housings are hermetically sealed and all internal joints are welded or thermal compression bonded, using proven materials to assure reliable operation under severe environmental conditions.

APPLICATION

HP series 3700 are versatile, passive, protective elements that are ideally suited for high frequency and microwave circuits including: T-R switches, Limiters, and Duplexers in Phased Array Radar Receivers, ECM Receivers, Telemetry Receivers, Signal Simulators, and Redundant Microwave Systems. The 3700 series has dual usage capability, as a switch, modulator, or attenuator. An external grounded dc return is required for limiter service. dc bias control current applied through this return allows operation as a switch, modulator, or attenuator.

DESIGN CHARACTERISTICS

Usable Frequency Range ....400 MHz to 12.4 GHz
Spike Leakage Over Usable
Frequency Range ....Less than 0.1 erg (pulse rise time = 30 ns)
Recovery Time ....20 ns max.

ENVIRONMENTAL RATINGS

Temperature, Storage ....− 65° to + 150°C
Temperature, Operating ....− 65° to + 150°C
Solder Immersion (3701 only) ....Device body totally immersed in solder, 230°C, 5 seconds
MIL-STD-750 reference and conditions
Temperature Cycling ....Method 1051, Test Condition B
Thermal Shock ....Method 1056, Test Condition A
Humidity ....Method 1021.1, omit initial conditioning
Shock ....Method 2016.1, 5 blows each X1, Y1, Y2, Z orientations, 0.5 ms pulse, 1500 G min., nonoperating
Vibration, Variable Frequency ....Method 2056
Constant Acceleration ....Method 2006, 2000 G

Figure 1 applies at room ambient temperatures only. The typical offset of varying ambient temperature upon leakage power is shown in Figure 2 measured at varying power levels at 10 GHz.

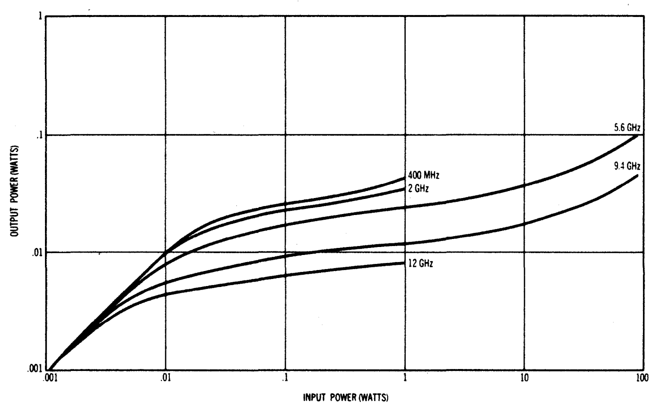


Figure 1. Typical output power vs. input power. T = 25°C.

ABSOLUTE MAXIMUM RATINGS

Maximum Forward Bias Voltage ....1.0 volt
Maximum Reverse Voltage ....30 volts
Maximum Incident Power ....1 watt CW
75 watt Peak Pulse for 1 μs width, 0.001 Duty
(See temperature derating curves.)

MECHANICAL CHARACTERISTICS

Size ....As shown in the Outline Drawings
Weight ....One gram maximum
Materials ....Case, Cover and Leads: Kovar
RF Connectors: Stainless Steel
Finish ....Case, Cover, Leads, and RF Connectors: Gold Plated, 50 μ inches, minimum

NOISE. HP 3700 series limiter modules behave as thermal resistances shunted across the transmission line. Their excess noise temperature is less than 20° Kelvin. This results in noise figures essentially equal to the insertion loss at low power levels (below the limiting threshold).

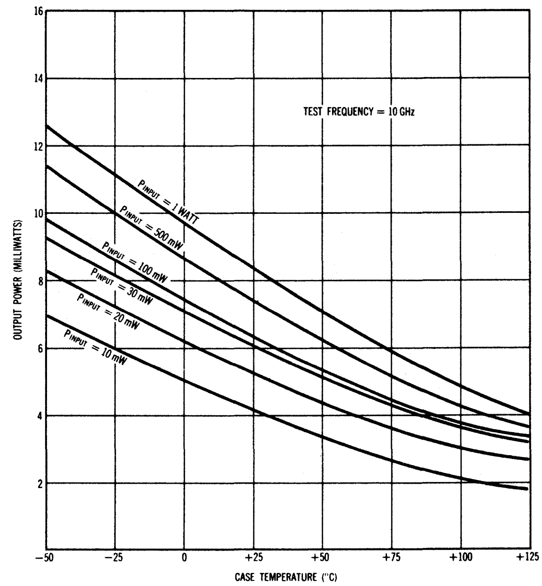


Figure 2. Temperature effects on leakage power.

TABLE I
VSWR, INSERTION LOSS, LIMITING THRESHOLD, POWER LEAKAGE

Specifications and Typical Performance — 3701 and 3711

Parameter	Test Condition	0.4 - 1 GHz		1 - 2 GHz		2 - 4 GHz		4 - 8 GHz		8 - 12.4 GHz	
		Spec.	Typ.	Spec.	Typ.	Spec.	Typ.	Spec.	Typ.	Spec.	Typ.
VSWR	0 dBm Power Level—in 50Ω Coax. Cable System	1.4:1 Max.	1.2:1	1.4:1 Max.	1.2:1	1.4:1 Max.	1.3:1	1.5:1 Max.	1.3:1	1.9:1 Max.	1.5:1
INSERTION LOSS	Same as VSWR	0.4 dB Max.	0.2 dB	0.4 dB Max.	0.2 dB	0.8 dB Max.	0.5 dB	1.2 dB Max.	1.0 dB	1.9 dB Max.	1.5 dB
LIMITING THRESHOLD	Variable CW Power		15 mW		12 mW		10 mW		10 mW		5 mW
CW POWER LEAKAGE	1 watt Power Input	80 mW Max.	70 mW	70 mW Max.	60 mW	60 mW Max.	50 mW	40 mW Max.	30 mW	30 mW Max.	20 mW
PULSE POWER FLAT LEAKAGE	75 watts Peak Pulse 1 μs Pulse Width, 0.001 Duty @ 5.6 and 9.4 GHz							150 mW Max.		120 mW Max.	

Power ratings are valid for operation at 25°C only. The derating curve of Figure 3 defines the temperature derating factors which apply over the operating temperature range, and which can be used with power handling limits to completely define the power capability of the limiter.

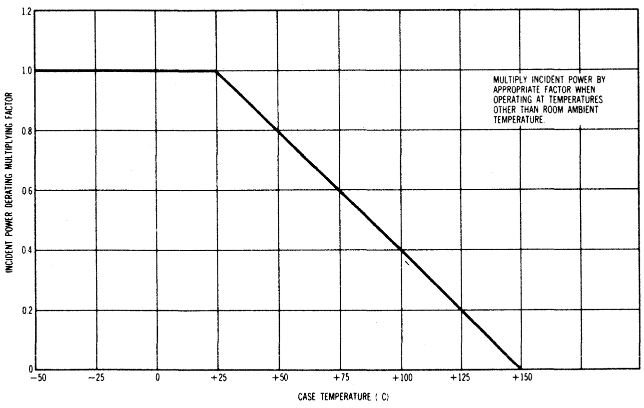


Figure 3. Temperature derating of incident power.

PHASE SHIFT. For power levels below the limiting threshold the phase shift of HP series 3700 limiters is virtually identical to that of 1.8 cm of air transmission line.

OUTPUT AMPLITUDE VARIATIONS

Above the limiting threshold, the output can abruptly change level as much as 3 dB with changing input power. This is caused by large amplitude second and third harmonic currents circulating through the limiter when the external circuit presents large reflections to the limiter terminals. These currents may add to or subtract from the self-bias current generated by the fundamental signal, lowering or raising the diode impedance and consequently decreasing or increasing the output level. Providing a good match at both limiter terminals at twice the signal frequency will eliminate the abrupt output variations.

MOUNTING OF 3701 MODULE

Since the module is a short section of coaxial transmission line, mounting joins the unit, electrically and mechanically, with other sections of transmission line so that the whole appears as a single transmission line of uniform impedance, although not necessarily of uniform dimensions.

Besides the obvious requirements of mechanical rigidity and accurate location, the most critical concern in the mounting of the outer conductor of the module is prevention of RF leakage. Very small radial gaps, on the order of a few tenths of a mil, may act as resonant sections of transmission line, exhibiting path-attenuation up to 20 dB less than that of the limiter. For this reason, the contact between the module and the outer conductor of the connecting transmission line must be made to be gap-free, either by means of a mechanical contact that is essentially zero gap, or through the use of conductive compounds, such as silver loaded epoxy. An alternative, to this ideal electrical contact is the use of loss "spoilers" in all possible leakage paths.

The two basic methods of mounting the outer conductor are (1) contact with the ends of the module; and (2) contacting the outer diameter. One of the main factors affecting the choice of methods is the desired diameter of the transmission line. For simple designs, the end contacting method is limited to lines with an I.D. of less than 0.187 inch, and the diameter contact method is limited to lines with an I.D. of 0.187 inch or greater.

An example of the end contacting method is shown in Figure 4. Mechanical pressure, such as that exerted by screw threads, maintains a zero gap at the contacting surfaces.

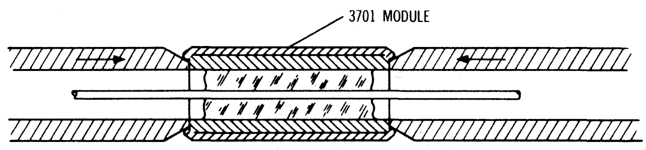


Figure 4. End contacting modules.

Mounting the limiter module by contacting the outside diameter is the simplest method mechanically, but is also the method which is most prone to RF leakage. For example, inserting the module into a coaxial line having an inside diameter the same as the outside diameter of the module. Because the dimensional tolerance on the module diameter is $+0.001/-0.000$ inch, a coaxial line bored for a line fit with a maximum diameter unit could allow a 0.001 inch loose fit with a minimum tolerance unit. This can result in a leakage path, particularly at frequencies where the length of the module is ½ wavelength. Also, a loose fit will not insure a good contact, which is a requirement for proper operation.

There are many techniques which will satisfactorily eliminate this leakage problem:

(1) The limiter module may be soldered into place. The HPA 3701 will withstand temperatures up to 230°C, which allows the use of most common soft solders.

(2) The module can be sealed by means of a conductive compound, either hardening or nonhardening. It is important that the compound have excellent conductivity, since any resistance will appear in series with the diode resistance and thereby reduce the limiter isolation. Several compounds which satisfy these requirements are commercially available.

(3) Conductive O-rings, of the rubber or soft metal type, or metal mesh may be used to seal leakage paths and insure a good contact. If more than one of these seals are used, maximum results will be obtained when they are placed ¼ wavelength apart. See Figure 5.

(4) Another method, which might be applicable to a high-volume operation, is to centerless grind the diameter of the module to a precise size. Coupled with accurate honing of the coaxial line, this will allow a press fit and simple assembly.

(5) The outside diameter of the 3701 may be given a coating of solder, then pressed into the coaxial line. The excess solder will shear off. With the ends of the module properly masked with a teflon bead, the solder may be applied by dipping in a solder pot. In this case it is recommended that the module be preheated to avoid thermal shock and possible damage.

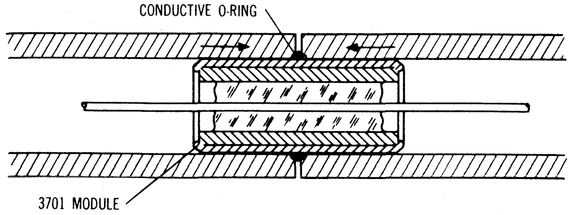


Figure 5a. Module mounting with "O" rings.

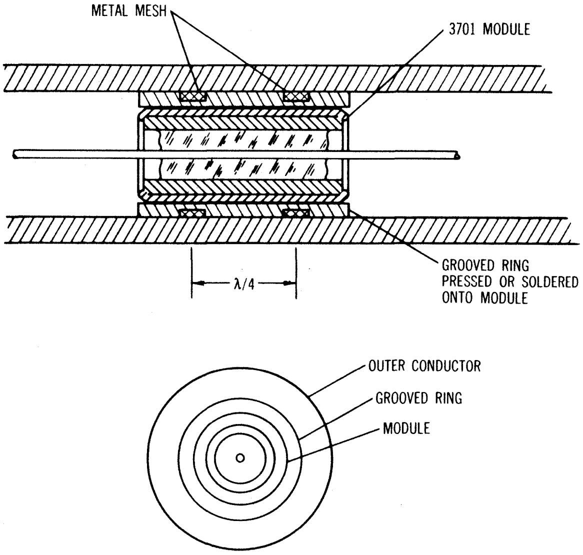


Figure 5b. Module mounting with "O" rings.

(6) The gap may be effectively eliminated by filling it with a lossy material such as a thin compressible sleeve or a lossy compound. With this method, a DC contact must be made by other means.

(7) Constructing the coaxial line as a split block simplifies mounting and also simplifies the use of compounds, O-rings, and metal mesh gaskets. However, if any gap remains between the two halves of the block it must be sealed by one of the above techniques to avoid possible RF leakage.

Mounting the center conductor of the line to the 3701 consists of making a suitable electrical/mechanical contact that is properly matched to the line impedance. Soldering or finger contacts with tapered or stepped pins will accomplish this. Two typical examples are shown, with pertinent dimensions, in Figure 6.

In attaching connectors to the coaxial line, standard RF design practices should be followed. Since the center conductors of the module are only 0.014 inch in diameter, connectors with captured center conductors should be used if rough handling might be encountered.

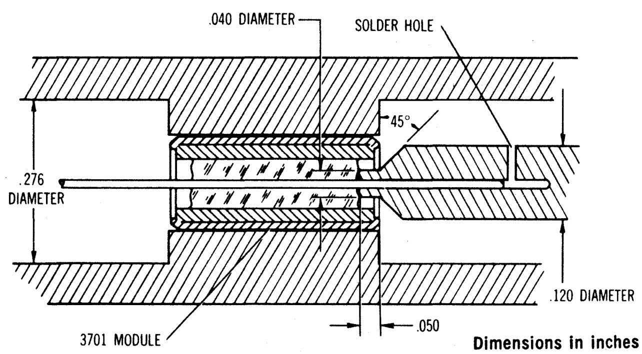


Figure 6a. Center pin contact.

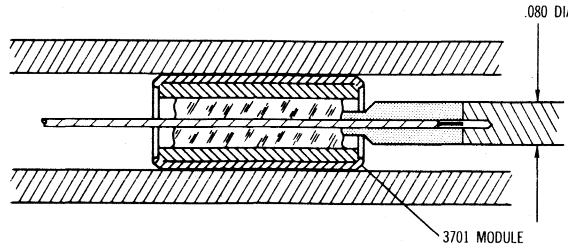


Figure 6b. Center pin contact.

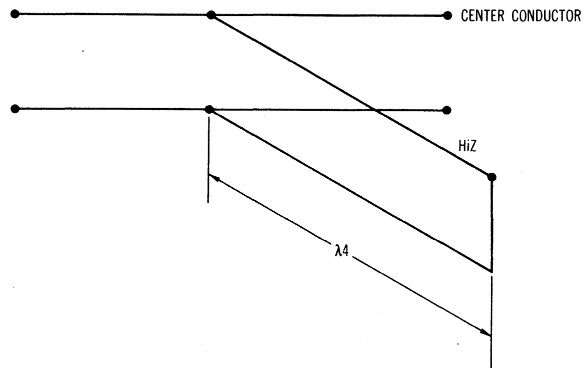


Figure 7. Quarter-wave dc return lines.

DC RETURN FOR 3701 and 3711

Since the diodes in the limiter modules are connected in shunt across the transmission line, a dc return path must be provided between center conductor and ground. This low resistance dc path must appear as a high shunt impedance to the RF signal. There are several ways of constructing a dc return, for example:

(1) A ¼ wavelength shunt transmission line can be used, as shown in Figure 7. The impedance of the shunt line should be high for maximum bandwidth. Easily obtainable impedance values give a good match over a bandwidth greater than one octave.

(2) A variation of the above method is the line of a ¼ wavelength section of helical transmission line, which can be fabricated from a small coil spring. The impedance of such a device is generally quite high, and the length is typically several times smaller than a normal transmission line of equivalent electrical length. See Figure 8.

(3) Commercially available bias tees perform quite well as dc returns.

(4) Lumped element filters, such as pi section filters, may also be used as dc return devices.

(5) Other system components may be utilized for the dc return. One example is the use of accessible center conductors on terminations of circulators; another is the utilization of a small wire connected to the probe of a waveguide to coax transition. Mounted at right angles to the electrical field, such a device does not upset the impedance of the transition. The input terminal of interdigital filters is often at dc ground, as is the loop of many microwave antennas.

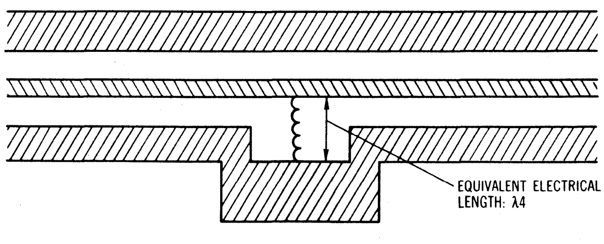
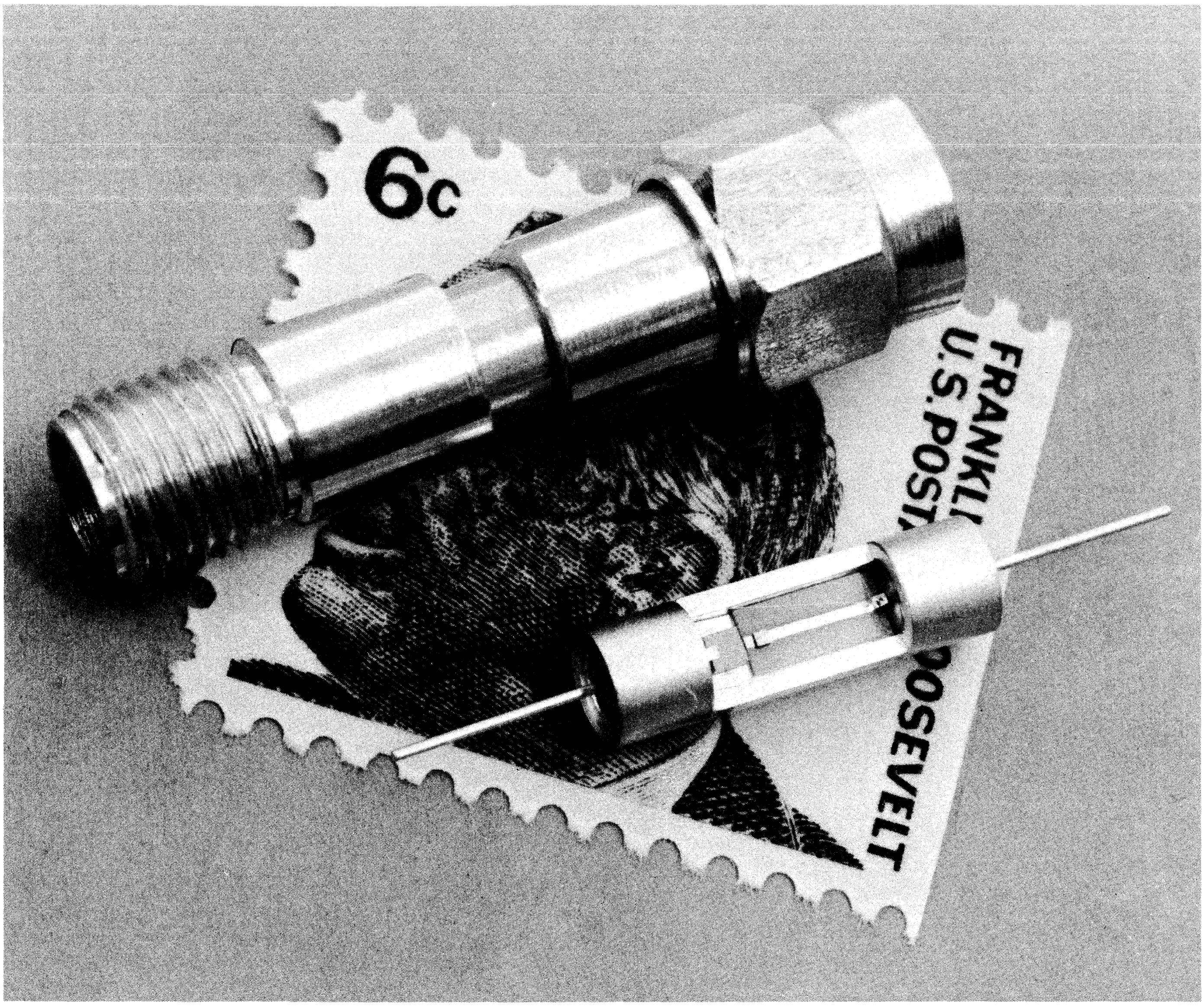


Figure 8. Helical spring dc return detail.

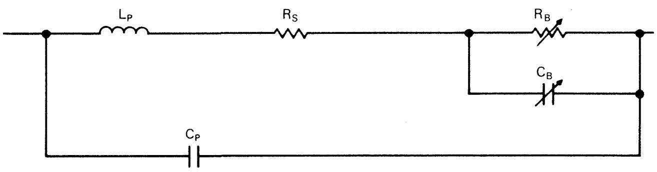
The 33800 Series Mixer/Detector Module



HEWLETT hp PACKARD

Introduction

Broadband applications of hot carrier diode mixers have been limited by the difficulties of matching the multi-element circuit which describes a packaged unit. Figure 1 shows the equivalent circuit of a diode with typical element values for several standard units. Figure 2 shows the impedance of a 2700 series diode with 200 or 80 ohm barrier resistance. The lower value may be obtained by using 6 milliwatts of local oscillator power or by adding DC bias to the more conventional 1 milliwatt level. The difficulty of matching such an admittance function is illustrated in Figure 3, showing a waveguide mount designed to measure noise figure. In order to achieve a moderate bandwidth of 400 MHz, four dimensions of the mount were optimized: the two waveguide short circuit positions, the diameter of the post, and the transverse location of the post.



TYPE	R_S (Ω)	C_B (pF)	C_P (pF)	L_P (nH)
5082-2400	7-11	0.75	.07	2
5082-2565	3-6	.5	.07	2

Figure 1. Equivalent Circuit of Package Diode

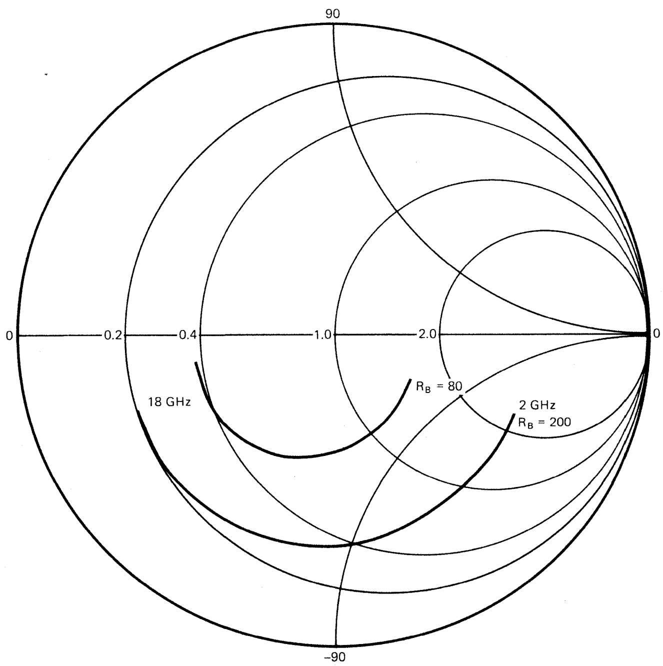


Figure 2. 5082-2700 Diode Impedance

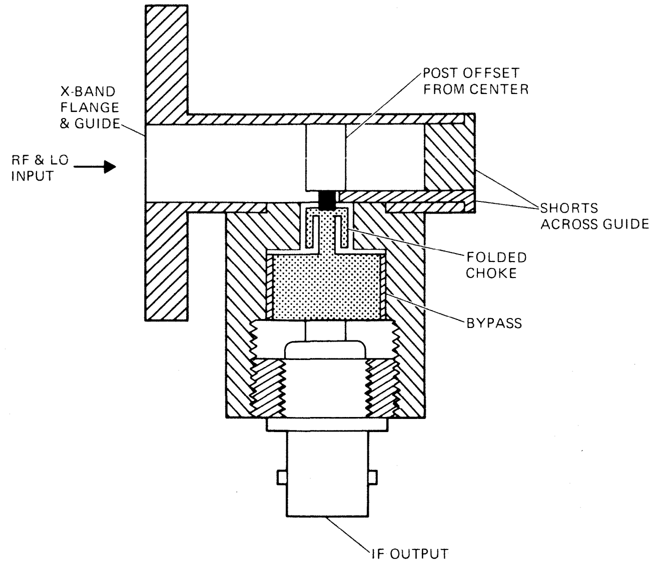


Figure 3. Mixer Test Mount of 5082-2700 Diode

Hybrid Integration

The development of microscopic assembly techniques makes it possible to design the semiconductor chip into a broadband circuit and to substitute the desired circuit elements for the package elements. The resulting integrated mixer is shown in Figure 4. The coaxial package with 3 mm connectors is common to a series of microwave components including limiters, switches, and impulse generators. These units are hermetically sealed and all parts are soldered or bonded to withstand extremes of temperature, shock, and vibration.

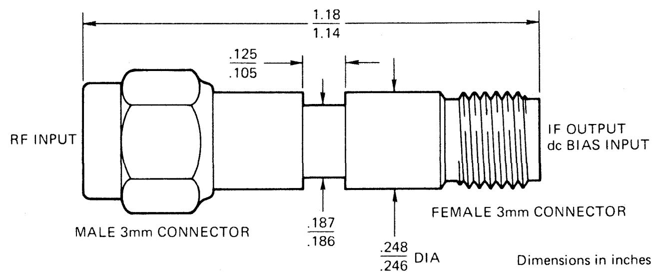


Figure 4. Mixer/Detector Module

Low Pass Filter

The equivalent circuit of the semiconductor-metal barrier is the barrier resistance shunted by its capacitance. There is an inherent bandwidth limitation related to the RC product.[1] By reducing the resistance with DC bias or high level local oscillator power, we were able to design the diode into a low pass filter with cutoff frequency above X band. The equivalent circuit is shown in Figure 5. The first approximations to the element values were obtained from Weinberg's tables.[2] Equivalent distributed elements were calculated and the resulting admittance plotted on a Smith Chart. The elements were then modified to center the admittance on the Smith Chart. Experimental adjustments

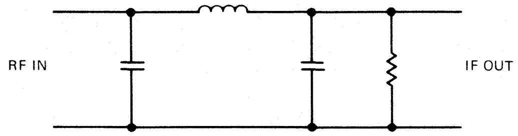


Figure 5. RF Equivalent Circuit

completed the design. Figure 6 is a photograph of the 33802A before the module is sealed. The coaxial input is connected to a 50 ohm section of microstrip transmission line with a bonded strap. The diagonal wire is a DC return, presenting a high impedance at frequencies above 2 GHz. The diode chip is soldered to a bypass capacitor. The IF output is taken from the semiconductor side of the diode, so that the output polarity of a detected pulse is positive. The series inductance in the equivalent circuit of Figure 5 is realized by the wire bonded to the diode and to the microstrip center conductor. The input shunt capacitance of the low pass filter is realized by the open line after this latter bond. The assembly is completed by sliding a tube over this unit and welding the edges. Compensated 3 mm connectors are then soldered in place. The complete assembly is shown in Figure 4. The 33801A has the opposite polarity. The assembly is similar, but the chip is soldered to the microstrip center conductor so that the output is taken from the metal side of the diode junction.

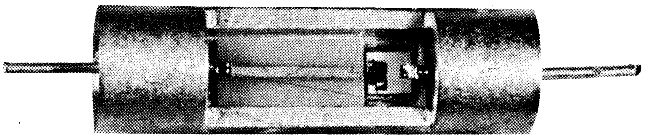


Figure 6. Internal View of Module

Noise Figure

The mixer module uses a hot carrier diode chip similar to that used in the 2700 series of pill diodes. Losses in the hermetic seal prevent the low noise figures of the 2700 type from being realized in the module. Best results in the first production units have been 7.0 dB for single side band noise figures including a 1.5 dB IF amplifier. Both the 33801A and the 33802A are conservatively specified as 8.5 dB, measured at 10 GHz. Figure 7 shows the frequency dependence.

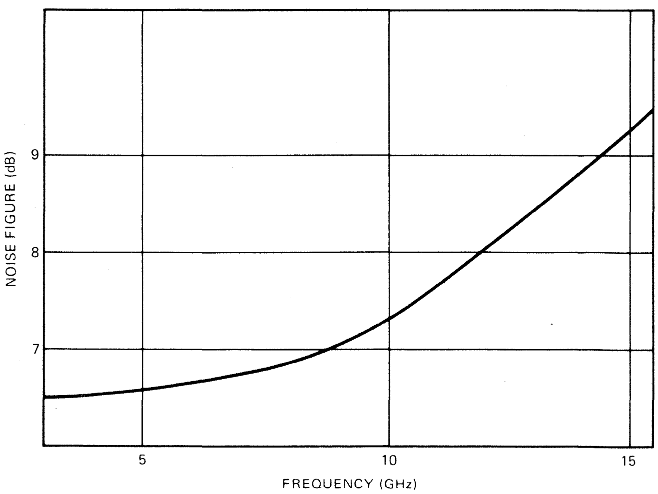


Figure 7. Noise Figure vs. Frequency Performance of Module

DC Bias

Although the barrier resistance may be lowered with sufficient local oscillator drive, production measurements are made at the 1 mW level, commonly available in systems. The data shown was taken with fixed bias voltage added to the local oscillator drive. The results may be optimized by adjusting the bias for specific frequency bands and local oscillator levels.

Figure 8 shows the 10 GHz performance at different local oscillator power levels. The typical rapid deterioration below 1 mW is shown in the zero bias curve. However, excellent performance at 0.1 mW may be obtained by using DC bias. The optimum bias for impedance matching is not the same as for noise figure, as shown by the intermediate curves.

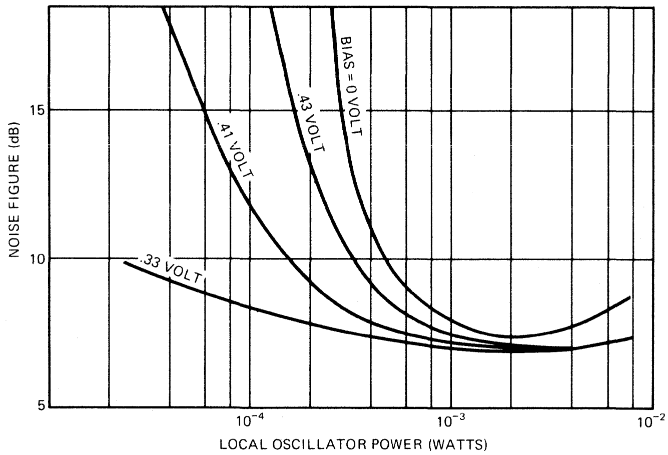


Figure 8. Noise Figure vs. Oscillator Power of Module

Bypass Capacitor

The bypass capacitor presents a short circuit to the RF input and an open circuit to the IF output. The capacitance is chosen as a compromise between these two requirements. Some RF voltage is developed across the capacitive reactance at low RF frequencies, subtracting from the voltage across the diode. Similarly, at high IF frequencies, the capacitive susceptance becomes appreciable so that part of the output current is shunted through the bypass. However, this loss may be diminished by incorporating the bypass capacitance into a low pass filter or by simply resonating the capacitance with a shunt inductance. Figure 9 is a bypass design aid showing the IF bandpass limitation when the latter tuning method is used and the RF loss due to series voltage drop across the capacitive reactance. The chart is used by drawing vertical lines at the lowest RF frequency of interest and at the IF bandwidth. Then a horizontal line is adjusted until the RF loss equals the IF loss. An example is shown in the chart. The lowest RF frequency of interest is assumed to be 3 GHz and the IF bandwidth 100 MHz. The optimum bypass value is 3 pF.

Standard values of capacitance are 17 pF and 10 pF. Since the DC return limits the low frequency performance below 2 GHz, the standard bypass limits only the IF bandwidth. In the example given, about 1.5 dB of loss is caused by the 10 pF standard bypass, compared to about 1/4 dB for the optimum value. A variety of bypass values is kept in stock for special orders.

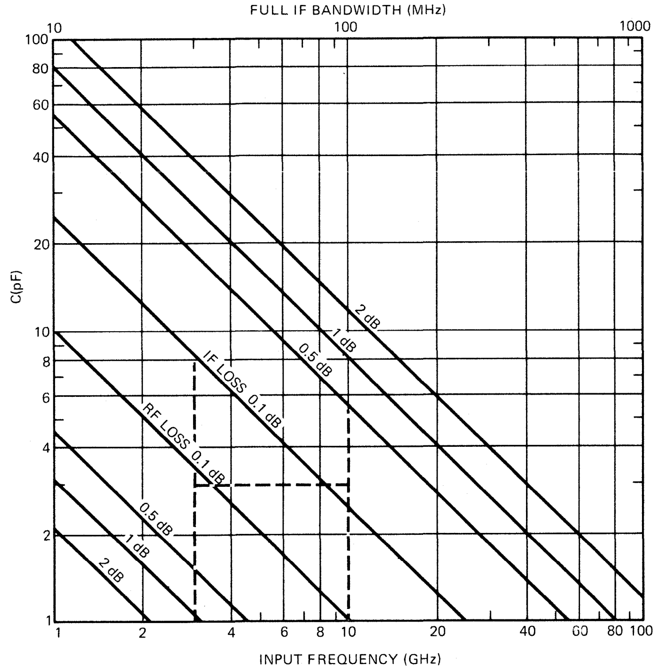


Figure 9. Bypass Capacity Design Curves

Video Detectors

Optimum bias for video detection is only a few microamperes, so that the low pass filter elements do not match the resulting high value of diode barrier resistance to a 50 ohm transmission line. However, the ability of the module to withstand extremes of shock and vibration has made the unit popular as a video detector even though it operates 2 or 3 dB below its capability.

Some analysis of video detection for hot carrier diodes has been presented in HP Application Note 907 and in an article by A. M. Cowley and H. O. Sorensen.[3] This analysis is extended in the appendix and shows that the input power required to produce an output 8 dB above the noise (a power level commonly called tangential sensitivity signal or TSS) is:

$$TSS = 2 \times 10^{-8}\ I_o B^{1/2} \left[R_A + \frac{25.5}{I_o} \left(1 + \frac{f_N}{B} \ln \frac{B}{f_L} \right) \right]^{1/2} \left[1 + \frac{R_S C^2 F^2}{I_o} \right]$$

where:
- I_o is bias current in microamperes
- B is video bandwidth in megahertz
- R_A is equivalent noise resistance of the video amplifier in kilohms
- R_S is the series resistance of the diode in ohms
- C is the diode barrier capacitance in picofarads
- F is the input frequency in gigahertz
- TSS is in milliwatts
- f_L is lower cutoff frequency of the video amplifier in megahertz
- f_N is noise corner (see Appendix)

Figure 10 shows the predicted behavior of sensitivity with respect to bias current for 10 GHz input frequency and 2 MHz video bandwidth. The equivalent noise resistance and lower cutoff frequency of the video amplifier are 750 ohms and 2 kilohertz, corresponding to the characteristics of the AEL 153A amplifier. The optimum bias is about 10 microamperes, but is not critical. Since the mismatch of the 33800A diode is not corrected at low bias levels, measured VSWR values of 4 or 5 are observed. The sensitivity curve is corrected for this reflection loss and compared to measured sensitivities in Figure 10. The forms of the curves are similar, but the theory predicts 3 or 4 dB better performance. This may be due to resistive losses in the module and imperfect diodes.

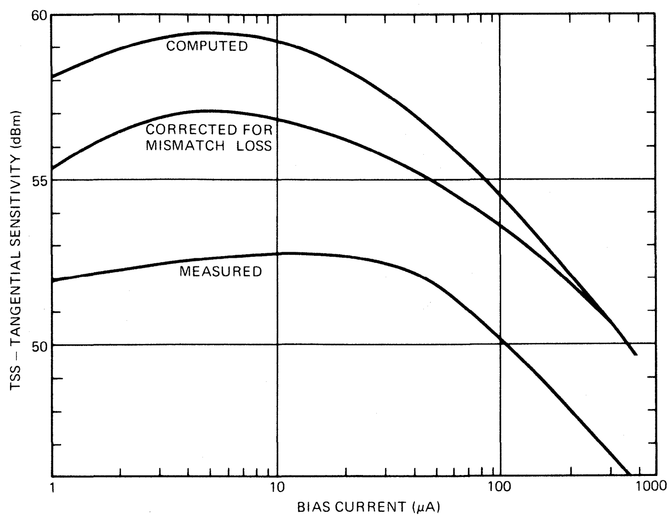


Figure 10. Detector Performance vs. Bias Current

The variation of sensitivity with frequency is shown in Figure 11. The mismatch loss may be overcome by using a tuner in front of the module. This is shown in the upper curve. Tuned sensitivity better than -52 dBm is typical over the 2 to 12.4 GHz frequency range. Detection efficiency is typically 3 millivolts per microwatt. This may be increased to 5 mV/μW by using a tuning device in front of the module. The detected voltage is proportional to input power at low power levels with the one dB compression point occurring at about 10 microwatts. This compression level may be raised to one milliwatt by shunting the output with about 500 ohms. At higher input levels, the detection becomes linear.

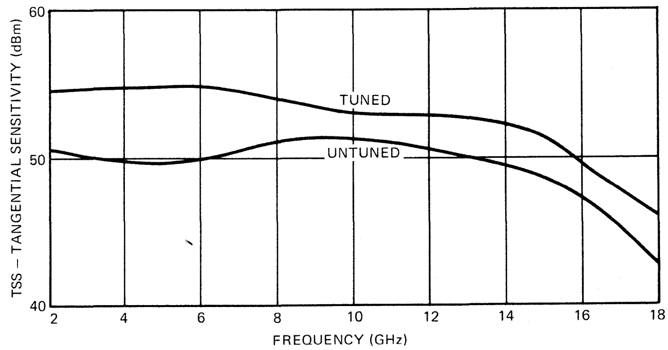


Figure 11. Detector Performance vs. Frequency

Temperature Sensitivity

The noise figure improves at low temperatures and increases at high temperatures. The total variation in noise figure from -60°C to +100°C is less than 1-1/2 dB. Similar variations in detection sensitivity may be expected.

Matched Detector Sensitivity

On special order, detector modules with outputs matched within one dB can be supplied. Another dB of spread may be expected at extreme temperatures.

Future Products

Improved mixer diodes and improved assembly methods will lower the noise figure specification by one or two dB. Different diodes are being developed specifically for detector applications. These units will be used in tuned detector mounts with tangential sensitivity of -56 dBm and detection efficiency of 8 mV/μW over octave bandwidths.

These mixer and detector modules will be integrated with HPA limiter diodes to provide limiter protected mixers and detectors. These units will also be integrated with broad band hybrids to provide broad band balanced mixers.

REFERENCES

1. Bode, H. W., Network Analysis & Feedback Amplifier Design, D. Van Nostrand Co., Inc., New York, N. Y., 1945

2. L. Weinberg, "Network Design by Use of Modern Synthesis Techniques & Tables," Tech. Memo 427, Hughes Aircraft Company, Research Laboratories, Culver City, Calif. (April 1956)

3. A. M. Cowley and H.O. Sorensen, "Quantitative Comparison of Solid-State Microwave Detectors," IEEE Trans. on Microwave Theory and Techniques, Vol. MTT-14, pp. 588-602, December, 1966.

APPENDIX

Tangential Sensitivity Signal

The sensitivity of a crystal-video receiver is defined by the tangential sensitivity signal, the input power required to raise a detected pulse on an oscilloscope out of the noise so that the bottom of the noise on the pulse is level with the top of the undisturbed noise. This measurement depends on the characteristics of the pulse, the video receiver, and the observer. Since these parameters can cause a variation of 2 or 3 dB, it is customary to define tangential signal sensitivity (TSS) as the input level required to produce a detected signal 8 dB above the rms noise level[1].

The total output noise voltage, V_T, depends on the noise from the amplifier, V_a, as well as the noise from the diode, V_n. Since the noise is uncorrelated,

$$\overline{V_T^2} = \overline{V_a^2} + \overline{V_n^2}. \tag{1}$$

The amplifier noise may be expressed as the thermal noise of the "equivalent noise resistance" R_A

$$\overline{V_a^2} = 4kTBR_A \tag{2}$$

where B is the amplifier bandwidth and T is the ambient temperature. The diode noise varies with frequency so it must be expressed as a differential:

$$\overline{\Delta V_n^2} = 4kTR_v t_W \left(1 + \frac{f_N}{f}\right)\Delta f, \tag{3}$$

where R_v is the video resistance of the diode and f is the video frequency. The symbol t_W is called the "white noise temperature ratio". Although this quantity is theoretically equal to 0.5 for perfect Schottky barrier diodes, the presence of series resistance raises the value close to unity. We will assume t_W to be unity in this analysis. The parameter f_N is the "noise corner", the video frequency for which the diode noise power is double the noise at high frequencies. For the diodes used in the 33800 series, f_N is about 1 MHz. Improved diodes under development will have a noise corner two or three orders of magnitude lower. The total noise voltage is the integral of (3) from the lower frequency limit, f_L, of the video passband, to the higher, f_H:

$$\overline{V_n^2} = 4kT\, R_v \left(B + f_N \ln \frac{f_H}{f_L}\right) \tag{4}$$

Since $B = f_H - f_L$ and $f_H >> f_L$, we may replace f_H by B.

$$\overline{V_n^2} = 4kT\, R_v \left(B + f_N \ln \frac{B}{f_L}\right) \tag{5}$$

Inserting (2) and (5) in (1),

$$\overline{V_T^2} = 4kTB\left[R_A + R_v\left(1 + \frac{f_N}{B}\ln\frac{B}{f_L}\right)\right] \tag{6}$$

The signal voltage, V_s, corresponding to the input power level TSS is

$$V_s = (\mathrm{TSS})\, \beta_o'\, R_v = 2.5\, V_T \tag{7}$$

where β_o' is the current responsivity defined in (23) of [3] as

$$\beta_o' = \frac{q}{2nkT}\,\frac{1}{\left[1 + \frac{R_S}{R_B}\right]\left[1 + \dfrac{4\pi^2C^2F^2R_SR_B}{1 + \frac{R_S}{R_B}}\right]} \tag{8}$$

where n is a number close to unity for hot carrier diodes. For most detector application $R_S/R_B << 1$ so this term will be neglected. Substituting (6) and (8) in (7),

$$\mathrm{TSS} = \frac{\dfrac{10\,nkT}{q}\,\dfrac{\sqrt{kTB}}{R_V}\left[R_A + R_V\left(1 + \frac{f_N}{B}\ln\frac{B}{f_L}\right)\right]^{1/2}}{\left(1 + 4\pi^2C^2F^2R_SR_B\right)} \tag{9}$$

The video resistance of the diode, R_V, is the series combination of the parasitic series resistance R_S and the nonlinear barrier resistance, R_B. Since R_S is assumed negligible,

$$R_V \cong \frac{nkT}{q(I_o + I_S)} \tag{10}$$

as derived in [3]. The saturation current I_S is several orders of magnitude less than the bias current I_o, and will be neglected. The equation for TSS in the text results from substituting (10) in (9) and letting n = 1.

$$TSS = 2 \times 10^{-8} I_o B^{1/2} \left[R_A + \frac{25.5}{I_o}\left(1 + \frac{f_N}{B} \ln \frac{B}{f_L}\right)\right]^{1/2} \left[1 + \frac{R_S C^2 F^2}{I_o}\right] \tag{11}$$

[1]S.N. Van Voorhis, Microwave Receivers, Vol. 23, Radiation Laboratory Series, Pg. 456, Boston Technical Publishers, Inc., 1964

TECHNICAL DATA

DESCRIPTION

HP series 33800 are broadband, hot carrier diode, mixer, or detector modules for use from 2 to 12.4 GHz. They consist of a passivated hot carrier diode chip, dc return, and bypass capacitor, functionally integrated into a 50-ohm miniature coaxial transmission line. Module housings are hermetically sealed and all internal joints are welded or thermal compression bonded, using proven materials to assure reliable operation under severe environmental conditions.

APPLICATIONS

HP series 33800 are versatile modules, designed as low pass filters, thus encompassing those portions of mixer/detector circuitry which are difficult to construct for use with broadband microwave equipment. Typical applications of series 33800 mixer/detector modules include electronic countermeasures and reconnaissance receivers, test equipment, signal simulators, and missile guidance systems.

ABSOLUTE MAXIMUM RATINGS (Note 1)

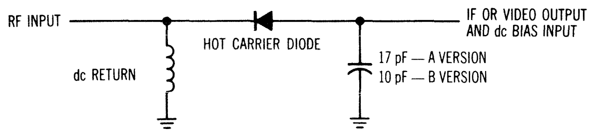
Maximum Incident CW Power ....100 mW
Maximum Incident Peak Pulse Power
(1 μsec duration, 0.001 Du) ....0.2 watt
Pulse Burnout (< 10 nsec pulse,
1 dB increase of NF_o) (Note 2) ....2 ergs

MECHANICAL CHARACTERISTICS

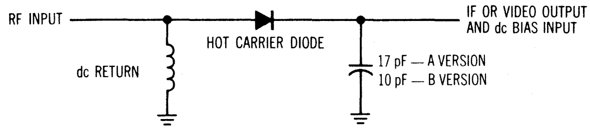
Size ....As shown in the outline drawing
Weight ....One gram maximum per module
Materials ....Case and Cover, Kovar; Connectors, Stainless Steel
Finish ....All pieces: Gold Plated, 50 microinches minimum

ENVIRONMENTAL RATINGS

Temperature, Storage .... − 65° to + 125°C
Temperature, Operating .... − 65° to + 125°C
Temperature Cycling ....Method 1051, Test Condition B*
Thermal Shock ....Method 1056, Test Condition A*
Humidity ....Method 1021.1, omit initial conditioning*
Shock ....Method 2016.1, 5 blows each X_1, Y_1, Y_2, Z orientations, 0.5 ms pulse, 1500 G. min. non-operating*
Vibration Variable Frequency ....Method 2056*
* MIL-STD-750 reference and conditions.



TYPE 3801 — REQUIRES POSITIVE dc BIAS



TYPE 3802 — REQUIRES NEGATIVE dc BIAS

CIRCUIT DESCRIPTION

The IF bandwidth is limited by the 17 pF bypass capacitor of the integrated circuit. Lower values of capacitance are available on special order.

VIDEO DETECTOR PERFORMANCE 33801A/B, 33802A/B

Typical Tangential Sensitivity 2 to 12.4 GHz
(2 MHz video bandwidth, bias current 50 μA)...... − 50 dBm

ELECTRICAL SPECIFICATIONS AT $T_A = 25°C$

Usable Frequency Range 2.0 to 12.4 GHz

Type Number	Characteristic	Symbol	Limits		Typ.	Unit
			Min.	Max.		
33801A/B, 33802A/B	S.S.B. Noise Figure (Note 3) Includes 1.5 dB IF N.F.	NF_o	—	8.5	7.5	dB
33801A/B, 33802A/B	IF Impedance (Note 4)	Z_{IF}	80	130	—	ohms
33803A/B	S.S.B. Noise Figure Match at 10 GHz	ΔNF_o	—	0.3	—	dB
33803A/B	IF Impedance Match	ΔZ_{IF}	—	25	—	ohms
33801A/B, 33802A/B	VSWR @ $V_B = 0.4$ volt approx.	—	—	2.5	2.0	—

Notes:

Note 1: These ratings are estimates based upon limited testings. Improved ratings may be available after completion of further testing.

Note 2. Three pulses with a pulse width of 10 ns maximum.

Note 3. Noise figure is measured at 10.0 GHz using an IF amplifier with 1.5 dB noise figure at 30 MHz; local oscillator power is 1.0 mW. DC bias is approximately 0.4 volt. For 33801 bias polarity is positive. For 33802 bias polarity is negative.

Note 4. The IF impedance is measured at 30 MHz, bias at 1.0 mW local oscillator power and approx. 0.4 volt dc.

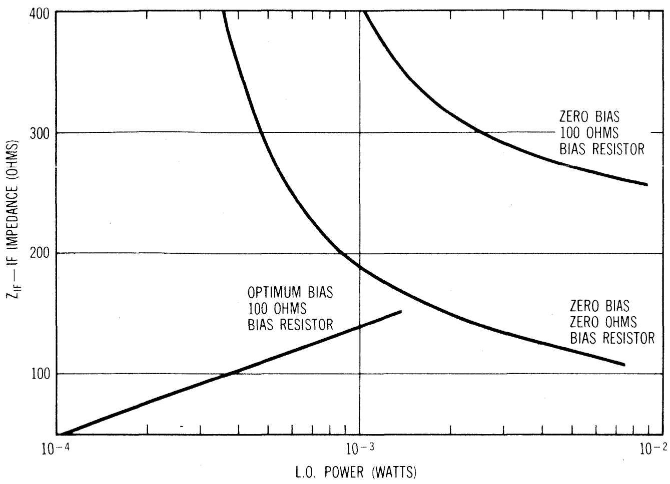


Figure 1. Typical IF Impedance vs. local oscillator power for various bias conditions.

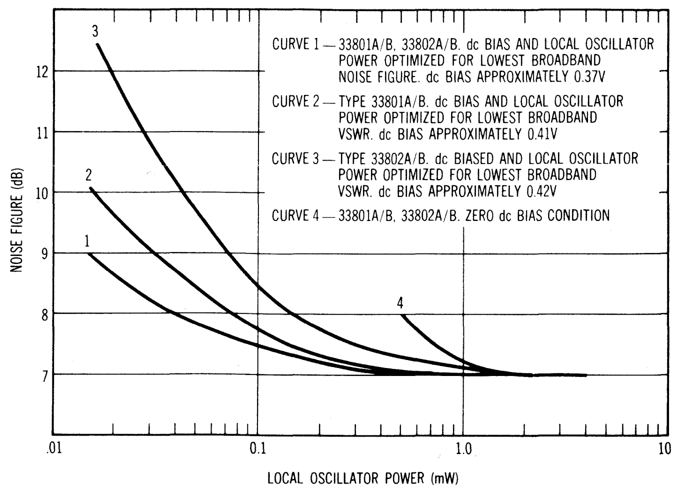


Figure 2. Typical N.F. vs. L.O. Power at 10 GHz.

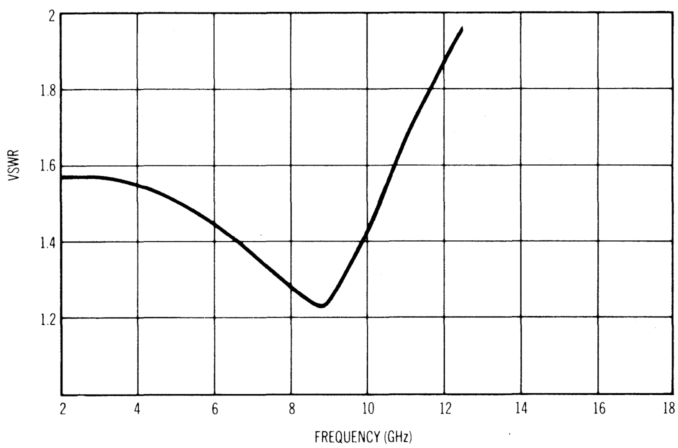


Figure 3. Typical VSWR (RF impedance) vs. Frequency. The bias may be adjusted to optimize performance for narrower frequency bands.

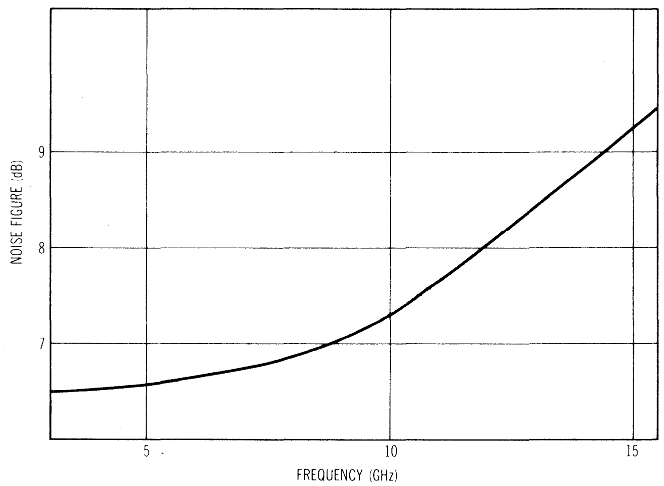


Figure 4. Typical N.F. vs. Frequency.

HEWLETT hp PACKARD

HYBRID INTEGRATED WIDEBAND AMPLIFIERS

series 35000A thru 35005A

- **HIGH RELIABILITY**
- **SMALL SIZE**
- **BROAD BANDWIDTHS**
- **HIGH GAIN**
- **WIDE DYNAMIC RANGE**

Description

GENERAL

The HP 35000A-35005A Wideband Amplifiers represent a combination of Hewlett-Packard's broad circuit design background and an advanced hybrid integrated circuit manufacturing process. Utilizing a tantalum-based thin film process and unpackaged semiconductor devices, this series of microcircuit amplifiers provides performance, reliability, and size advantages unmatched by conventional designs using packaged semiconductor devices and discrete passive elements.

The tantalum thin film process provides stable lumped- and distributed-constant passive networks with precise geometry and high component density. Unpackaged high-performance planar semiconductor devices afford the highest possible performance by eliminating the parasitic reactances and thermal resistance associated with the device package. Synthetic sapphire is used as the circuit substrate because of its uniform dielectric properties, surface smoothness, and thermal conductivity. The result is an optimum combination of state-of-the-art materials, devices, and techniques.

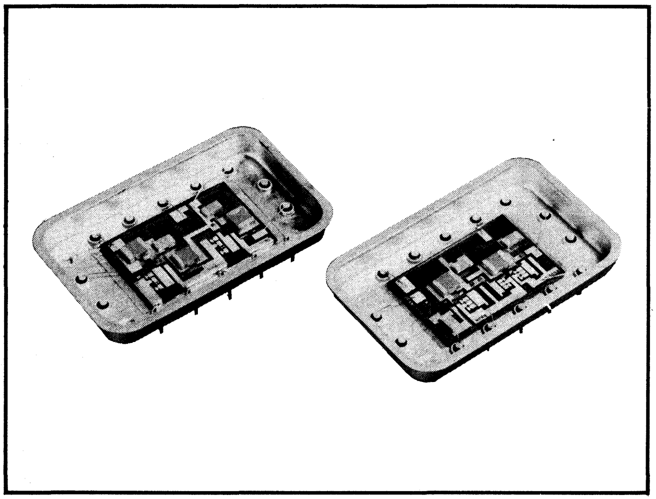
PERFORMANCE

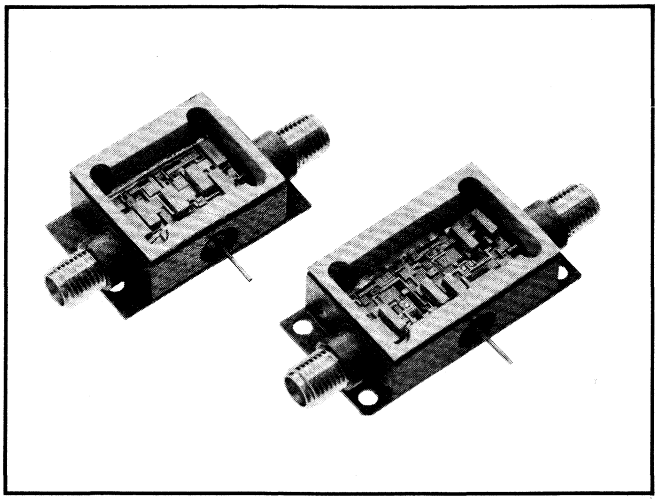
These amplifiers are ideal for wideband 50-ohm system applications where size and reliability are important considerations. They are also desirable as replacements for discrete component amplifiers, due to their low price and excellent electrical performance. Bandwidths range from 0.1 - 100 MHz to 0.1 - 2.0 GHz, and gains per package from 20 to 40 dB. Low-level stages have output levels up to 0 dBm, power stages to +20 dBm. Harmonic content and intermodulation products are at least 20 dB down at rated output. Due to their well-matched port impedances, units are readily cascaded for flat, high gain characteristics.

RELIABILITY

The 35000A-35005A Wideband Amplifiers bring the inherent reliability of hybrid integrated circuit processing to many systems previously requiring fragile, short-lived high frequency or microwave devices. Hermetically sealed, these amplifiers are immune to environments that would severely damage their discrete component counterparts. Microcircuit construction minimizes the number of wired interconnections necessary to build and incorporate these amplifiers in a system. These factors, coupled with the well-documented long-term stability of thin-film passive components, make this series of amplifiers attractive for high reliability applications.

HP 35000-Series Amplifiers



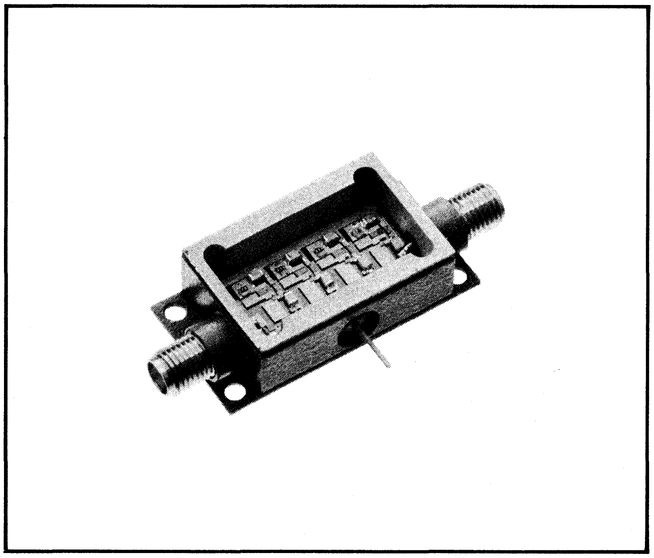


HP 35000A and HP 35001A **0.1 - 100 MHz**

These amplifiers are compatible low-level and power stages covering 0.1 to 100 MHz. The 35000A has 30 dB gain and low distortion at output levels up to 0 dBm. The 35001A has 20 dB gain and will supply +20 dBm with low harmonic distortion. Although shown here in packages designed for printed circuit board mounting, these units are also available in packages with coaxial input/output connectors similar to those shown for the 35002A and the 35003A.

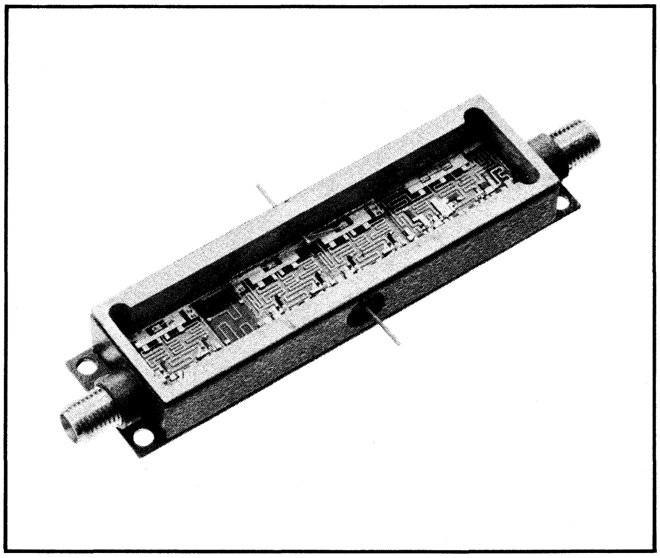
HP 35002A and HP 35003A **0.01 - 400 MHz**

These amplifiers are also compatible stages with 0.01 - 400 MHz bandwidth and 20 dB gain. The 35002A operates at output levels up to 0 dBm and has a noise figure less than 5 dB. The 35003A will deliver +20 dBm with low harmonic distortion. They are available in the packages designed for printed circuit board mounting, as well as in the packages shown above.



HP 35004A **0.01 - 1.3 GHz**

This amplifier provides 25 dB minimum gain from 0.01 to 1.3 GHz. It will supply an undistorted 10 mW. Its noise figure is typically less than 10 dB across its band.



HP 35005A **0.1 - 2.0 GHz**

This amplifier has 40 dB gain from 0.1 to 2.0 GHz and will deliver 20 mW with low harmonic distortion. Its noise figure is typically less than 12 dB.

Technology

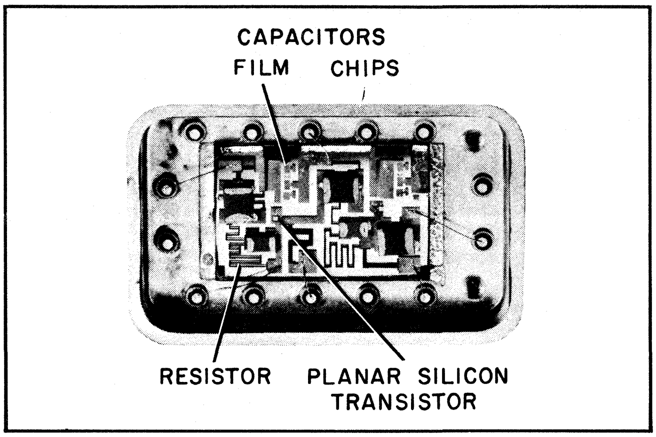
SUBSTRATE: The foundation for a microcircuit is the insulating substrate. The resulting circuit performance, reliability, and versatility are heavily dependent on this material. For this reason, the 35000-series uses single-crystal sapphire oriented with the C-axis in the plane of the substrate. This accomplishes several things. First, the dielectric constant is the same for the dominant TEM mode traveling in any direction on the substrate; second, the expansion coefficient parallel to the surface is very similar to that of the materials used for both resistors and capacitors. For example, sapphire substrates on which resistors and capacitors have been fabricated were heated to 500°C, then dipped immediately in liquid nitrogen with no effect on adhesion.

The other properties of this substrate include dimensional precision to a few tenths of a mil, high thermal conductivity, good microwave properties, relatively high dielectric constant (9.6) for fabricating small microwave structures, resistance to selective etchants required and, most important of all, a very good surface finish. This finish permits 0.1 mil geometry, stable resistors with very good uniformity for inexpensive batch trimming, and stable, pin-hole-free capacitors.

RESISTORS: The thin-film resistors in the 35000-series circuits have sheet resistances of 30 Ω/□ and 50 Ω/□ with a TCR of about −50 ppm, and 500 Ω/□ with a TCR of −300 ppm. Geometries approaching 0.1 mil provide a wide range of resistor values.

CAPACITORS: Numerous thin-film capacitors are used to obtain a desired circuit performance. Some of the capacitance densities obtained with standard processing are 10^{-4}, 10^{-3}, 10^{-2}, 10^{-1}, 0.33 and 1 pF per square mil. Breakdown voltages exceed 200 volts for all except the 0.3 and 1 pF per square mil capacitors. Capacitors larger than a few thousand pF are applied in discrete form.

CONDUCTORS: The conductors used are primarily gold; other materials such as molybdenum are used for adhesion and as a diffusion barrier. The deposited gold has a sheet resistance of 0.1 Ω/□ and patterns approaching 0.1 mil can be obtained.



HP 35000A construction is typical of 35000-series circuits. Circuit above is complete except for package lid.

The conductors used in the circuits for interconnections, bonding pads, and strip lines are electroplated with gold and have a sheet resistance of 2×10^{-3} Ω/□, a resolution of 0.1 mil, and an absolute precision of about 0.2 mil for accurate strip line elements.

ACTIVE DEVICES: Active devices are bonded on the circuit as discrete components. The devices are used in chip form: first, because of the necessity of eliminating parasitics associated with packages at high frequencies; second, to obtain maximum power-handling capabilities by bonding the device directly to the substrate; and third, to obtain better reliability by eliminating extra connections.

Every active device is nondestructively tested in chip form and then selected for each application by an automatic system capable of measuring the devices from 0.1 to 12.4 GHz. The device is then ready to put in a microcircuit, with full assurance not only that it will work but that the circuit will perform as required. Circuit yields are quite high, even with many devices per circuit.

Specifications

(With 50-ohm Source and Load Impedances)

HP 35000A

Frequency Range: 0.1 - 100 MHz
Gain: 30 dB minimum
Gain Flatness: ±1.5 dB
Noise Figure: Typically less than 8 dB, 1 - 100 MHz
Output Level: > +5 dBm at 1-dB gain compression point
Distortion: Harmonics at least 50 dB down at output levels up to 0 dBm
Impedances: 50 Ω both ports, $|\rho| < 0.13$ (VSWR < 1.3)
Power Requirements: +20 V at 75 mA maximum
Price: $150.00, 1-9; $134.00, 10-24

HP 35001A

Frequency Range: 0.1 - 100 MHz
Gain: 20 dB minimum
Gain Flatness: ±2 dB
Noise Figure: Typically less than 10 dB, 1 - 100 MHz
Output Level: > +19 dBm at 1-dB gain compression point
Distortion: Harmonics at least 35 dB down at output levels up to +10 dBm; at least 20 dB down at +20 dBm
Impedances: 50 Ω both ports, $|\rho| < 0.13$ (VSWR < 1.3)
Power Requirements: +20 V at 350 mA maximum; −10 V at 350 mA maximum
Price: $200.00, 1-9; $178.00, 10-24

Specifications (Cont'd)

HP 35002A

Frequency Range: 0.01 - 400 MHz

Gain: 20 dB

Gain Flatness: ±0.5 dB

Noise Figure: < 5 dB, 1 - 400 MHz

Output Level: > +7 dBm at 1-dB gain compression point

Distortion: Harmonics at least 40 dB down at output levels up to 0 dBm

Impedances: 50 Ω both ports, $|\rho| < 0.2$ (VSWR < 1.5)

Power Requirements: +28 V at 45 mA maximum

Price: $292.00, 1-9; $248.00, 10-24

HP 35003A

Frequency Range: 0.01 - 400 MHz

Gain: 20 dB

Gain Flatness: ±0.5 dB

Noise Figure: Typically less than 10 dB, 1 - 400 MHz

Output Level: > +23 dBm at 1-dB gain compression point

Distortion: Harmonics at least 40 dB down at output levels up to +10 dBm; at least 20 dB down at +20 dBm.

Impedances: 50 Ω both ports, $|\rho| < 0.2$ (VSWR < 1.5)

Power Requirements: +40 V at 200 mA maximum

Price: $360.00, 1-9; $306.00, 10-24

HP 35004A

Frequency Range: 0.01 - 1.3 GHz

Gain: 25 dB minimum

Gain Flatness: ±2 dB

Noise Figure: Typically less than 10 dB

Output Level: +16 dBm at 1-dB gain compression point

Distortion: Harmonics at least 30 dB down at output levels up to +10 dBm

Impedances: 50 Ω both ports, $|\rho| < 0.25$ (VSWR < 1.7)

Power Requirements: +20 V at 200 mA maximum; −10 V at 200 mA maximum

Price: $766.00, 1-9; $650.00, 10-24

HP 35005A

Frequency Range: 0.1 - 2.0 GHz

Gain: 40 dB minimum

Gain Flatness: ±3 dB

Noise Figure: Typically less than 12 dB

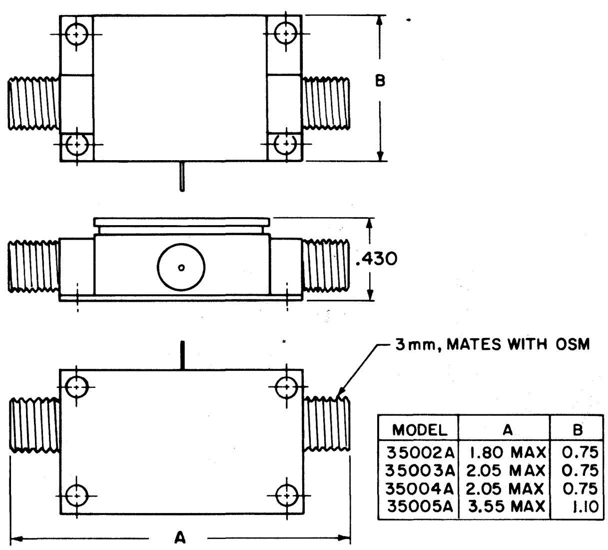
Output Level: +16 dBm at 1-dB gain compression point

Distortion: Harmonics at least 30 dB down at output levels up to +10 dBm

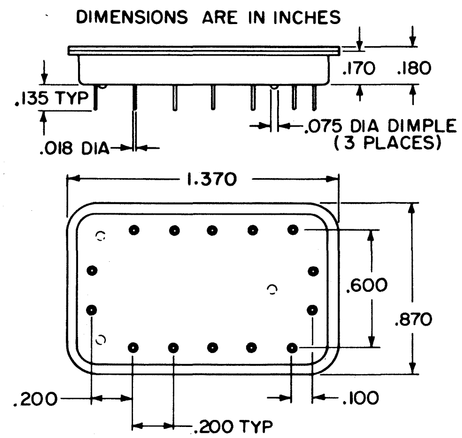
Impedances: 50 Ω both ports, $|\rho_{in}| < 0.5$ (VSWR < 3); $|\rho_{out}| < 0.33$ (VSWR < 2)

Power Requirements: +20 V at 300 mA maximum; −10 V at 300 mA maximum

Price: $1,500.00, 1-9; $1,275.00, 10-24



MODEL	A	B
35002A	1.80 MAX	0.75
35003A	2.05 MAX	0.75
35004A	2.05 MAX	0.75
35005A	3.55 MAX	1.10



HEWLETT PACKARD

NPN EPITAXIAL SILICON TRANSISTOR CHIPS f_{max} to 6.0 GHz

models 35800A 35801A 35802A

MICROWAVE CHARACTERISTICS GUARANTEED

DESCRIPTION

These gold-backed, passivated silicon chips are suitable for miniaturized oscillator and amplifier applications up to 5 GHz.

The chips are 100% probed for the guaranteed "s" parameters. Then they are packaged in individual plastic compartments for shipment. (Note 1)

The unique moly-gold contact systems permit alloying temperatures as high as 400°C for a maximum period of ten minutes without degrading device characteristics.

Absolute Maximum Ratings at 25°C Free Air Temperature	HP 35800A	HP 35801A	HP 35802A
Collector-Base Voltage, V_{CBO}	25 volts	25 volts	25 volts
Collector-Emitter Voltage, V_{CEO}	15 volts	15 volts	20 volts
Emitter-Base Voltage, V_{EBO}	1.5 volts	1 volt	2 volts
Collector Current, Ic	60 mA	75 mA	200 mA
Maximum Junction Temperature (Note 2)	125°C	125°C	125°C
Storage Temperature Range	−65 to +200°C	−65 to +200°C	−65 to +200°C

Electrical Characteristics at 25°C Free Air Temperature

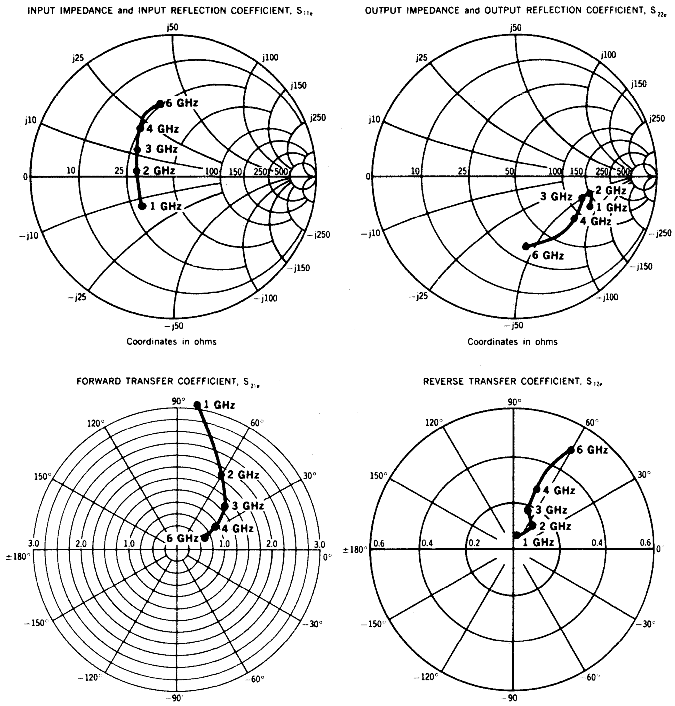
	Parameter	Test Conditions	HP 35800A Min.	Typ.	Max.	Test Conditions	HP 35801A Min.	Typ.	Max.	Test Conditions	HP 35802A Min.	Typ.	Max.	Units
BV_{CBO}	Collector-Base Breakdown Voltage	$I_C = 10\ \mu A$ $I_E = 0$	25	—	—	$I_C = 20\ \mu A$ $I_E = 0$	25	—	—	$I_C = 100\ \mu A$ $I_E = 0$	25	—	—	V
BV_{EBO}	Emitter-Base Breakdown Voltage	$I_E = 10\ \mu A$ $I_C = 0$	1.5	—	—	$I_E = 50\ \mu A$ $I_C = 0$	1	—	—	$I_E = 10\ \mu A$ $I_C = 0$	2	—	—	V
BV_{CEO}	Collector-Emitter Breakdown Voltage (Note 3)	$I_C = 2$ mA. $I_B = 0$	15	—	—	$I_C = 2$ mA $I_B = 0$	15	—	—	$I_C = 10$ mA $I_B = 0$	20	—	—	V
I_{CBO}	Collector Current Cutoff	$V_{CB} = 15$ V $I_E = 0$	—	—	1.0	$V_{CB} = 15$ V $I_E = 0$	—	—	2.0	$V_{CB} = 15$ V $I_E = 0$	—	—	5	μA
h_{FE}	Static Forward Current Transfer Ratio	$V_{CB} = 15$ V $I_C = 15$ mA	20	—	—	$V_{CB} = 15$ V $I_C = 30$ mA	20	—	—	$V_{CB} = 15$ V $I_C = 30$ mA	20	—	—	—
$\|S_{fe}\|^2$	Transducer Power Gain (CE) (Note 4)	$V_{CB} = 15$ V $I_C = 15$ mA f = 2 GHz (3 GHz)	4.3 (1.5)	5.2 (2.0)	— —	$V_{CB} = 15$ V $I_C = 30$ mA f = 2.0 GHz	2.8	3.3	—	$V_{CB} = 15$ V $I_C = 30$ mA (70 mA) f = 1 GHz	4.0 (4.0)	5.2 (5.2)	— —	dB dB
$\|S_{cb}\|^2$	Three-terminal Transducer Power Gain (Note 4)	$V_{CB} = 15$ V $I_C = 15$ mA f = 2 GHz	1.8	2.0	—	$V_{CB} = 15$ V $I_C = 30$ mA f = 2.0 GHz	1.3	1.5	—	$V_{CB} = 15$ V $I_C = 30$ mA f = 1 GHz	1.0	2.0	—	dB
f_s	Frequency at which $\|S_{cb}\| = 0$ dB ($f_{max} > f_s$) (Note 4)	$V_{CB} = 15$ V $I_C = 15$ mA	3.8	4.0	—	$V_{CB} = 15$ V $I_C = 30$ mA	2.8	3.0	—	$V_{CB} = 15$ V $I_C = 30$ mA	1.5	2.0	—	GHz
f_T *	Frequency at which $\|h_{fe}\| = 1$	$V_{CB} = 15$ V $I_C = 15$ mA	—	4.0	—	$V_{CB} = 15$ V $I_C = 30$ mA	—	3.5	—	$V_{CB} = 15$ V $I_C = 30$ mA	—	3.0	—	GHz
f_{max} *	Maximum Frequency of Oscillation	$V_{CB} = 15$ V $I_C = 15$ mA	—	6.0	—	$V_{CB} = 15$ V $I_C = 30$ mA	—	4.3	—	$V_{CB} = 15$ V $I_C = 30$ mA	—	3.0	—	GHz

Chip Size (inches):	0.015 x 0.015 x 0.004	0.015 x 0.015 x 0.004	0.020 x 0.020 x 0.004

* Computer-calculated from s parameter measurements.

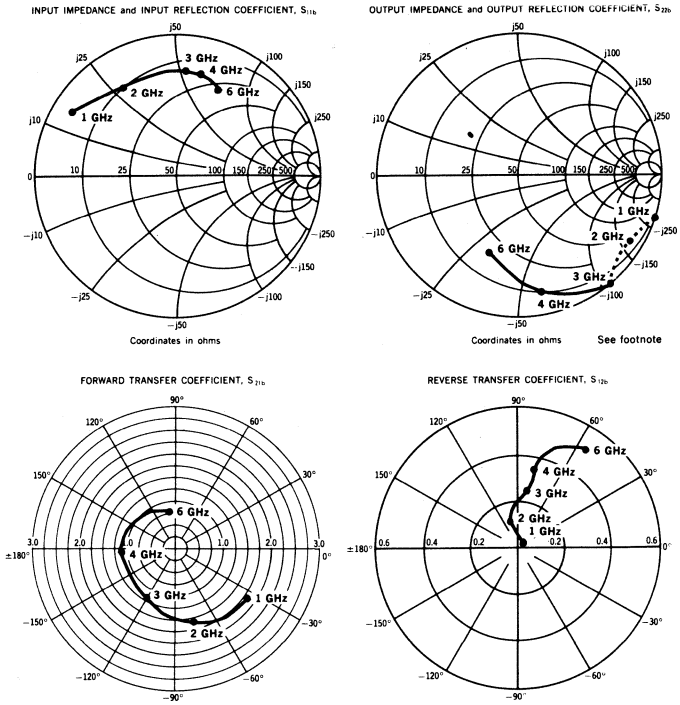
SMALL-SIGNAL COMMON-EMITTER S PARAMETERS

V_{CE} = +15 V, I_C = +15 mA, Z_G = Z_L = 50 ohms + j0, T_A = 25°C



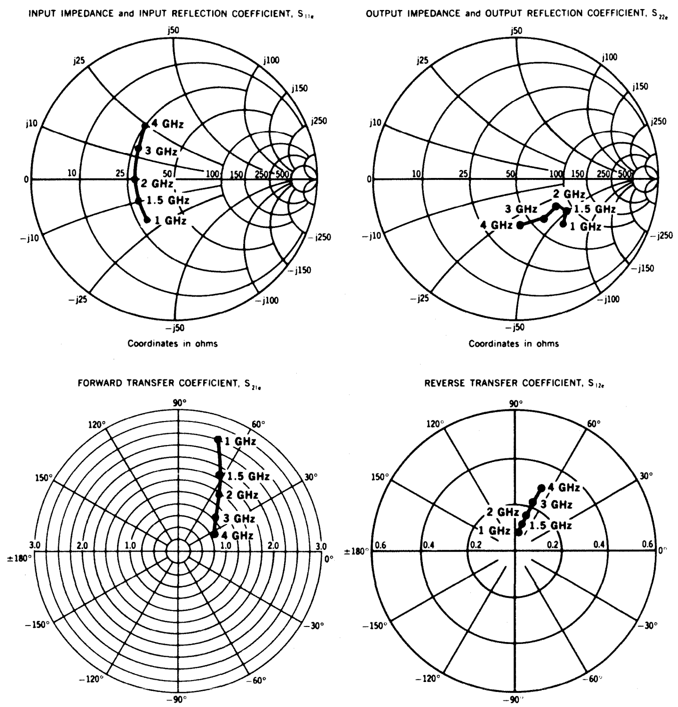
SMALL-SIGNAL COMMON-BASE S PARAMETERS

V_{CB} = +15 V, I_C = +15 mA, Z_G = Z_L = 50 ohms + j0, T_A = 25°C



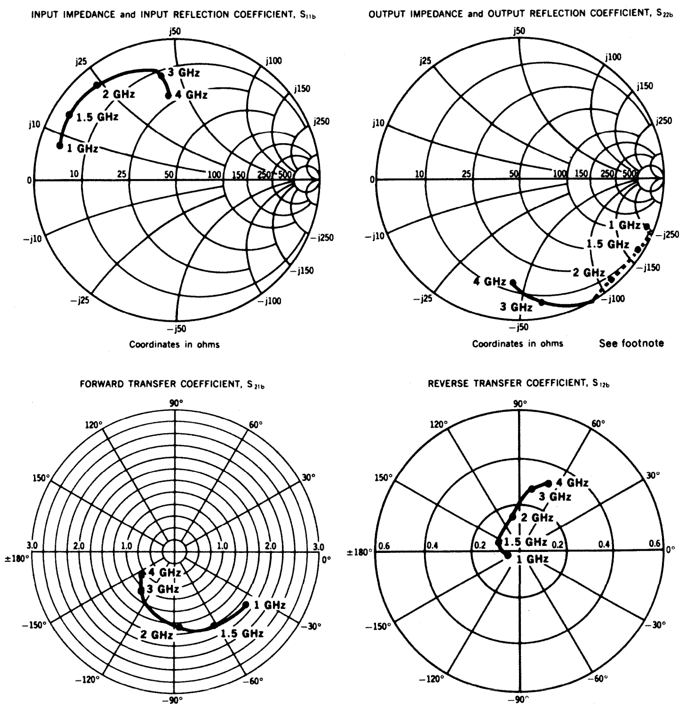
SMALL-SIGNAL COMMON-EMITTER S PARAMETERS

V_{CE} = +15 V, I_C = +35 mA, Z_G = Z_L = 50 ohms + j0, T_A = 25°C



SMALL-SIGNAL COMMON-BASE S PARAMETERS

V_{CB} = +15 V, I_C = +35 mA, Z_G = Z_L = 50 ohms + j0, T_A = 25°C

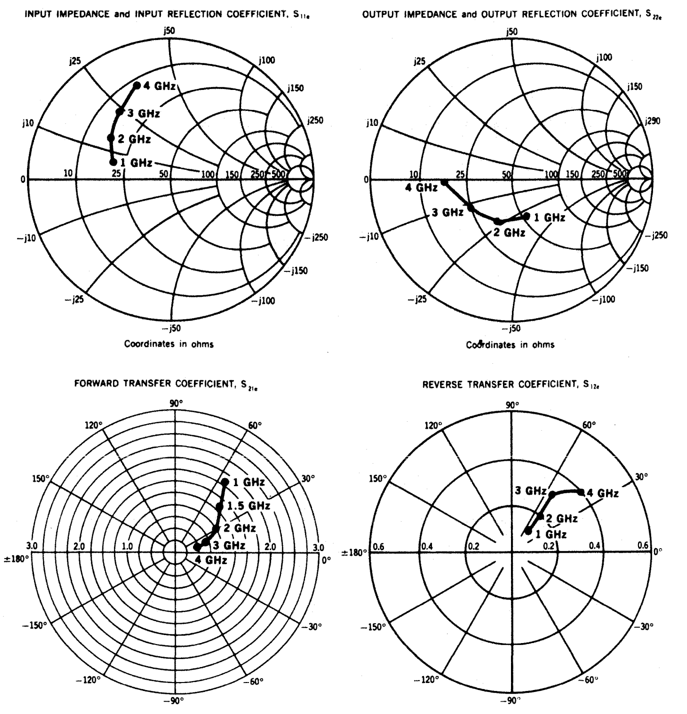


Notes: Data includes effects of 0.7 mil bonding wire 20 to 30 mils long.
Dotted curve represents complex conjugate of $1/S_{22b}$.

Notes: Data includes effects of 0.7 mil bonding wire 20 to 30 mils long.
Dotted curve represents complex conjugate of $1/S_{22b}$.

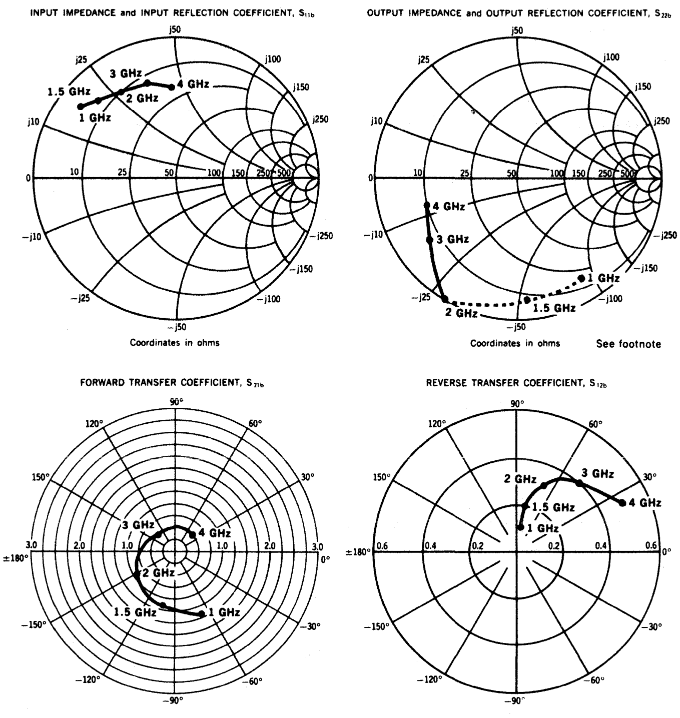
SMALL-SIGNAL COMMON-EMITTER S PARAMETERS

V_{CE} = +15 V, I_C = +30 mA, $Z_G = Z_L$ = 50 ohms + j0, T_A = 25°C



SMALL-SIGNAL COMMON-BASE S PARAMETERS

V_{CB} = +15 V, I_C = +30 mA, $Z_G = Z_L$ = 50 ohms + j0, T_A = 25°C



NOTE 1

OPTIONAL CHARACTERIZATION DATA. Each 35800A, 35801A, or 35802A can be supplied with its individual microwave characteristics. Standard data packages include the scattering parameters and maximum available gains for both common emitter and common base configurations. This data can be supplied at 5, 10, or 15 points, where the measurement frequency and operating point can be varied over wide limits. Nine standard options define the number of data points and variable parameters.

Data Points: Measurements can be made at the following frequencies and bias points:

Frequency: 250, 500, 750, 1000, . . . 6,000 MHz.
Collector Current: 2, 4, 6, 8, . . . 100 mA.
Collector-Base Voltage: 3, 4, 5, 6, . . . 17 V.

Options 01-03 provide data vs. frequency for one bias point. Options 04-06 provide data vs. collector current for one collector-base voltage and at a single frequency. Options 07-09 provide data vs. collector-base voltage for one collector current and at a single frequency. More than one optional data package can be ordered with each device.

Option 01: Data taken at 5 frequencies. Specify start frequency (MHz), frequency increment (MHz), collector current (mA), and collector-base voltage (volts). Price: $5.00.

Option 02: Data taken at 10 frequencies. Specify as outlined in Option 01. Price: $10.00.

Option 03: Data taken at 15 frequencies. Specify as outlined in Option 01. Price: $15.00.

Option 04: Data taken at 5 collector currents. Specify frequency, start collector current, current increment, and collector-base voltage. Price: $5.00.

Option 05: Data taken at 10 collector currents. Specify as outlined in Option 04. Price: $10.00.

Option 06: Data taken at 15 collector currents. Specify as outlined in Option 04. Price: $15.00.

Option 07: Data taken at 5 collector-base voltages. Specify frequency, collector current, start collector-base voltage, and voltage increment. Price: $5.00.

Option 08: Data taken at 10 collector-base voltages. Specify as outlined in Option 07. Price: $10.00.

Option 09: Data taken at 15 collector-base voltages. Specify as outlined in Option 07. Price: $15.00.

EXAMPLES:

Option 01, 1000, 250, 10, 15 will provide data at 1000, 1250, 1500, 1750, and 2000 MHz with I_c = 10 mA and V_{CB} = 15 V.

Option 05, 2000, 6, 2, 10 will provide data at 2000 MHz with I_c = 6, 8, 10, ... 22, 24 mA and V_{CB} = 10 V.

NOTE 2

Thermal resistance from junction to substrate for each device does not exceed 40°C/watt. These measurements were taken with the transistors die attached to pure gold pedestals. Junction and substrate temperatures were measured with an infrared detector with a 0.003-inch diameter measurement field.

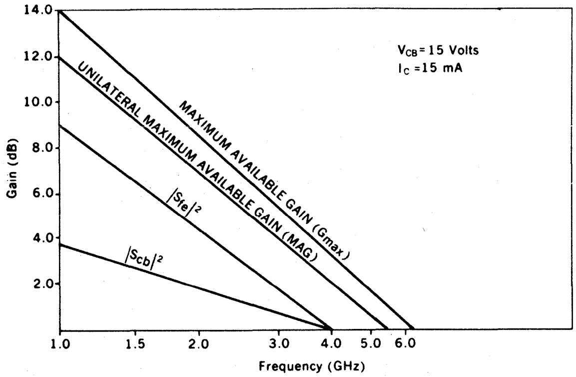
NOTE 3

This parameter must be measured using pulse techniques. PW = 300 μs, Duty Cycle $\leq$ 2%.

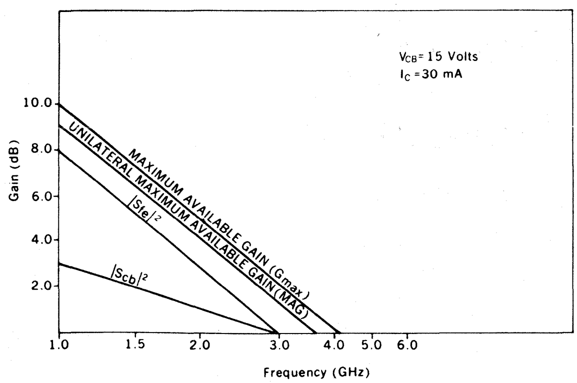
NOTE 4

G_{max} = Maximum available power gain in common emitter configuration (optimum loads).
$|S_{fe}|^2$ = Transducer power gain in common emitter configuration with 50-ohm source and load impedance.
f_{max} = Maximum frequency of oscillation.
$|S_{cb}|^2$ = Transducer power gain with 50 Ω emitter resistance and 50 Ω source and load.
f_s = Frequency at which $|S_{cb}|$ goes through 0 dB.

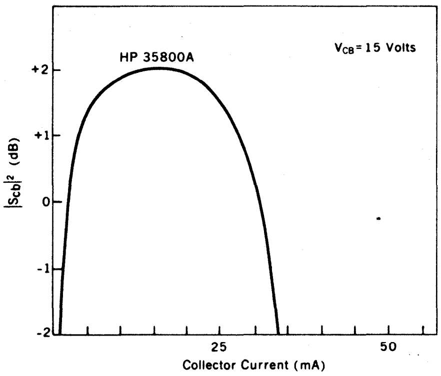
HP 35802A TYPICAL DATA



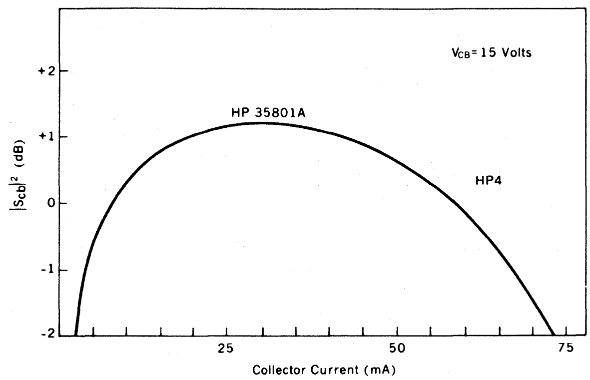
HP 35801A TYPICAL DATA



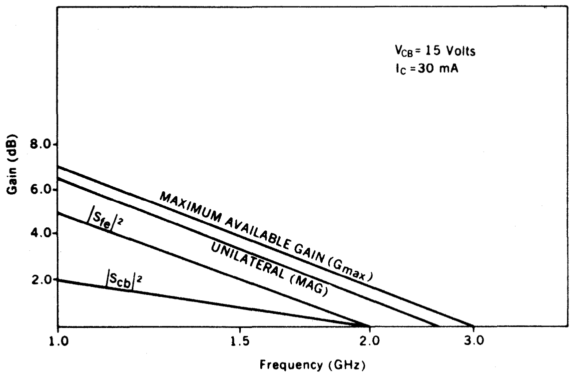
TYPICAL $|S_{cb}|^2$ versus COLLECTOR CURRENT f = 2.0 GHz



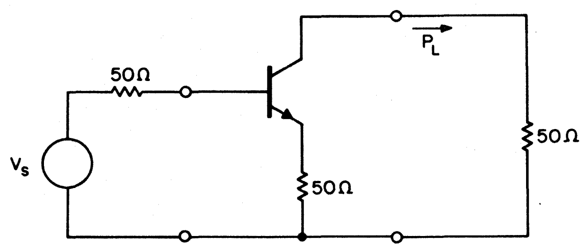
TYPICAL $|S_{cb}|^2$ versus COLLECTOR CURRENT f = 2.0 GHz



HP 35800A TYPICAL DATA

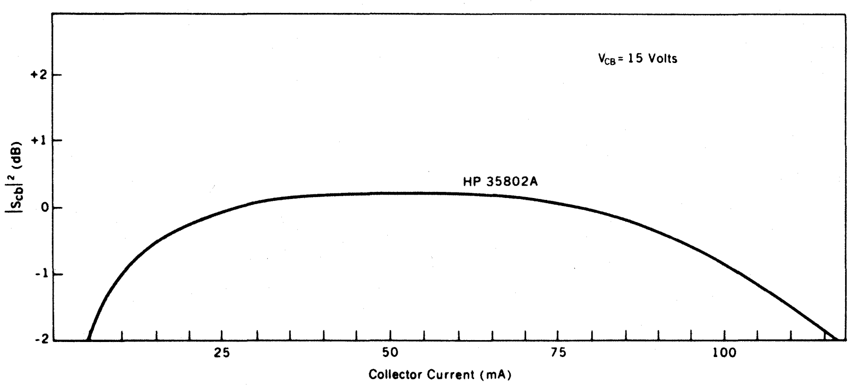


TYPICAL CHARACTERISTICS 35802A



$$|S_{cb}|^2 = G_T = \frac{P_L}{P_{AVS}} \qquad P_{AVS} = \frac{1}{4}\left(\frac{V_S^2}{50}\right)$$

TYPICAL $|S_{cb}|^2$ versus COLLECTOR CURRENT f = 2.0 GHz



PRICES

	1-9	10-24	25-99
35800A	$ 80	$ 71	$ 68
35801A	75	67	64
35802A	65	58	55

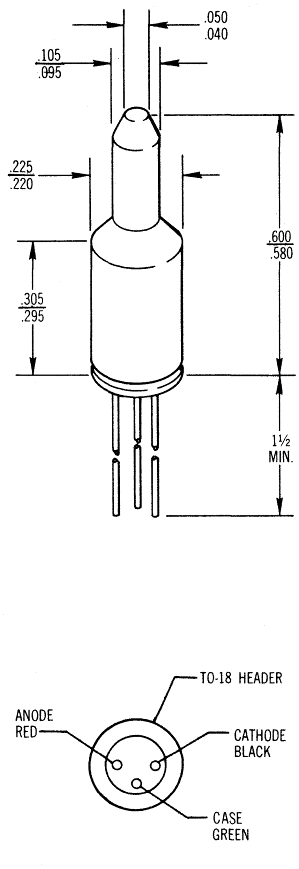
Minimum order quantity is five chips. See page 3, Note 1, for optional characterization data.

optoelectronic devices

HEWLETT hp PACKARD

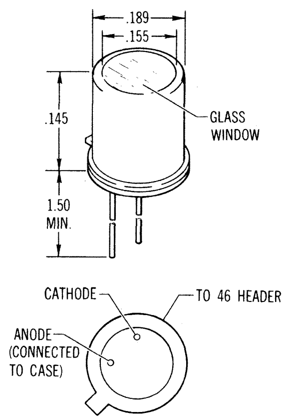
GaAs INFRARED SOURCE

HP 5082-4100 series

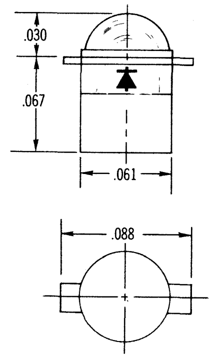


HP 5082-4104

f 258,60



HP 5082-4120



HP 5082-4107

Dimensions in inches

HPA gallium arsenide electroluminescent diodes radiate in a narrow band at a wavelength of 9000Å when forward biased. This radiation may be switched on or off in nanoseconds.

The light source may be used in conjunction with HPA ultra-fast photodiodes as a fast infrared photon-coupled circuit, or as an optical transducer. Other applications include tape or card readers and optical shaft encoders.

The 5082-4104 has a hermetically sealed, glass fiber-optic light guide which effectively places the 0.020 inch diameter round emitting source at the end surface of the device. By this means the available radiation is increased by a factor of twenty.

The 5082-4120 is packaged on a TO-46 header with a plane glass window cap. The 0.024 inch square radiation source is located 0.100 inch behind the 0.155 inch diameter window. The anode is grounded to the case.

The 5082-4107 has a low capacitance Kovar and ceramic package of very small dimensions with a hemispherical lens. The diode chip is located 0.060 inch behind the front surface of the lens.

NOTES:

1. Maximum Peak Pulse Current:

   $I_{avg.\ max.}$ = maximum allowed average current at a specified temperature. ($I_{avg.\ max.} = 100$ mA for the 5082-4120 and 5082-4107 at 25°C.)

   I_{peak} = maximum peak (rectangular pulse) current.

   $$N_I = \frac{I_{peak}}{I_{avg.\ max.}}$$

   N_I must meet all the following conditions:

   (A) $N_I \leq 20$

   (B) $N_I < \frac{1}{50t}$

   (C) $N_I < \frac{1}{ft}$

   where t = pulse duration in seconds
   and f = pulse repetition frequency (Hz)

2. Irradiance Calculation:

   J_o is the radiation vector along the axis of the infrared source. Using J_o the irradiance H, at any distance d from the source is obtained from:

   $$H = \frac{J_o}{d_2}$$

   Where J_o is in μwatt/steradian
   d is distance in centimeters
   and H is in μwatts/cm²

   To calculate the irradiance at a point not on the axis, the radiation vector J_o must be multiplied by a reduction factor obtained from the radiation pattern at the particular angle in question.
   For example, the μwatts/steradian at an angle of 30° from the normal, $P_{30°}$, for the 4120 would be 0.82 x J_o. The irradiance at a distance, d, can now be found by using $H = \frac{P_{30°}}{d_2}$.

3. 5082-4107 Mounting Recommendations (see Figure 7):

   a. The 5082-4107 device is intended to be soldered to a printed circuit board having a thickness of from 0.020 to 0.060 inch (0.051 to 0.152 cm).

   b. Soldering temperature should be controlled so that at no time does the case temperature approach 280°C. The lowest solder melting-point in the device is 280°C (gold-tin eutectic). If this temperature is approached, the solder will soften, and the lens may fall off. Lead-tin solder is recommended for mounting the package, and should be applied with a small soldering iron, for the shortest possible time, to avoid the temperature approaching 280°C.

   c. Contact to the lens end should be made by soldering to one or both of the tabs provided. Care should be exercised to prevent solder from coming in contact with the lens.

   d. If printed circuit board mounting is not convenient, wire leads may be soldered or welded to the device using the precautions noted above.

	LIGHT EMISSION CHARACTERISTICS @ 25°C		
Characteristic	Total Power Output		Axial Radia-tion Intens (See Note
Symbol	P	P	J_o
Units	μW	μW	μW/Steradi
Test Conditions	I = 70 mA	I = 100 mA	I = 50 mA
5082-4104			
Min.			
Typ.	120		50
Max.			
5082-4120			
Min.		150	
Typ.		200	100
Max.			
5082-4107			
Min.		75	
Typ.		150	200
Max.			

* Not isolated from header.

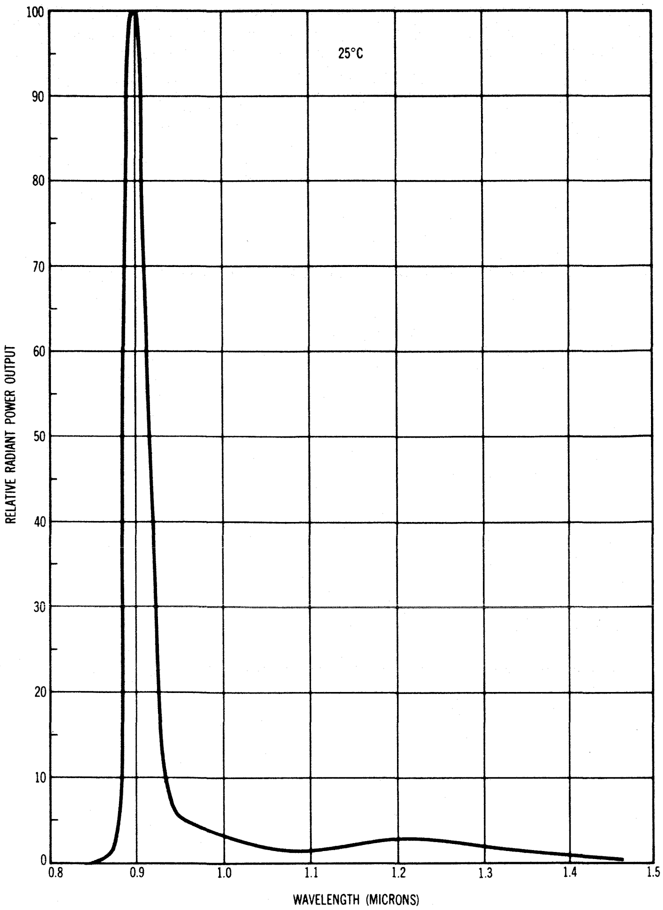


Figure 1. Emission spectrum.

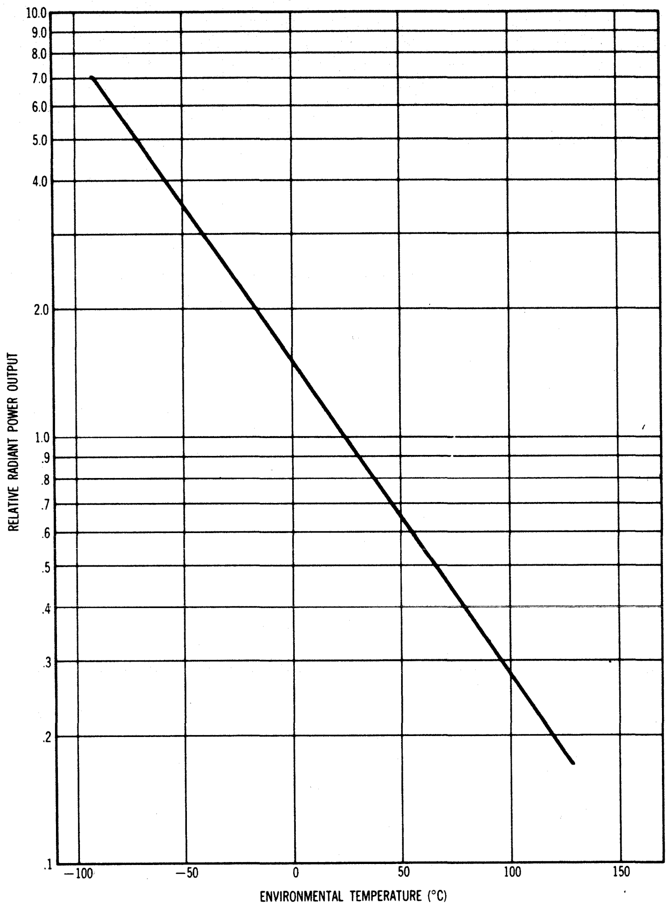


Figure 2. Temperature dependence of radiant power output.

ELECTRICAL CHARACTERISTICS @ 25°C							ABSOLUTE MAX. RATINGS
Forward Voltage		Breakdown Voltage	Zero Bias Capacitance	Rise Time	Diode to Header Resistance	Diode to Header Capacitance	Maximum Current
V_F	V_F	V_{BR}	C_O				
Volts	Volts	Volts	pF	nsec	ohms	pF	mA
= 70 mA	$I_F = 100$ mA	$I_R = 100\ \mu A$	f = 1 MHz	$I_F = 30$ mA			25°C
		5					
			120	70	10^9	2	
1.3							70
		3					
			250	100	*	*	
	1.4						100
		5					
			250	100	*	*	
	1.3						100

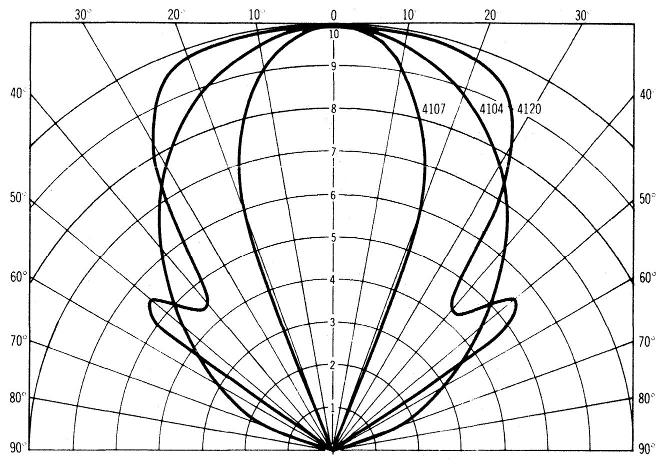


Figure 3. Radiation pattern.

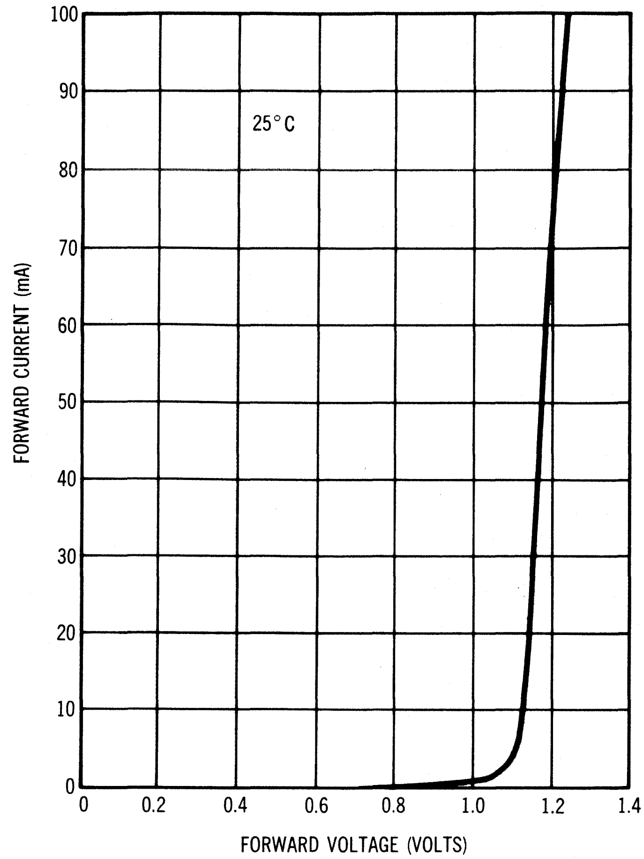


Figure 5. Typical V-I characteristics.

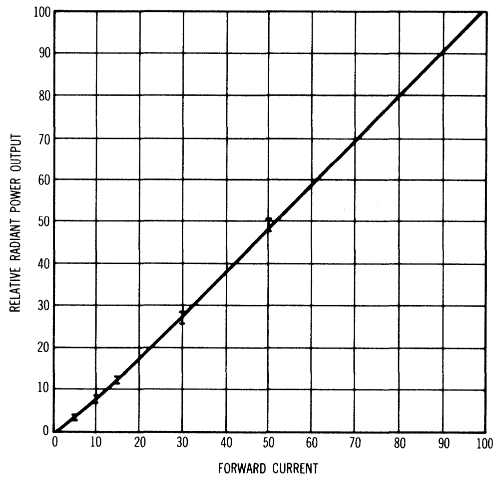


Figure 4. Typical transfer characteristics.

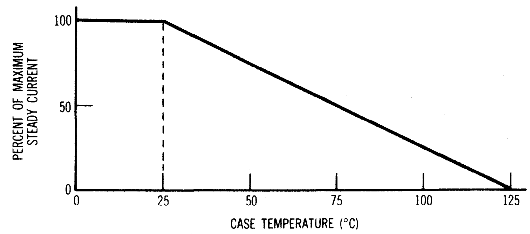


Figure 6. Recommended maximum steady current.

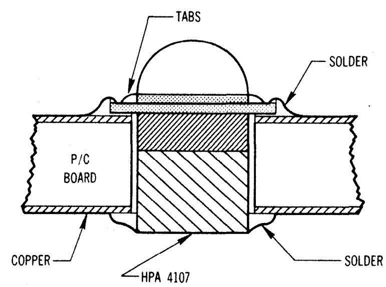
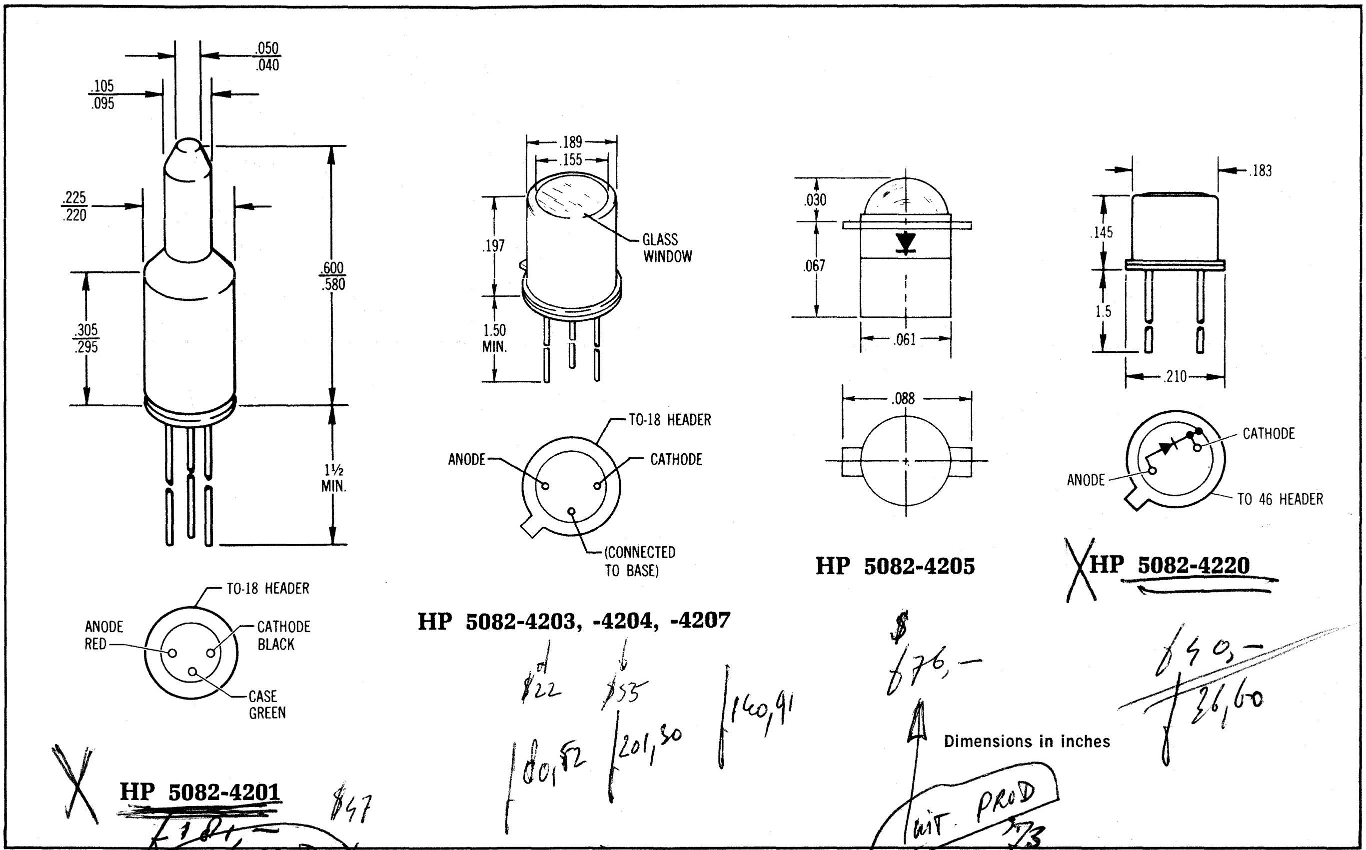


Figure 7. Recommended mounting of HP 5082-4107.

PIN PHOTODIODE

HP 5082-4200 series



The HP ~~silicon~~ planar PIN photodiodes are ultrafast light detectors for visible and near infrared radiation. Their response to blue and violet is unusually good for low dark current silicon photodiodes.

The speed of response of these detectors is less than one nanosecond. Laser pulses shorter than 0.1 nanosecond may be observed. The frequency response extends from dc to 1 GHz.

The low dark current of these planar diodes enables detection of very low light levels. The quantum detection efficiency is constant over six decades of light intensity, providing an excellent dynamic range.

The 5082-4201 has an integral glass fiber-optic light guide which places the 0.020 inch diameter sensitive zone optically on the end surface of the device. Both photodiode terminals are electrically insulated from the header.

The 5082-4203, -4204, and -4207 are packaged on a standard TO-18 header with a plane glass window cap. For versatility of circuit connection, they are electrically insulated from the header. The light sensitive area of the 5082-4203 and -4204 is 0.020 inch (0,508 mm) in diameter and is located 0.075 inch (1,905 mm) behind the window. The light sensitive area of the 5082-4207 is 0.040 inch (1,016 mm) in diameter and is also located 0.075 inch (1,905 mm) behind the window.

The 5082-4205 is in a low capacitance Kovar and ceramic package of very small dimensions, with a hemispherical lens.

The 5082-4220 is packaged on a TO-46 header with the 0.020 inch (0,508 mm) diameter sensitive area located 0.100 inch (2,540 mm) behind a flat glass window.

NOISE FREE PROPERTIES

The noise current of the PIN diodes is negligible. This is a direct result of the exceptionally low leakage current, in accordance with the shot noise formula $I_N = (2qI_R\Delta f)^{1/2}$. Since the leakage current does not exceed 400 picoamps for the 5082-4204 at a reverse bias of 10 volts, shot noise current is less than 1.2×10^{-14} amp $Hz^{-1/2}$ at this voltage.

Excess noise is also very low, appearing only at frequencies below 100 Hz, and varying approximately as 1/f. When the output of the diode is observed in a load, thermal noise of the load resistance (R_L) is 1.28×10^{-10} $(R_L)^{-1/2} \times (\Delta f)^{1/2}$ at 25°C, and far exceeds the diode shot noise for load resistances less than 100 megohms (see Figure 6). Thus in high frequency operation where low values of load resistance are required for high cut-off frequency, all PIN photodiodes contribute virtually no noise to the system (see Figures 6 and 7).

Ultra-fast operation is possible because the HP PIN photodiodes are capable of a response time less than one nanosecond. A significant advantage of the device is that this great speed of response is exhibited at relatively low reverse bias (−10 to −20 volts).

Because of its high sensitivity over a wide spectral range, unprecedented speed of response, unrivaled low-noise performance, and low capacitance, the HP PIN photodiodes are the most useful and versatile silicon photodiodes available.

NOTES:

1. Peak Pulse Power
   When exposing the diode to high level irradiance the following photocurrent limits must be observed:

   $$I_P\,(\text{avg}) < \frac{0.1}{E_P}$$

   and

   $$I_P\,(\text{peak}) < 500\text{ mA} \quad \text{or}$$

   $$< \frac{1000\text{ Amps}}{t(\mu\text{sec})} \quad \text{or}$$

   $$< \frac{I_p\,(\text{avg})}{ft}$$

   whichever of the above three conditions is least.
   I_P—photocurrent
   E_P—supply voltage
   t—pulse duration
   f—pulse repetition rate
2. Current Responsivity
   Response of the photodiode to a uniform field of irradiance H, parallel to the polar axis is given by

OPTICAL CHARACTERISTICS AT 25°C

Characteristics		Response at 7700 Å (1) β_H	Sensitive Area	Diameter		Speed of Response	D*	Noise Equivalent Power
Units		μA/mW/cm²	cm²	Inches	mm	nsec	cm Hz$^{1/2}$/watt	NEP
Test Conditions		V = −20 R_L = 1 MΩ				V = −20 R_L = 50Ω	(0.8, 100, 6)	Watts
5082-4201	Min.						0.9×10^{12}	
	Typ.	1.0	2×10^{-3}	0.020	0,508	<1		
	Max.							5.1×10^{-14}
5082-4203	Min.						0.9×10^{12}	
	Typ.	1.0	2×10^{-3}	0.020	0,508	<1		
	Max.							5.1×10^{-14}
5082-4204	Min.						4.1×10^{12}	
	Typ.	1.0	2×10^{-3}	0.020	0,508	<1		
	Max.							1.2×10^{-14}
5082-4205	Min.						3.95×10^{12} (2)	
	Typ.	1.5 (2)	3×10^{-3} (2)	0.010	0,254	<1		
	Max.							1.4×10^{-14}
5082-4207	Min.						2.5×10^{12}	
	Typ.	4.0	8×10^{-3}	0.040	1,016	<1		
	Max.							3.6×10^{-14}
5082-4220	Min.						0.57×10^{12}	
	Typ.	1.0	2×10^{-3}	0.020	0,508	<1		
	Max.							8×10^{-14}

NOTES:
(1) Response at 7700 Å can be specified as 0.75 electrons/photon and 0.5 μA/μW for all devices.
(2) Specification includes lens effect.

$I = \beta_H \times H$ for 7700 Å. The response from a field not parallel to the axis can be found by multiplying β_H by a normalizing factor obtained from the radiation pattern at the angle in question. For example, the multiplying factor for the 5082-4207 with irradiance H, at an angle of 40° from the polar axis is 0.8. If $H = 1\ \text{mW/cm}^2$, then $I = k \times \beta_H \times H$; $I = 0.8 \times 4.0 \times 1 = 3.2\ \mu$amps.

To obtain the response at a wavelength other than 7700 Å, the relative spectral response must be considered. Referring to the spectral response curve, Figure 1, obtain response, X, at the wavelength desired. Then the ratio of the response at the desired wavelength to response at 7700 Å is given by:

$$\text{Ratio} = \frac{X}{0.5}$$

Multiplying this ratio by the current response at 7700 Å will give the current response at the desired wavelength.

3. 5082-4205 Mounting Recommendations
   a. The 5082-4205 is intended to be soldered to a printed circuit board having a thickness of from 0.020 to 0.060 inch (0,051 to 0,152 cm).
   b. Soldering temperature should be controlled so that at no time does the case temperature approach 280°C. The lowest solder melting point in the device is 280°C (gold-tin eutectic). If this temperature is approached, the solder will soften, and the lens may fall off. Lead-tin solder is recommended for mounting the package, and should be applied with a small soldering iron, for the shortest possible time, to avoid the temperature approaching 280°C.
   c. Contact to the lens end should be made by soldering to one or both of the tabs provided. Care should be exercised to prevent solder from coming in contact with the lens.
   d. If printed circuit board mounting is not convenient, wire leads may be soldered or welded to the devices using the precautions noted above.

ELECTRICAL CHARACTERISTICS AT 25°C							MAXIMUM RATINGS		
Junction Capacitance		Capacitance to Shield		Dark Current		Series Resistance	Steady Reverse Voltage	Peak Inverse Voltage	Power Dissipation
pF	pF	pF	pF	pA	pA	Ω	Volts	Volts	mW
$V_R = -10$ V	$V_R = -25$ V	$V_R = -10$ V	$V_R = -25$ V	$V_R = -10$ V	$V_R = -25$ V				25°C
	1.5		2						
					2000	50	50	200	100
	1.5		2						
					2000	50	50	200	100
2.0		2							
				400		50	20	200	100
0.7		*							
				150		50	50	200	50
5.5		2							
				2000		50	20	200	100
2.0		*							
					5000	50	50	200	100

* Not isolated from header.

Exceeding the peak inverse voltage may cause permanent damage to the diode. Forward current is harmless to the diode, within the power dissipation limit. For optimum performance, the diode should be reverse biased at between 5 and 20 volts.

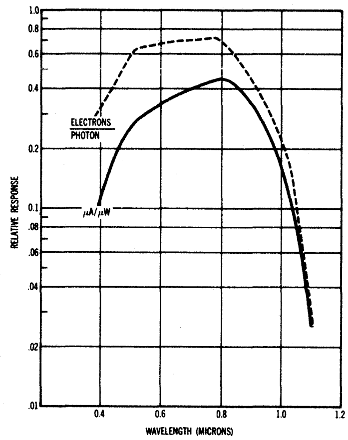


Figure 1. Spectral response.

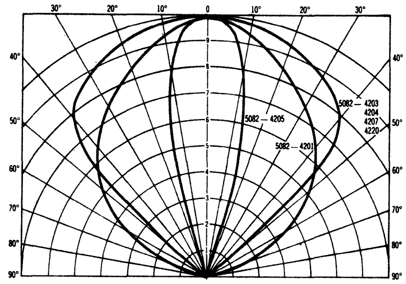


Figure 2. Relative directional sensitivity of the PIN Photodiodes.

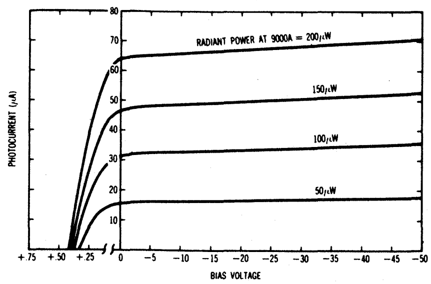


Figure 3. Typical output characteristics at 7700 Å.

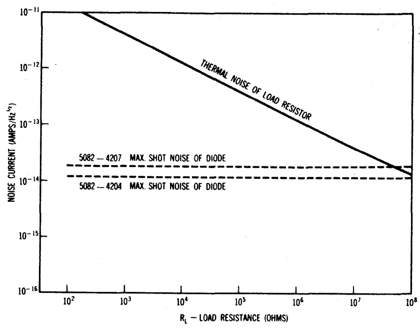


Figure 6. Noise vs. load resistance.

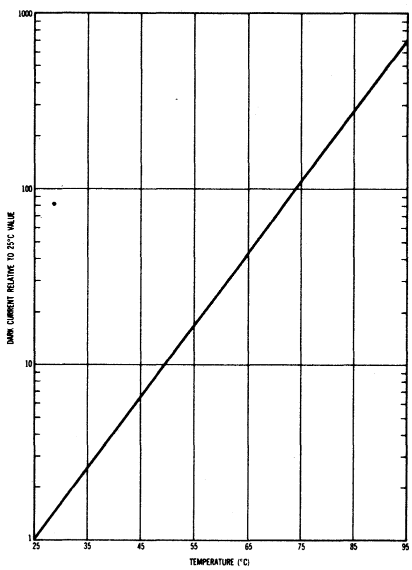


Figure 4. Dark current at —10 V bias vs. temperature.

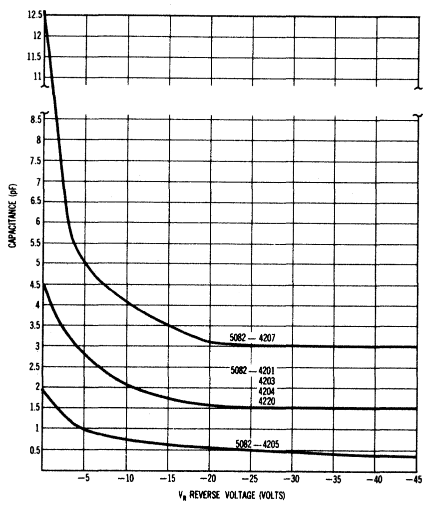


Figure 5. Typical capacitance variation with applied voltage.

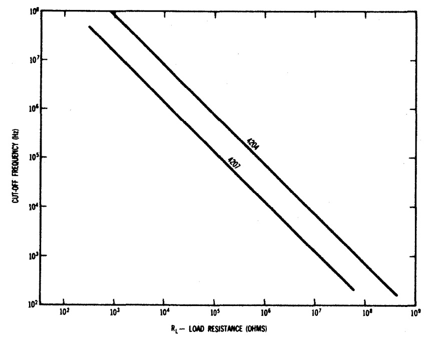


Figure 7. Photodiode cut-off frequency vs. load resistance (C = 2 pF).

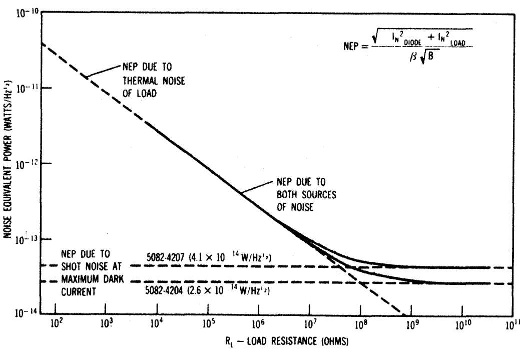


Figure 8. Noise equivalent power vs. load resistance.

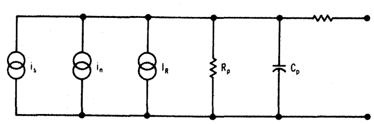


Figure 9.

i_s = Signal current $\approx 0.5\ \mu A/\mu W$

i_n = Shot noise current

$< 1.2 \times 10^{-14}$ amps/Hz$^{1/2}$ (5082-4204)

$< 4 \times 10^{-14}$ amps/Hz$^{1/2}$ (5082-4207)

I_R = Dark current

$< 400 \times 10^{-12}$ amps at —10 V dc (5082-4204)

$< 2000 \times 10^{-12}$ amps at —10 V dc (5082-4207)

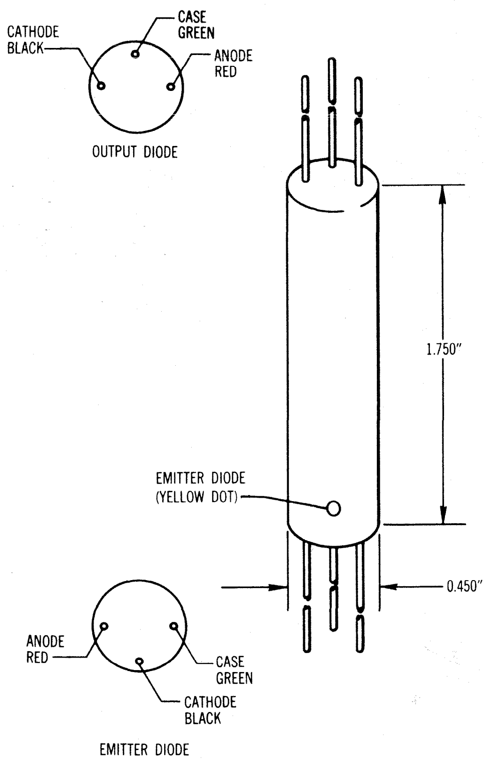
$R_P = 10^{11}\ \Omega$

$R_S = < 50\ \Omega$

HEWLETT PACKARD

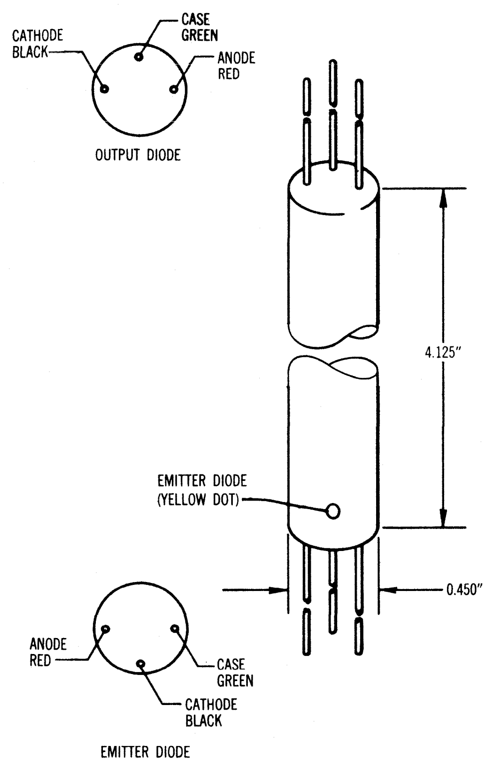
PHOTON COUPLED ISOLATORS

HP 5082-4300 series

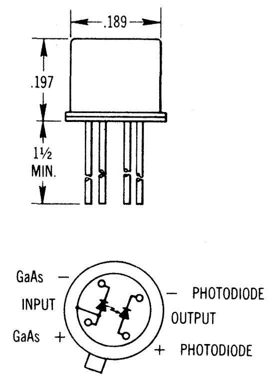


HP 5082-4303

ƒ 440,-
$ 110,-



HP 5082-4309



HP 5082-4310

Dimensions in inches

The HP Photon Coupled Isolators are wide bandwidth signal coupling elements each comprised of a gallium arsenide electroluminescent diode infrared source and a silicon PIN photodetector. Electrical input signals are applied to the GaAs diode, which emits infrared radiation in proportion to the instantaneous forward current. The radiation from the GaAs diode is guided via a light pipe into the PIN photodiode in the 4303 and 4309. In the 4310 and 4320 the source and detector are separated by a thin optically transparent insulator. The electrical signals resulting at the photodiode can thereby be controlled from an input which may be in a separate and electrically isolated circuit.

The insulation resistance between input and output for the 4303 and 4309 exceeds 10^{11} ohms, shunted by less than 0.01 pF. The 4303 can withstand 20,000 volts between input and output, and the 4309 50,000 volts. Separate headers and shields on the input and output sections permit a high degree of circuit isolation. Applications include replacing video pulse transformers, RF signal couplers and switches.

The insulation resistance between input and output for the 4310 and 4320 is typically 10^{11} ohms shunted by 2 pF. The 4310 and 4320 can withstand 200 volts between input and output. The isolator is packaged on a TO-18 header with four leads, and the anode of the input diode is electrically connected to the case.

INPUT CHARACTERISTICS (GaAs Diode) at 25°C

	5082-4303			5082-4309			5082-4310/4320			Units	Test Conditions
	Min.	Typ.	Max.	Min.	Typ.	Max.	Min.	Typ.	Max.		
Forward Voltage			1.3			1.3				Volts	$I_F = 50$ mA
									1.4	Volts	$I_F = 100$ mA
Series Resistance		2			2			2		Ohms	$I_F = 50$ mA
Breakdown Voltage	5			5			3			Volts	$I_R = -100\ \mu A$
Capacitance Zero Bias		120			120			250		pF	
Modulation Rise Time		70			70			100		nsec	$I = 30$ mA
Diode to Header Resistance		10^9			10^9					Ohms	

MAXIMUM RATINGS

Maximum DC Forward Current @ 25°C			70			70			100	mA	
Maximum Operating Temperature			125°C			125°C			125°C		

OUTPUT CHARACTERISTICS (Silicon PIN Photodiode) at 25°C

	5082-4303		5082-4309		5082-4310		5082-4320		Units	Test Conditions
	Typ.	Max.	Typ.	Max.	Typ.	Max.	Typ.	Max.		
Dark Current		2		2		10		50	nA	$V = -25$ V
Series Resistance		50		50		50		50	ohms	$V = +1$ V
Junction Cap	2		2		2.5		2.5		pF	$V = -20$ V
Capacitance to Shield	2		2						pF	

MAXIMUM RATINGS

Steady Reverse Voltage		50		50		50		50	Volts	
Peak Inverse Voltage*		200		200		100		100	Volts	
Steady State Power Dissipation		100		100		100		100	mWatts	

* **Note:** Exceeding the peak inverse voltage may cause permanent damage to the diode. Forward current is harmless to the diode within the power dissipation limit. For optimum performance the diode should be reverse biased at between 5 and 20 volts.

TRANSFER CHARACTERISTICS at 25°C

	5082-4303		5082-4309		5082-4310/4320		Units	Test Conditions
	Typ.	Min.	Typ.	Min.	Typ.	Min.		
DC Current Transfer Ratio I_2/I_1	0.0002		0.0002					$I_1 = 2$ mA $V = -25$ V
I_2/I_1	0.0004		0.0004					$I_1 = 30$ mA $V = -25$ V
I_2/I_1					0.002	0.0015		$I_1 = 100$ mA $V = -25$ V
Cutoff Frequency of Current Transfer	7.0		7.0		3.5		MHz	
Capacitance Coupling, Shield Grounded	0.01		0.01		2*		pF	
Breakdown Voltage Case to Case		20,000		50,000			Volts	
Breakdown Voltage Emitter to Detector						200	Volts	

* Case grounded.

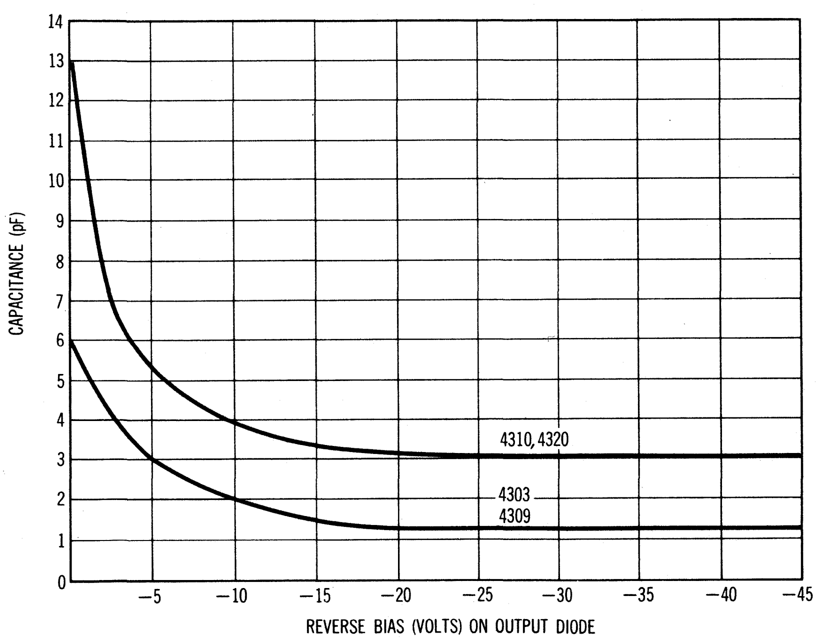


Figure 1. Typical capacitance variation with reverse bias ($t = 1$ ms, $f = 1$ MHz).

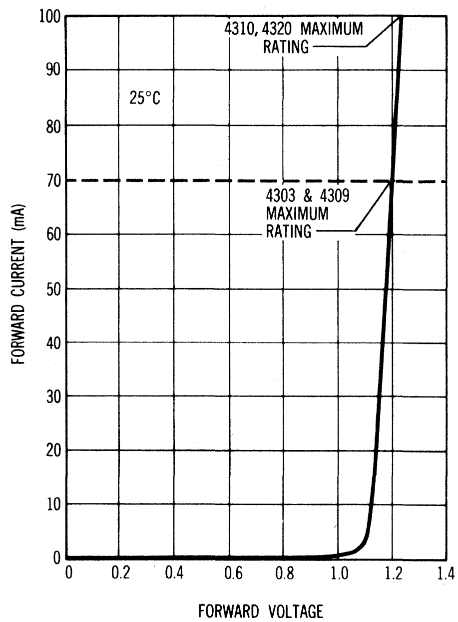
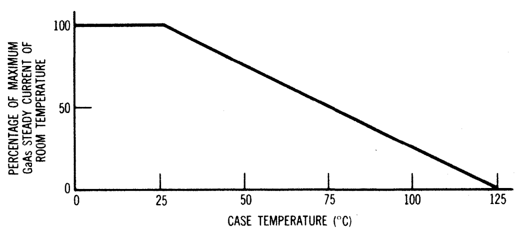


Figure 3. Typical input diode V-I characteristics.

Figure 2. Derating curve.



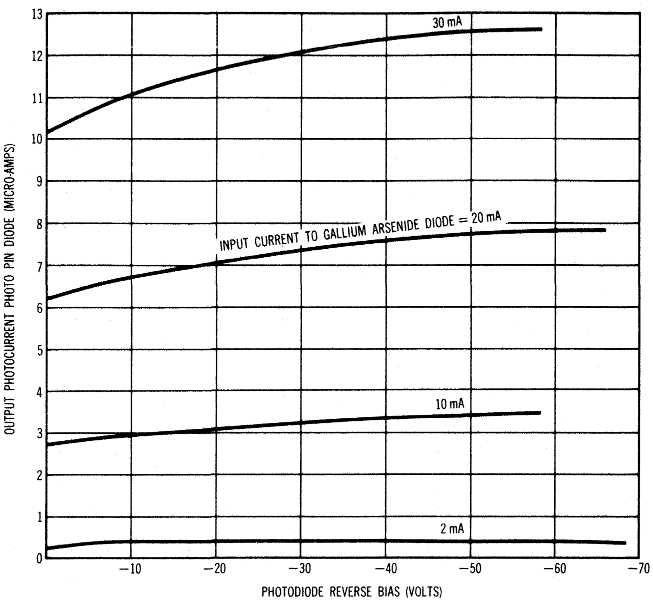


Figure 4. Typical output characteristics 4303 and 4309 Isolators.

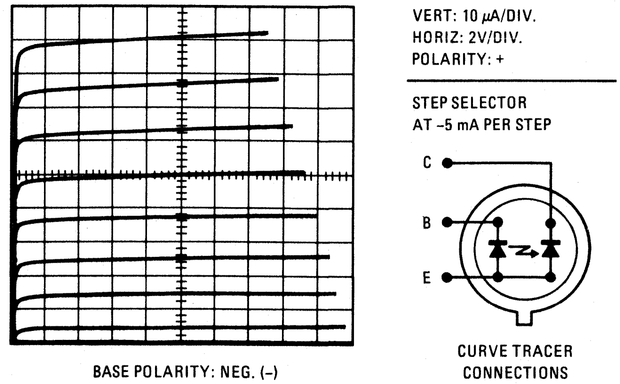


Figure 5. Curve tracer connections and display of current transfer characteristics of the HP 4310 and 4320 Isolator.

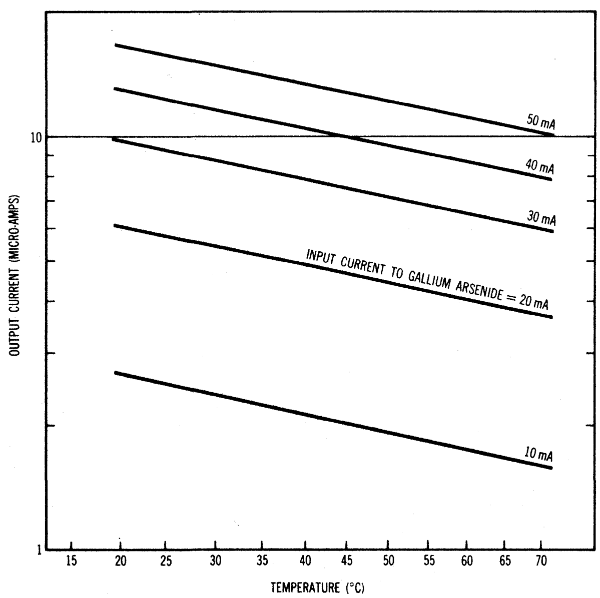


Figure 6. Temperature variation of current transfer for the 4303 and 4309.

(**Note:** The 4310 and 4320 have temperature dependence curves similar to the 4303 and 4309.)

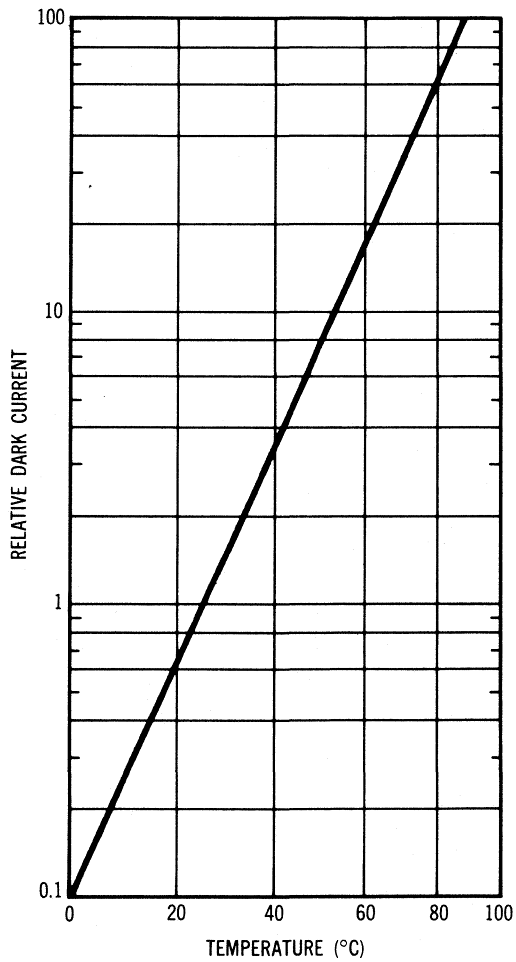


Figure 7. Typical dark current of PIN vs. temperature normalized.

photoconductor devices

HEWLETT hp PACKARD

PHOTO CONTROLLED RESISTOR

HP
5082-4507
5082-4508

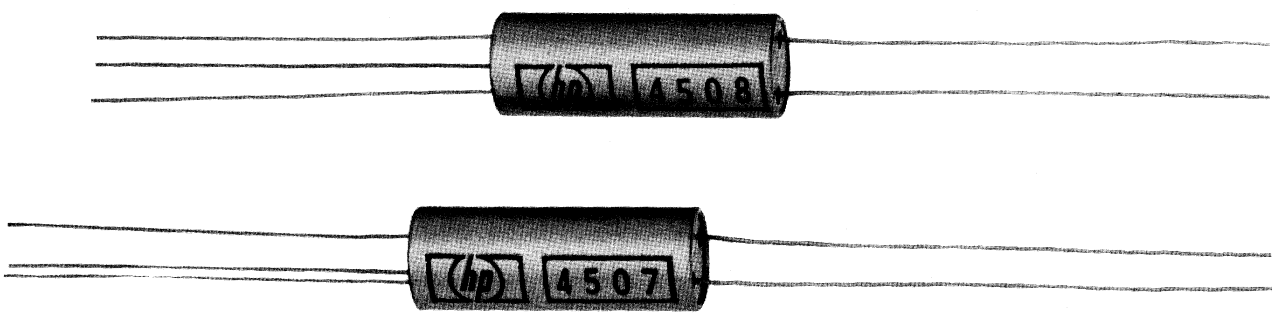
Low Generated Noise and Offset

Large Dynamic Range of Signal Handling Capability

High Isolation Between Drive and Signal Circuits

Temperature Stable

Fast Switching



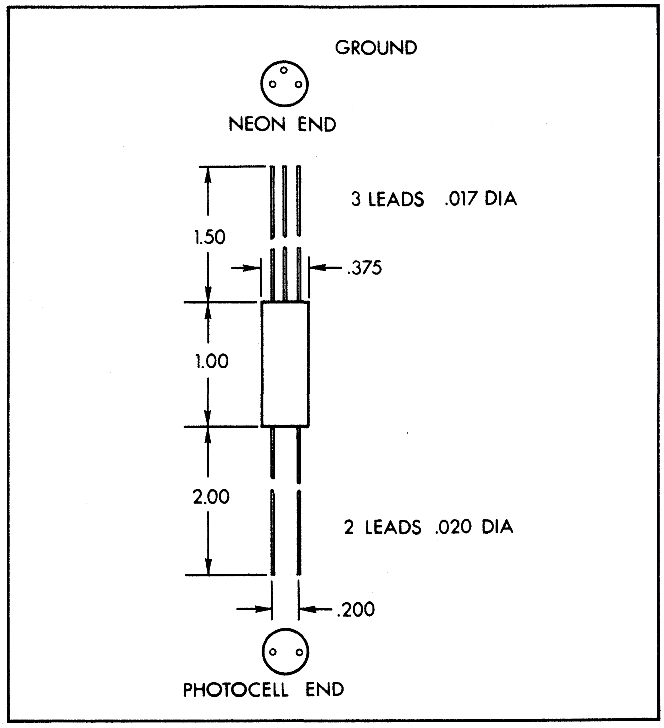
HP 5082-4507 and 4508 are Photo Controlled Resistors (PCR) utilizing a neon glow lamp and a high speed hermetically sealed photoconductive cell in a single package.

A high degree of electrical isolation between the photoconductor and lamp is provided (coupling capacitance is typically <10 femtofarads) by internal electrostatic shielding and the configuration of the leads.

The photoconductor of the HP 5082-4507 and 4508 PCR's is designed for operation over a wide dynamic range. Low level signals may be switched, chopped, or modulated without introduction of excess noise or offsets. To minimize the possibility of unwanted thermocouple emf's, the photoconductor leads are OFHC copper.

PCR's may be used in a wide variety of configurations to provide single and multi-pole switching of signals. On/off ratios of 10^{12} or higher can be achieved by using more than one PCR per signal path.

Price: Quantity, 1-9, $8.00; 10-99, $6.80



ABSOLUTE MAXIMUM RATINGS (25°C)

Voltage, cell leads and neon leads to case (case grounded)	± 300 V
Voltage across cell	± 100 V
Power Dissipation (Photoconductor only)	50 mW
Derate at 1.25 mW/°C above 25°C	

Note: Caution must be taken when operating at high altitudes not to exceed the corona discharge voltage between the photoconductor cell or lamp leads and the case.

PATENT RELEASE STATEMENT

Purchasers of HP PCR's will receive a royalty-free license to use HP PCR's in circuits covered by United States Patent Number 3,014,135.

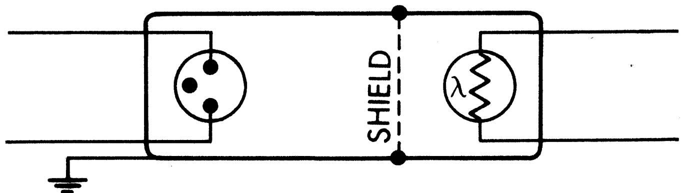


Figure 1. PCR Schematic Diagram (both types).

CHARACTERISTICS (25°C unless noted)

	Photoconductor	5082-4507	5082-4508
R_L,	illuminated resistance (0.8 mA neon current)	220 K Ω max.	10 K Ω max.
		150 K Ω typ.	6.8 K Ω typ.
R_D,	dark resistance	100 M Ω min.	100 M Ω min.
T_R,	turn-on time*	1 ms max.	1 ms max.
T_D,	turn-off time**	2 ms max.	2 ms max.
ΔR_L	with temperature change from 10°C to 55°C	2.5 X max.	2.5 X max.

* Time to 2 X R_L from OFF condition.
** Time to 10 X R_L from ON condition.

Maximum DC to 1 Hz voltage appearing at the photocell terminals due to internal generation under isothermal conditions: ± 2 μV over the temperature range $+10$°C to $+55$°C.

NEON LAMP DRIVE REQUIREMENTS (Lamp is GE A1C or equivalent)

Firing Voltage	± 150 V DC max.	± 135 V DC nominal	95 V AC RMS nominal
Maintaining Voltage		± 70 V nominal	
► Operating Current	± 1.5 mA max.	± 1.2 mA nominal (for 25,000-hour life)	

Note: A current limiting resistor (normally 47 K Ω) must be placed in series with the neon lamp so that after firing it draws approximately 1.2 mA but not more than 1.5 mA. See GE Glow Lamp Bulletin 3-1504R for information concerning lamp life. There are no polarity restrictions on the lamp drive.

HEWLETT hp PACKARD

DUAL CELL PHOTO CONTROLLED RESISTOR

HP 5082-4509

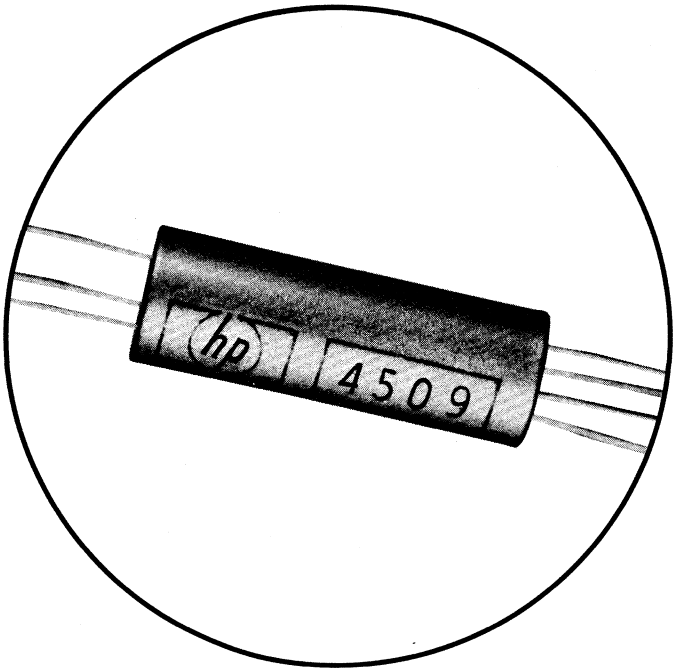
Low Excess Noise

Large Dynamic Range

High Isolation Between Drive and Signal Circuits

Temperature Stable

Voltage Controlled Resistor



A Dual Photo Controlled Resistor (PCR), the HP 5082-4509 combines in a single package a 12-volt incandescent lamp and a hermetically sealed dual photoconductive cell manufactured by HP.

The 5082-4509 is designed for use in control circuits and very low frequency switching (less than 10 Hz) applications. The voltage controlled resistance has a dynamic range in excess of five decades. Electrical isolation between lamp and photoconductive cell is greater than $10^{12}\Omega$ with coupling capacitance less than 0.05 pF.

ELECTRICAL SPECIFICATIONS AT 25°C

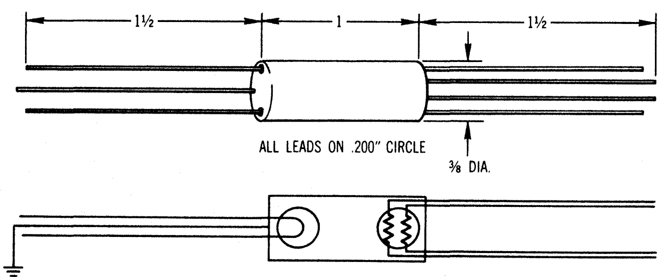
	Min.	Typ.	Max.	Test Conditions
R_L—Illuminated cell resistance (steady state)		3.9 KΩ	6.8 KΩ	10 V drive
R_D—Dark resistance	100 MΩ	500 MΩ		0 V drive
Resistance balance (Note 2)		90%		
Tracking (Note 3)		10%		3 V to 10 V
Coupling capacitance lamp to cell		0.03 pF	0.05 pF	
Capacitance (Note 4)				
cell to cell		1.2 pF	2.5 pF	
cell to case		2.5 pF	5.0 pF	
cell shunt		1.5 pF	3.0 pF	

ABSOLUTE MAXIMUM RATINGS (25°C unless otherwise noted)

Lamp voltage (Note 6) .... 12 Vdc (at approx. 45 mA)
Operating temperature range .... 0 to 65°C
Breakdown voltage cell to case, lamp to case, with case grounded .... 200 V
Voltage, case to cell .... 200 V
cell to cell .... 200 V
across each cell .... 100 V
Cell dissipation .... 125 mW/cell (See figure 2)

NOTES:

1. Conditions prior to test—2 hours minimum of room light (approximately 80 fc) storage at 25°C.
2. Resistance balance = $\dfrac{R_{LIT} \text{ of lower resistance cell}}{R_{LIT} \text{ of higher resistance cell}} \times 100\%$.
3. Tracking is the percent error between cell A and cell B in each package.
   $$\% \text{ error (at 25°C)} = \left[\frac{R_A/R_B \text{ at } H}{R_A/R_B \text{ at } H_o} - 1\right] \times 100.$$
4. Capacitance measurements made while cell is in the dark.
5. At 65°C cells should be stored under light with a minimum duty cycle of 20% to maintain the listed electrical specifications.
6. At 10 V maximum lamp drive, life expectancy of the lamp is in excess of 40,000 hours.



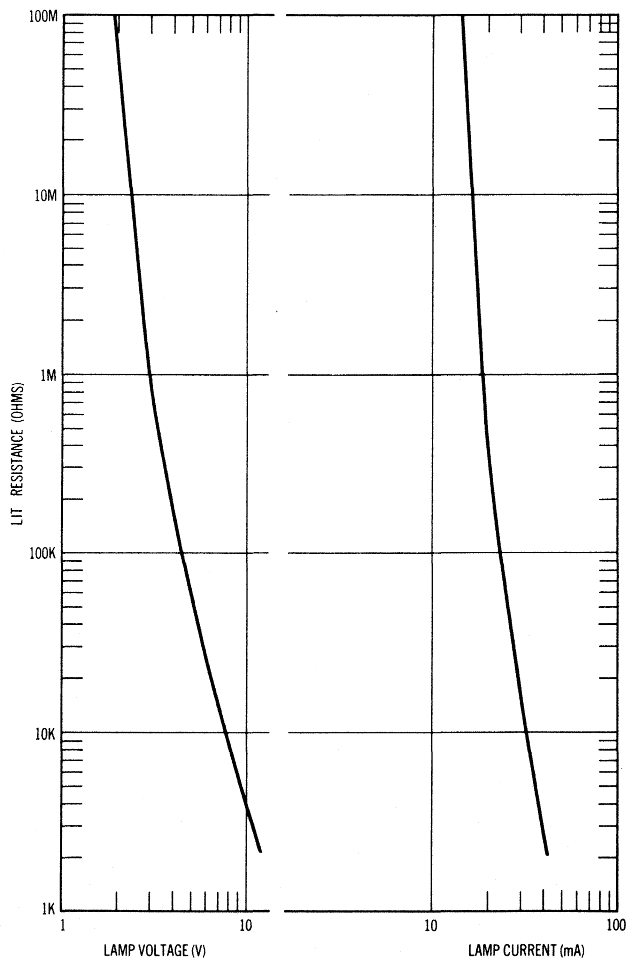


Figure 1. Lamp current and lamp voltage vs. photocell lit resistance.

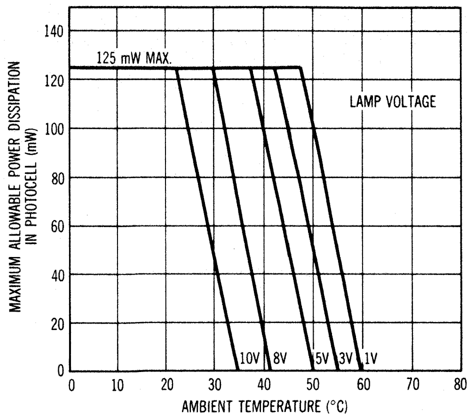


Figure 2. Maximum allowable power dissipation in photocell vs. ambient temperature for various incandescent lamp voltages.

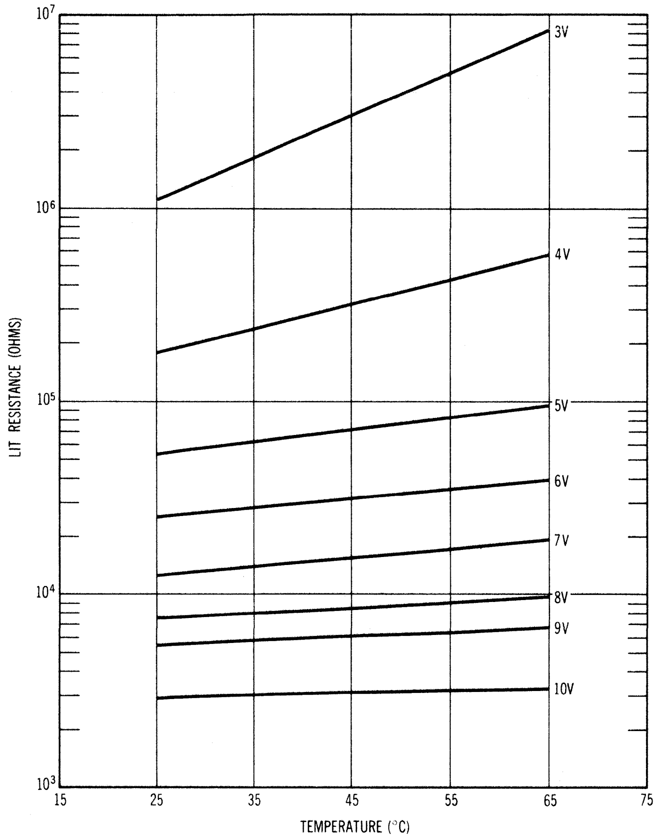


Figure 3. Photocell lit resistance as a function of temperature for various incandescent lamp voltages.

HEWLETT hp PACKARD

PHOTO CONTROLLED RESISTOR

HP
5082-4510

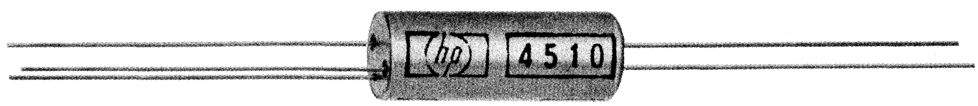
LOW EXCESS NOISE

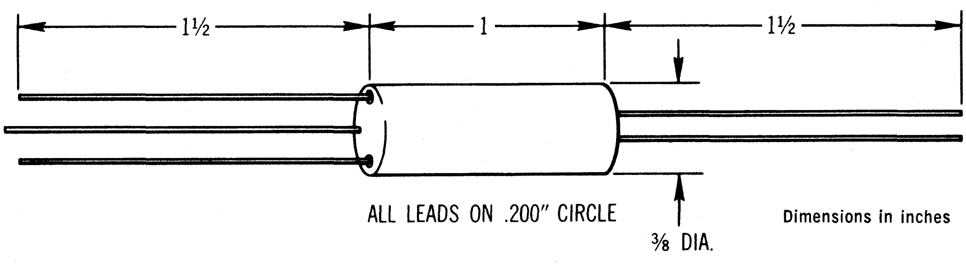
LARGE DYNAMIC RANGE

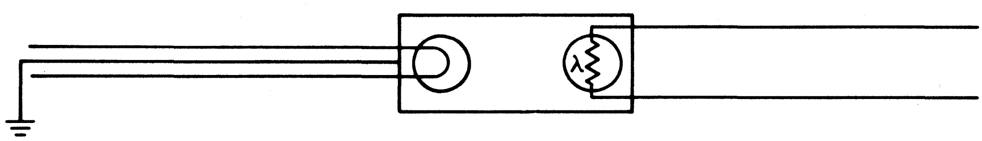
HIGH ISOLATION BETWEEN DRIVE AND SIGNAL CIRCUITS

TEMPERATURE STABLE

VOLTAGE CONTROLLED RESISTOR







The HP 5082-4510 is a Photo Controlled Resistor (PCR) which combines in a single package a 12-volt incandescent lamp and a hermetically sealed photoconductive cell manufactured by HP.

The 5082-4510 is designed for use in control circuits and very low frequency switching (less than 10 Hz) applications. The voltage controlled resistance has a dynamic range in excess of five decades. Electrical isolation between lamp and photoconductive cell is greater than $10^{12}\Omega$ with coupling capacitance less than 0.01 pF.

ELECTRICAL SPECIFICATIONS AT 25°C

	Min.	Typ.	Max.	Test Conditions
R_L—Illuminated Cell Resistance (Steady State)		1 KΩ	2 KΩ	10 V drive
R_D—Dark Resistance	100 MΩ	500 MΩ		0 V drive
Cell Shunt Capacitance		3.0 pF	5.0 pF	
Coupling Capacitance Lamp to Cell		0.005 pF	0.01 pF	

Absolute Maximum Ratings (25°C unless otherwise noted)

Lamp Voltage (Note 1) .... 12 Vdc (at approximately 45 mA)
Operating Temperature Range .... 0 - 65°C
Breakdown Voltage Cell to Case,
Lamp to Case, with Case Grounded .... 200 V
Cell Voltage .... 100 V
Cell Dissipation .... 125 mW (See Figure 2)

NOTE 1: At 10 V maximum lamp drive, life expectancy of lamp is in excess of 40,000 hours.

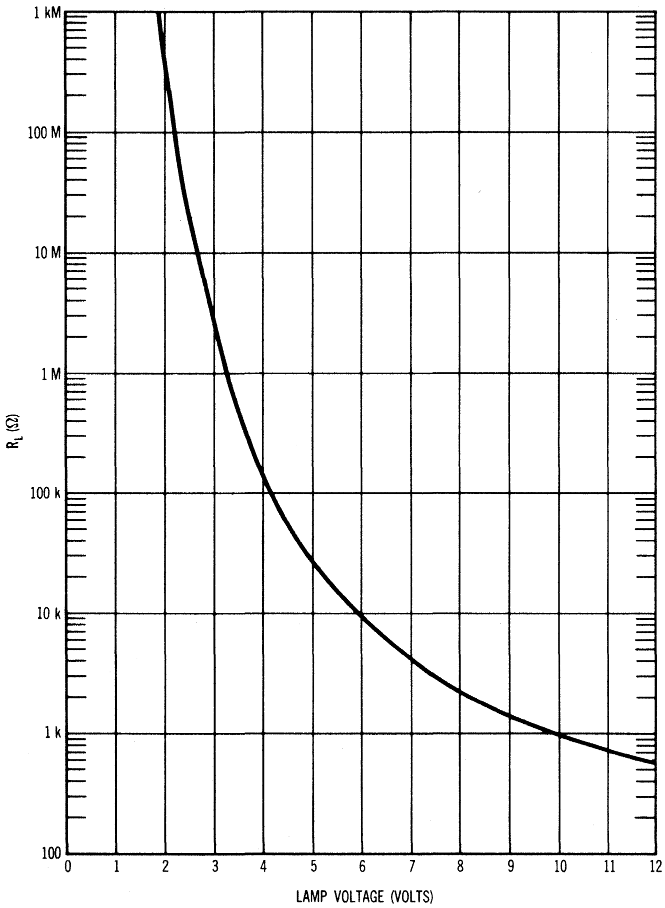


Figure 1. Lamp voltage vs. photocell lit resistance.

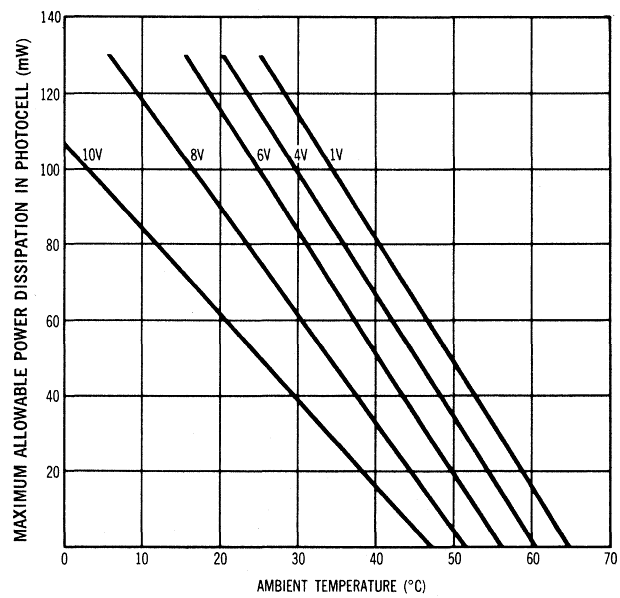
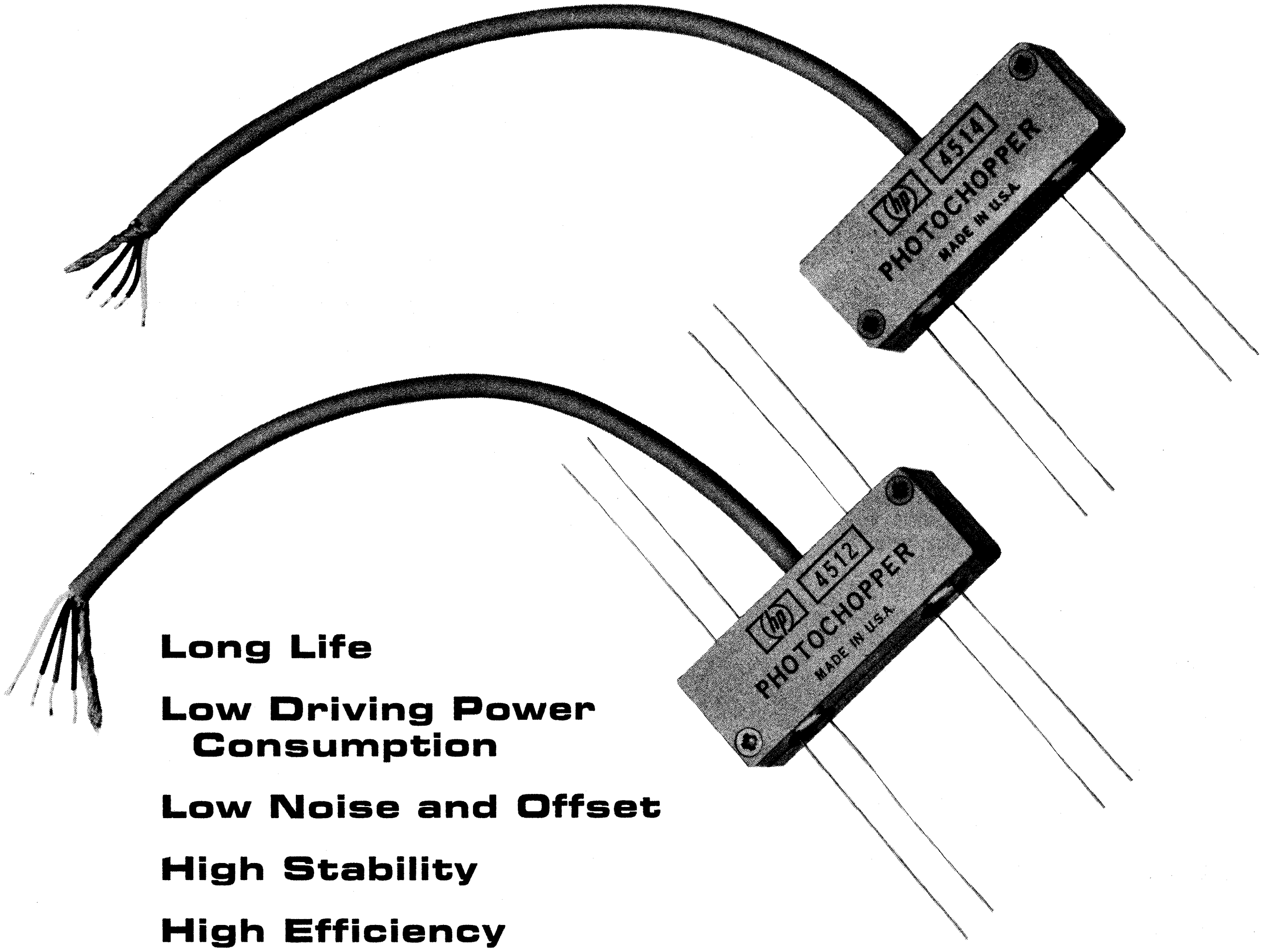


Figure 2. Maximum allowable power dissipation in photocell vs. ambient temperature for various incandescent lamp voltages.

HEWLETT PACKARD

PHOTOCHOPPER

HP 5082-4511/12/13/14



Long Life

Low Driving Power Consumption

Low Noise and Offset

High Stability

High Efficiency

Large Dynamic Range

The HP 5082-4511 and 4512 are four-cell, double-pole double-throw photochoppers, while the 5082-4513 and 4514 are two-cell, single-pole double-throw photochoppers. The photochoppers utilize specially designed hermetically sealed photoconductive cells optimized for speed and stability, illuminated by neon glow lamps which may be excited by a variety of external circuits.

The mechanical design insures the efficient coupling of light from the self-contained neon glow lamps to the photocells. Particular attention has been paid to the electrostatic shielding of the photoconductive cells from the potential on the neon glow lamp electrodes. To provide the maximum circuit flexibility, all cell leads and lamp leads are brought out individually.

The HP 5082-4511 features a high input impedance modulator for use with high impedance signal sources; the HP 5082-4512, a low impedance modulator for low impedance signal sources. The demodulator of both types provides an effective low output impedance.

The HP 5082-4513 features a high input impedance modulator for use with high impedance signal sources; the HP 5082-4514, a low input impedance modulator for low impedance sources.

ELECTRICAL SPECIFICATIONS @ 25°C
Chopping frequency 100 Hz; neon current 2.25 mA square wave drive

In the circuit of Figure 1, Notes 1-6	5082-4511			5082-4512			5082-4513			5082-4514		
Modulator	**Min.**	**Typ.**	**Max.**	**Min.**	**Typ.**	**Max.**	**Min.**	**Typ.**	**Max.**	**Min.**	**Typ.**	**Max.**
R_S	360K	1.8M	—	15K	75K	—	360K	1.8M	—	15K	75K	—
R_P	—	72K	290K	—	3K	12K	—	72K	290K	—	3K	12K
$\alpha = \frac{R_S}{R_P}$	15	25	—	15	25	—	15	25	—	15	25	—
Offset		1 μV			1 μV			1 μV			1 μV	
Demodulator	**5082-4511**			**5082-4512**								
R_S	15K	75K	—	15K	75K	—						
R_P	—	3K	12K	—	3K	12K						
$\alpha = \frac{R_S}{R_P}$	15	25	—	15	25	—						

Notes:
1. All specifications will be met within one hour of turn-on.
2. All resistance measurements made with a capacitor damped ohmmeter.
3. R_S—the time average resistance of two alternately illuminated cells connected in series.
4. R_P—the time average resistance of two alternately illuminated cells connected in parallel.
5. α—the ratio of R_S to R_P. (By normalizing R_S to R_P a figure of merit related to the decay time or speed of the cell is obtained. The relationship of α vs. frequency is shown in Figure 2.)
6. Offset—the dc voltage required at the modulator input under isothermal conditions to produce zero voltage at the modulator output.

MAXIMUM RATINGS

All types @ 25°C (unless otherwise noted)

P_D—Photocell Power Dissipation (per cell) .... 125 mW*
V_C—Photocell Voltage .... 100 volts
V_B—Breakdown Voltage Cell to Case .... 200 volts
I_{neon}—Glow Lamp Peak Current .... 3.50 mA**
I_{neon}—Glow Lamp Average Current during Conduction .... 2.75 mA**
T_A—Operating Ambient Temperature Range.... 0 to + 65°C

* Derate linearly to zero at 65°C.
** Operation of neons with reverse polarity may cause degraded performance.

RECOMMENDED DRIVE REQUIREMENTS (all types):

E_L—Neon Glow Lamp Supply Voltage....+ 170 V peak min.
I_L—Neon Glow Lamp Current .... 2.25 mA
(Current limiting resistors must be provided externally to produce the rated neon current with the supply voltage used.)

OPERATING NOTES

1. Although these components are used primarily as series-shunt photochoppers, it is important to realize that these devices are combinations of photoconductors (photocells) and lamps without constraints imposed by any internal interconnections. The parameters specified (R_S, R_P, and α) were chosen to give the maximum design flexibility.

   The performance of these components is a function of the circuit in which they are used. Although the rest of this data sheet is devoted to showing how to obtain optimum performance in a series-shunt chopper configuration, there are many other types of applications, a few of which are:
   (1) Dual single or double pole relays.
   (2) Two- and four-channel modulators, either series or shunt.
   (3) One- and two-channel series-shunt type or center-tap type.

2. Drive Circuits

   A variety of circuits can be used to drive the neon glow lamps in the 5082-4511 through 4514. Two of the circuits are shown at the end of this section. Information on neon glow lamps may be obtained from lamp manufacturers' publications. Several publications of this type are:

   "Glow Lamp Manual," General Electric Co., 1963, edited by S. W. Tuttle and C. R. Dougherty.

   "Evaluating and Applying Neon Glow Lamps," by E. E. Bauman, Signalite Application News, Vol. 2, No. 6.

   Also recommended are:

   "Photoresistive Choppers, An Engineer's View," by R. Y. Moss, Electronic Design News, Dec. 1964.

   HP Application Note 911, "Low Level DC Operation Using HP Photochoppers."

   Both of these discuss neon lamp characteristics and photochopper considerations in general.

Two Lamp Relaxation Oscillator

$$f \simeq \frac{1}{RC}\left(\frac{E\text{-}120}{200}\right)$$

$$I_{neons} \simeq \frac{2\,(E\text{-}70)}{R}$$

We recommend that for good stable operation E be at least 250 volts. The above equations give approximate values, due to the great variation in the neon firing and maintaining voltage. A frequency adjust is recommended to achieve a desired chopping frequency. The change in frequency for a change in voltage E is given by

$$\frac{\Delta F}{F} = \frac{\Delta E}{E\text{-}120}$$

for E = 250 V, 1% change voltage gives approximately a 2% change in frequency.

Direct Power Line

A simple neon drive circuit which can be used to drive the chopper is shown below. The electrical specifications given in this data sheet, however, do not apply when this type of drive circuit is used. Further information on this type of drive can be obtained from HP Application Note 911.

The neons used in HP photochoppers would have an average life of 10,000 hours with 2.25 mA square wave drive based on the manufacturer's data and failure criteria. At the recommended drive voltage, lifetimes well in excess of 10,000 hours can be expected.

3. Modulation Efficiency

Figure 3 gives the intrinsic modulating efficiency (η) of the modulator which is for a zero source impedance and an infinite load. Non-zero source impedances and finite load impedances, however, affect the conversion of dc to ac. Using the circuit in Figure 10, the effective modulation efficiency can be calculated from the equation below.

$$\text{Modulation Efficiency} = \frac{E\,p\text{-}p}{E_{SOURCE}} \times 100\% =$$

$$\simeq \frac{\eta\, 100\%}{\left[\frac{1}{R_{SOURCE}} + \frac{1}{R_S}\right] [R_P + R_{AMP} + 1/4]} \times \frac{R_{AMP}}{R_{SOURCE}}$$

Where R_{SOURCE} is the signal source impedance, R_{AMP} is the amplifier input impedance.

The capacitors in Figure 10 must be large enough so that no significant chopping frequency voltages appear across them.

η is taken from Figure 3, and is close to unity for frequencies below 200 Hz.

Effective modulating efficiencies below 200 Hz approach unity under the following conditions,

$$R_{SOURCE} \leq \frac{R_S}{100} \text{ and } R_{AMP} \geq 100\, R_P.$$

4. Effective Input and Output Modulator Impedances

The effects of source impedance, R_{SOURCE}, and load impedance, R_{AMP}, on the modulator input and output impedances can be given by the following expressions.

$$R_{IN} \cong \frac{4R_S\,(R_P + R_{AMP})}{R_S + 4\,(R_P + R_{AMP})}$$

$$R_{OUT} \cong R_P + \frac{R_S\, R_{SOURCE}}{4\,(R_S + R_{SOURCE})}$$

5. Series-Shunt Demodulator Configuration

A series-shunt demodulator circuit is shown in Figure 10. The capacitors must be large enough that no significant chopping frequency voltages appear across them. Formulas for the output impedance and demodulation efficiency are given below.

$$R_{OUT} \cong \frac{4\,(R_O + R_P)\,\alpha\, R_P}{4\,(R_O + R_P) + \alpha\, R_P}$$

which simplifies to:

$$R_{OUT} \cong \frac{4\,\alpha\, R_P}{\alpha + 4} \text{ for } R_O << R_P$$

where R_O is amplifier output impedance.

$$\text{Demodulator Efficiency} \cong \frac{\alpha\, R_P\, \eta}{4\,(R_O + R_P) + \alpha\, R_P} \times \frac{R_{LOAD}}{R_{LOAD} + R_{OUT}}$$

which simplifies to:

$$\text{Demodulator Efficiency} \cong \frac{\alpha\, \eta}{\alpha + 4} \times \frac{R_{LOAD}}{R_{LOAD} + R_{OUT}}$$

$$\text{for } R_O << R_P$$

6. Chopping Frequency Effects

Effective modulating efficiency is a function of chopping frequency and follows the curve in Figure 3 (η vs. frequency). The expression for modulating efficiency discussed in Section 3 is usable for all frequencies providing the proper η is used.

R_P can be considered independent of frequency. R_S at any frequency can be obtained from the equation $R_S = \alpha\, R_P$ (where α is selected from the α vs. frequency curve, Figure 2). R_{IN} and R_{OUT} can then be calculated at any frequency from the expression given in Section 4.

7. Overall System Efficiency

The overall efficiency of a series-shunt modulator-demodulator circuit is the product of the modulator efficiency given in Section 3 and demodulator efficiency given in Section 5.

8. Circuit Effects

The performance of the HP photochoppers is largely dependent on the external environment and the circuit in which the chopper is employed. Every care has been taken in the design and manufacture of the photochoppers to minimize thermoelectric, photovoltaic, chemically generated, and synchronously induced emf's which can appear as noise in many chopper applications. Comparable precautions and care must be taken in the surrounding circuitry and environment if the maximum built-in capability of the photochopper is to be realized.

Being solid state devices, photoconductors, like transistors, vary from unit to unit and also with temperature, as indicated in Figure 4. Just as the effects of transistor parameter variations can be stabilized by negative feedback, the effects of photoconductor parameter variations can also be stabilized by including the modulator and demodulator in the amplifier feedback loop. See Application Note 911 for a further discussion of this subject.

9. High Temperature Effects

The photoconductor used in the HP 5082-4511 through 4514 photochoppers can be damaged by extended exposure to high temperatures when not operating. Storage for periods in excess of two hours at 65°C should be avoided.

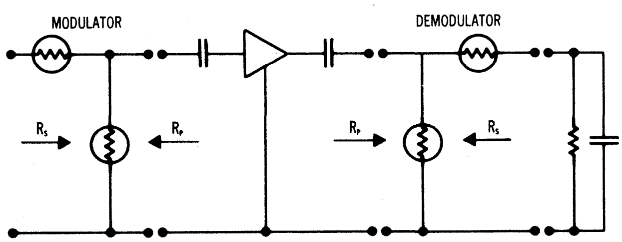


Figure 1. Schematic representation of a series-shunt chopper amplifier circuit.

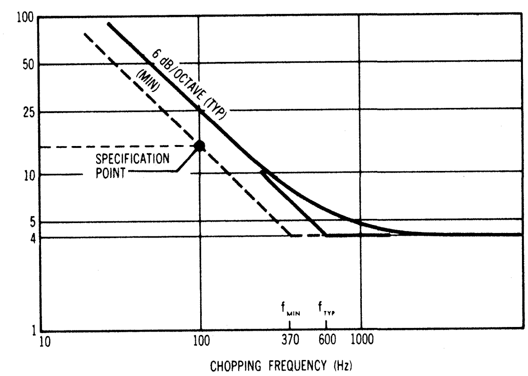


Figure 2. Typical α vs. frequency.

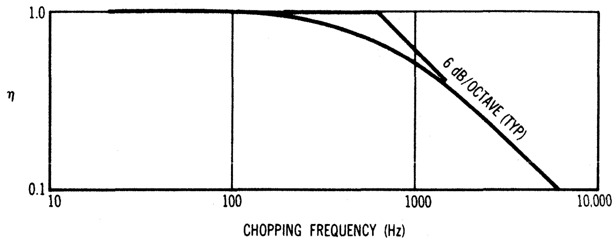


Figure 3. Typical η vs. frequency.

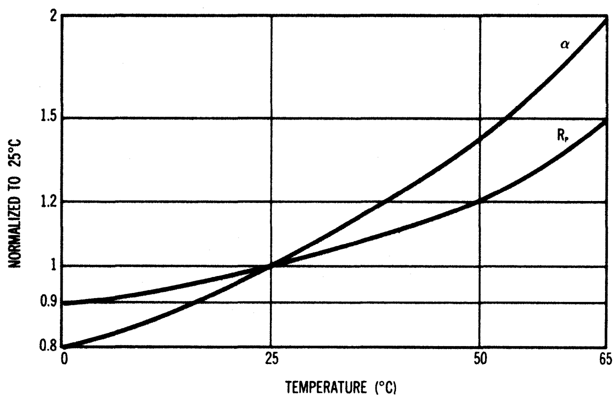


Figure 4. Typical variations of α and R_P (normalized to 1 at 25°C) vs. temperature.

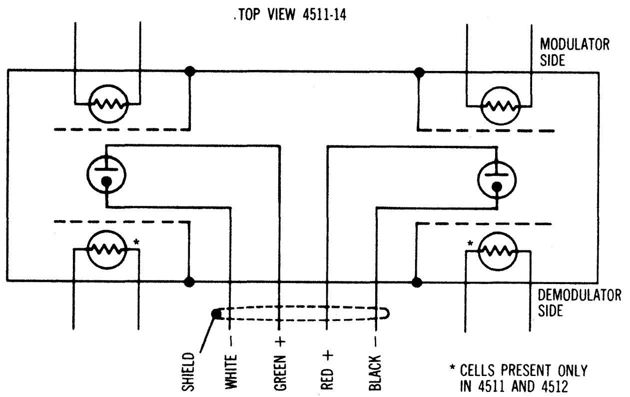


Figure 5. Schematic representation of photochoppers.

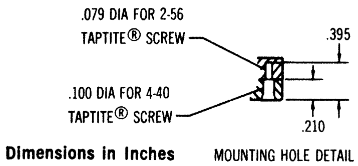


Figure 6. Mounting hole detail.

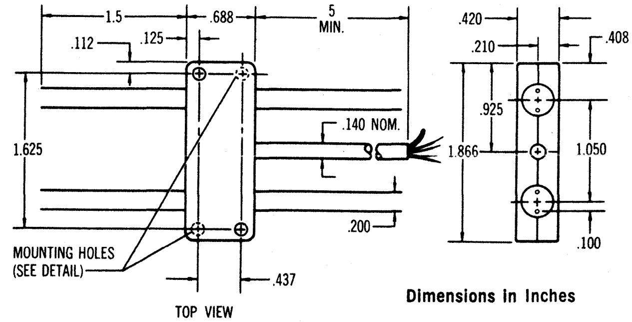


Figure 7. Mechanical outline and mounting information.

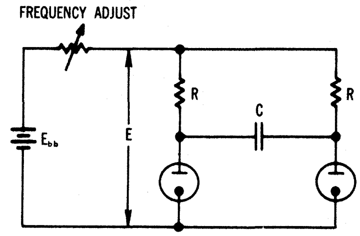


Figure 8. Two neon lamp relaxation oscillator drive.

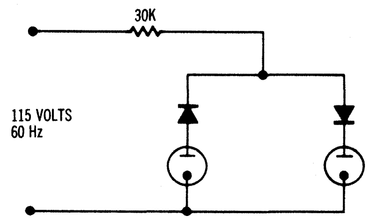


Figure 9. 60 Hz line drive.

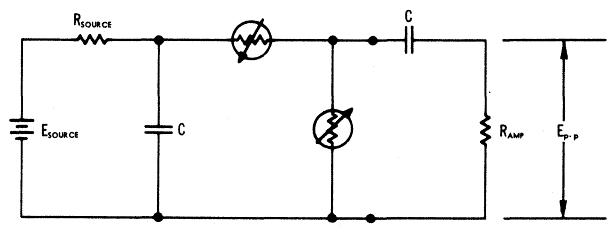


Figure 10. Schematic representation of modulator portion of chopper.

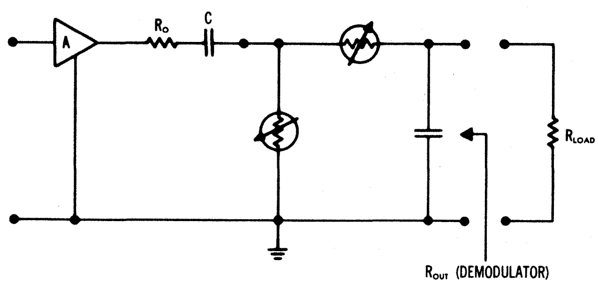
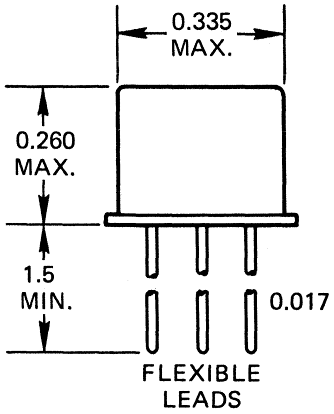


Figure 11. Schematic representation of demodulator portion of chopper.

HEWLETT hp PACKARD

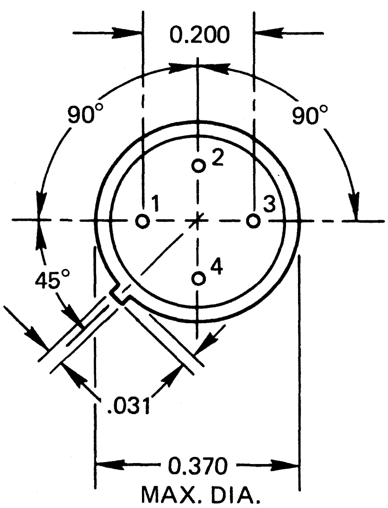
TO-5 PHOTOCELL/LAMP

HP 5082-4521 series



TERMINAL CONNECTIONS

LEADS 2 AND 4	LAMP
LEADS 1 AND 3	PHOTOCELL



LOW COST: $5.25 Each (In 1000 Quantity)

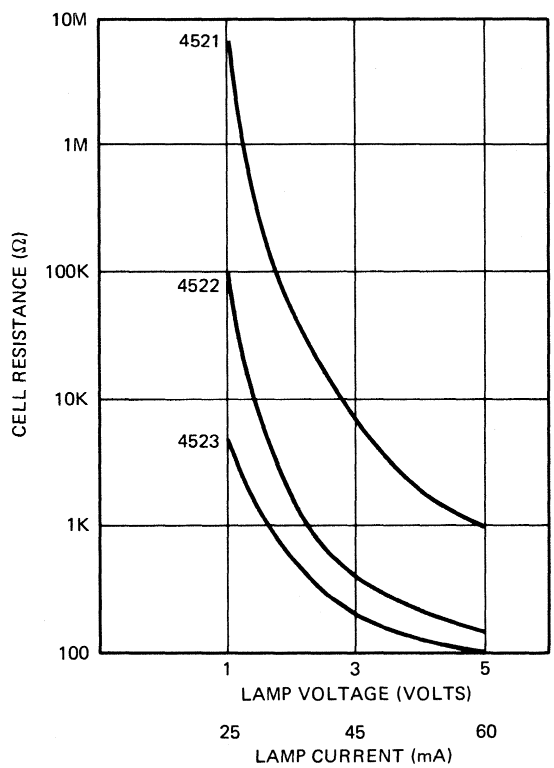
SMALL SIZE: Hermetic TO-5 Case Contains Lamp and Cell

MAXIMUM POWER: 100 mW at 25°C

TEMPERATURE RANGE: −50°C to +65°C

HP Type	Typical Cell Resistance at 5 V, 60 mA Lamp Drive	Minimum Off Resistance	Maximum Lamp Voltage	Maximum Peak Cell Voltage
5082-4521	1 kΩ	1000 MΩ	5 V	300 V
5082-4522	150 Ω	100 MΩ	5 V	250 V
5082-4523	100 Ω	10 MΩ	5 V	200 V

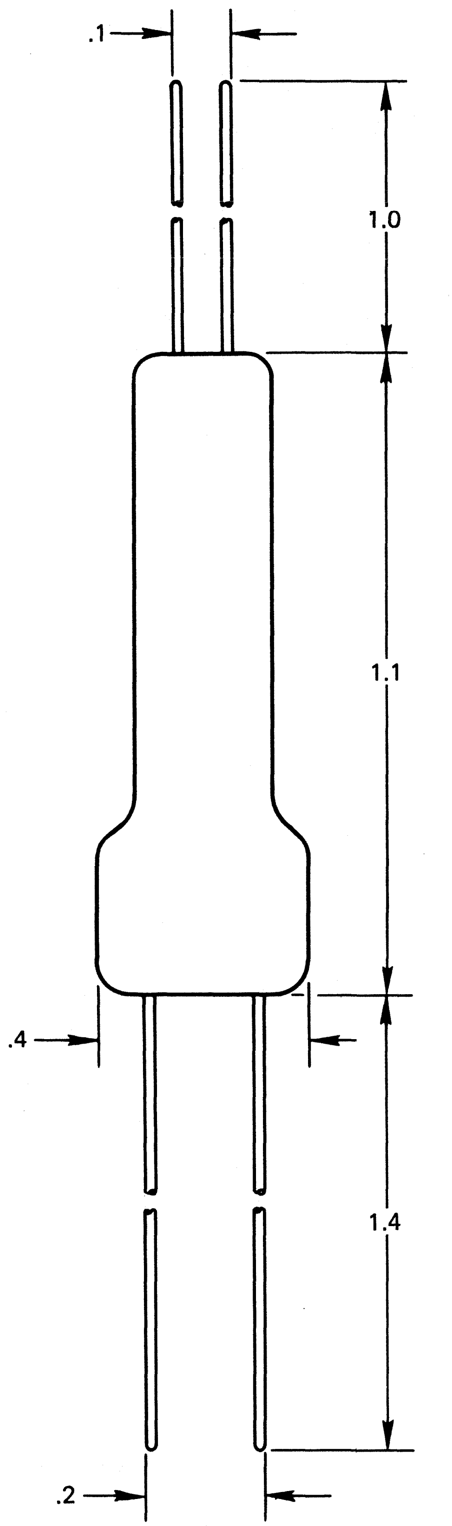
The HP 5082-4521, 4522, and 4523 each contains a photocell and a 5-volt lamp in a single TO-5 package. At 5 V maximum lamp drive, life expectancy is in excess of 100,000 hours.



HEWLETT hp PACKARD

AXIAL PHOTOCELL/LAMP

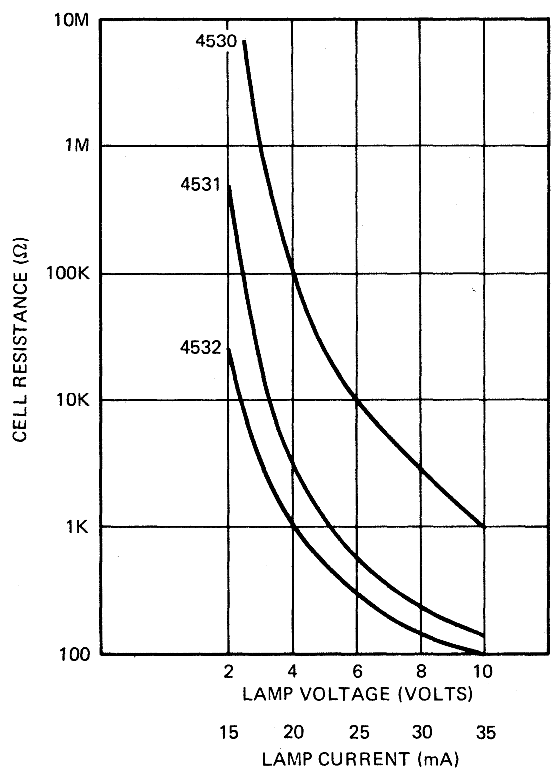
HP 5082-4530 series



LOW COST: $3.75 Each (In 1000 Quantity)
HERMETICALLY SEALED PHOTOCELL
AXIAL LEAD PACKAGE
MAXIMUM POWER: 125 mW at 25°C
TEMPERATURE RANGE: −50°C to +65°C

HP Type	Typical Cell Resistance at 10 V, 35 mA Lamp Drive	Minimum Off Resistance	Maximum Lamp Voltage	Maximum Peak Cell Voltage
5082-4530	1 kΩ	1000 MΩ	10 V	300 V
5082-4531	150 Ω	100 MΩ	10 V	250 V
5082-4532	100 Ω	10 MΩ	10 V	200 V

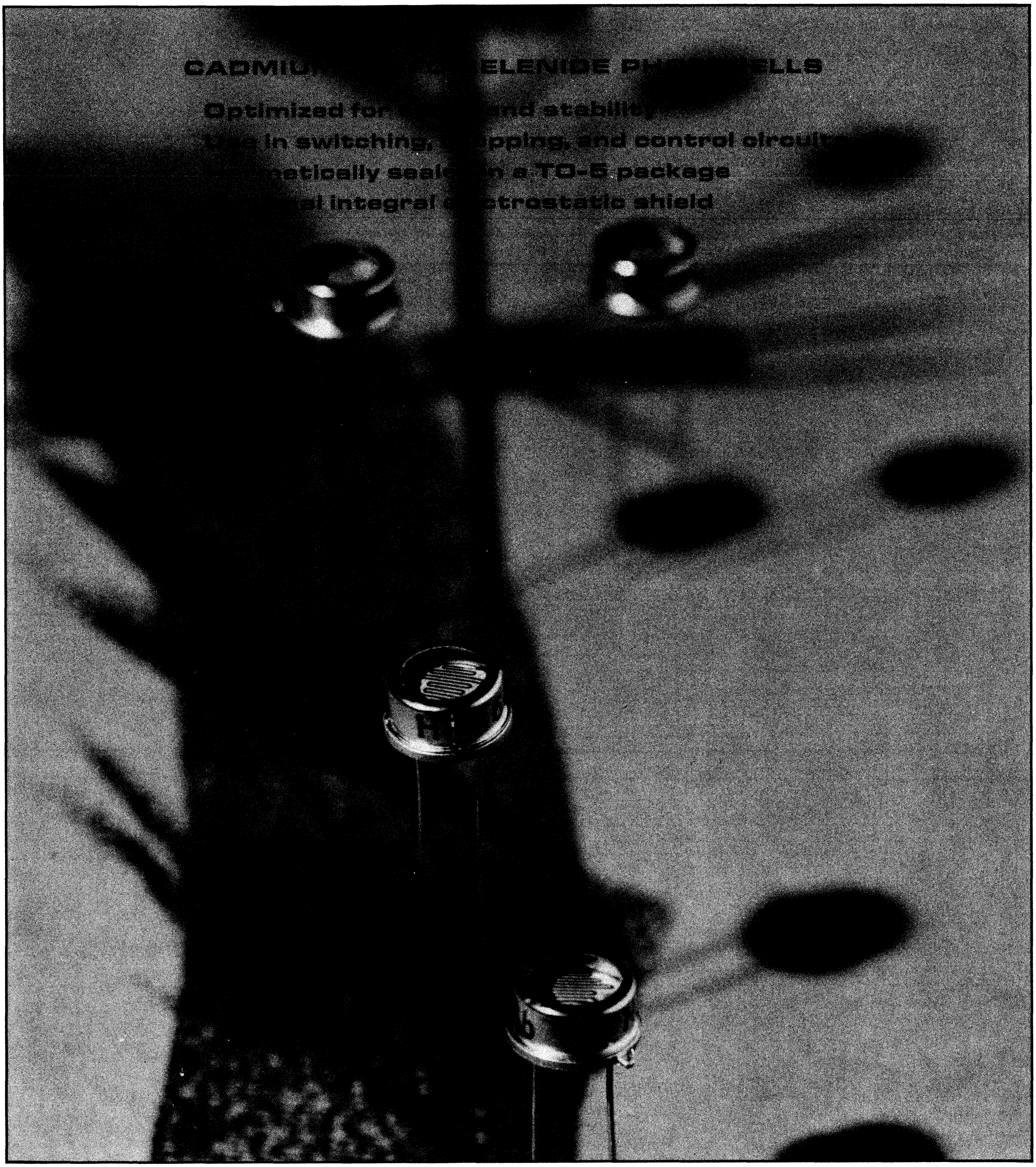
The HP 5082-4530, 4531, and 4532 each contains a photocell and a 10-volt lamp in a single axial lead package. At 10 V maximum lamp drive, life expectancy of the lamp is in excess of 40,000 hours.



HEWLETT PACKARD

PHOTOCELL

HP
5082-4600
series

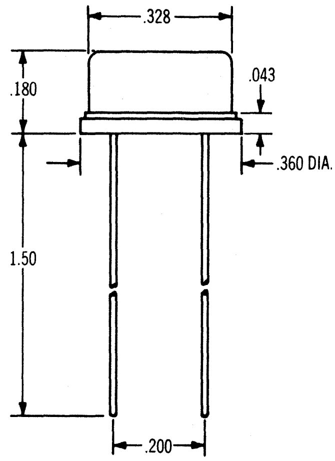


ELECTRICAL SPECIFICATIONS at 25°C (Note 1)

Type	R_{LIT} KΩ ± 50%	Electrostatic Shield	R_{DARK}	Decay Time (Note 2)
5082-4601	100			
-4602	4			
-4603	120	Contains Shield	100 MΩ Min.	1.2 msec typical
-4604	5	Contains Shield	500 MΩ Typical	2.0 msec maximum
-4606	10			
-4608	12	Contains Shield		

ELECTRICAL SPECIFICATIONS—All Types

Power Rating ....125 mW at 25°C (derated to 0 at 65°C)
Maximum Voltage ....Case to leads ± 200 V
Temperature Coefficient........1.5 typical, 2.0 max. (Note 3)
Maximum Operating Temp. Range.....................0 - 65°C
Peak Spectral Response ....6550 Å



DIMENSIONS IN INCHES

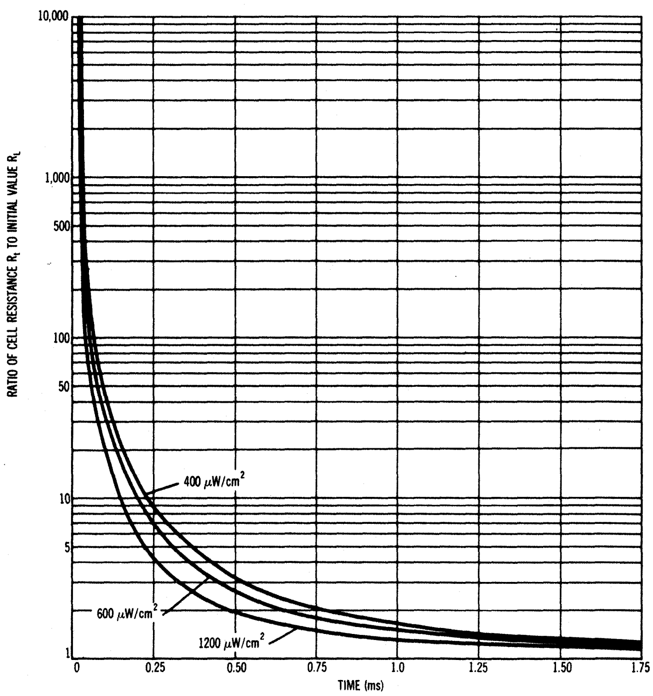


Figure 1. Typical cell turn-on characteristics at 25°C.

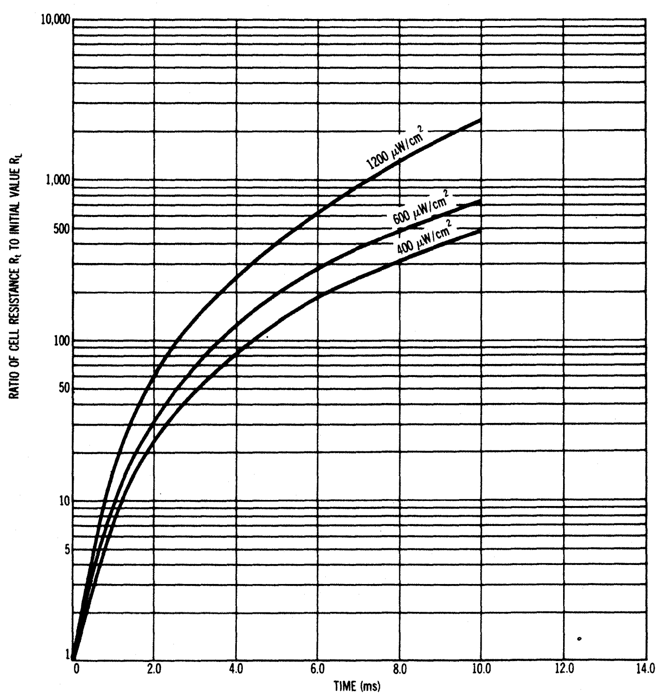


Figure 2. Typical cell turn-off characteristics at 25°C.

TABLE I—Typical Parameter Values in Figure 3

Type	5082-4601 -4603	5082-4602 -4604	5082-4606 -4608
R_{IN}	10 M	500 K	1 M
R_{OUT}	100 K	5 K	10 K
Eff.*	95%	97%	95%
Conditions:			
R_{LOAD}	1 MΩ	100 KΩ	100 KΩ
R_{SOURCE}	0	0	0

R_{IN} = time average modulator input impedance with a given load impedance

R_{OUT} = time average modulator output impedance with a given source impedance

$$\text{* Efficiency} = \frac{\text{Vp-p across } R_{LOAD}}{\text{dc Input Voltage}}$$

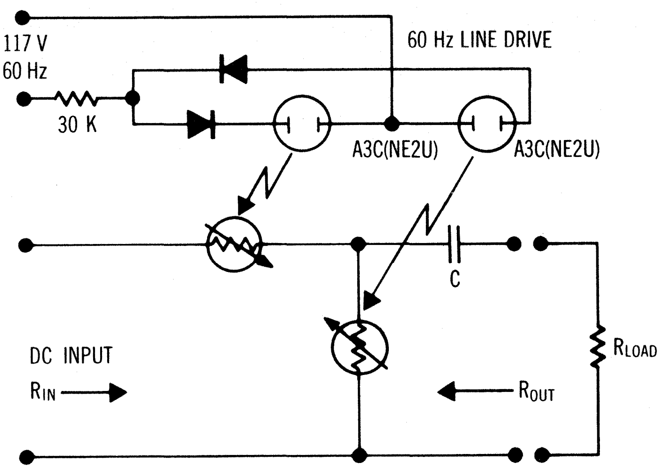


Figure 3. Typical 60 Hz line drive. Note light intensity is in excess of 600 μwatts/cm².

NOTES

1. Conditions prior to test: 2 hours minimum storage at 25°C in room light (approximately 80 fc).
   R_{LIT} measured at an irradiance of 600 μwatts/cm², $\lambda \approx$ 6500 Å.
   600 μwatts/cm² can be obtained by using a high brightness neon glow lamp, Type NE2U or equivalent, with approximately 1.5 mA of current. Cell-neon spacing, approximately 1/32 inch.
2. Decay time: time required for cell resistance to increase from R_{LIT} to 10 times R_{LIT}.
3. Temperature Coefficient $= \dfrac{R_{LIT} @ 65°C}{R_{LIT} @ 25°C}$.

HEWLETT hp PACKARD

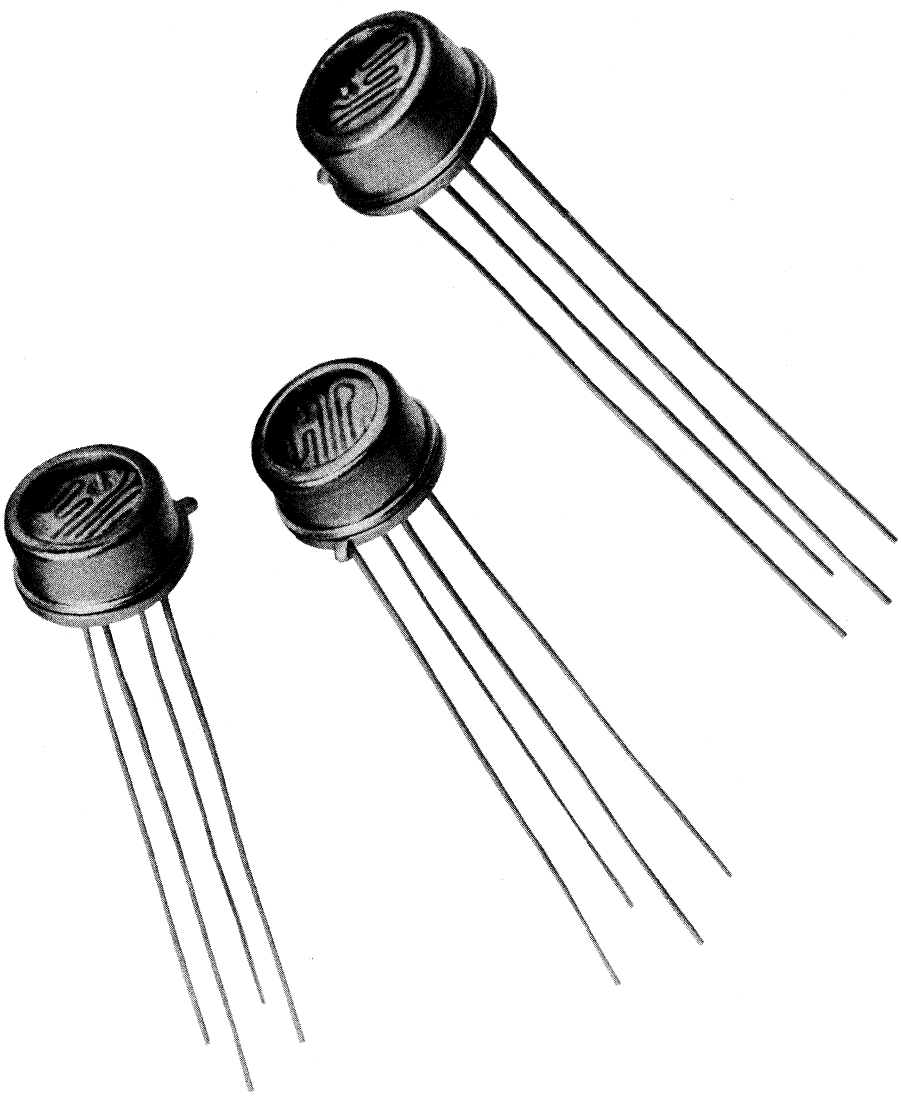
DUAL PHOTOCELL HP 5082-4610

CADMIUM SULFO-SELENIDE DUAL PHOTOCELLS

- Two completely independent and isolated photocells
- Hermetically sealed TO-5 package
- Integral electrostatic shield

OFFER WIDE RANGE OF APPLICATIONS

- Full wave photochoppers where offset, drift, and small size are important
- Control areas where tracking of two independent photocells with time, temperature, and light level are important



ELECTRICAL SPECIFICATIONS at 25°C (each cell)

R_{LIT} .... 15 K ± 50% (Note 1)
Resistance Balance .... 90% typical (Note 2)
R_{DARK} .... 100 MΩ minimum, 500 MΩ typical
Decay Time .... 0.7 msec typical, 1.5 msec max. (Notes 1 and 3)
Temperature coefficient .... 1.5 typical, 2.0 max. (Note 4)
Peak Spectral Response .... 6550 Å
Tracking (10 μW/cm² < H < 10,000 μW/cm²).... 5% typical (Note 5)

Capacitance (Note 6)	Typical	Maximum
Cell to Cell	1.2 pF	2.5 pF
Cell to Case	2.5 pF	5.0 pF
Cell Shunt	1.5 pF	3.0 pF

ABSOLUTE MAXIMUM RATINGS at 25°C (unless otherwise noted)

Power Dissipation .... 125 mW each cell (derate to 0 at 65°C) 250 mW total
Voltage, Case to Cell .... 200 volts
Cell to Cell .... 200 volts
Operating and Storage Temperature Range .... 0 - 65°C

NOTES

1. Conditions prior to test—2 hours minimum of room light (approximately 80 fc) storage at 25°C. R_{LIT} and decay time measured at an irradiance of 600 μwatts/cm² from neon source.
2. Resistance balance =
$$\frac{R_{LIT} \text{ of lower resistance cell}}{R_{LIT} \text{ of higher resistance cell}} \times 100\%.$$
3. Decay time—time required for cell resistance to increase from R_{LIT} to 10 R_{LIT}.
4. Temperature coefficient $= \dfrac{R_{LIT} \text{ at } 65°C}{R_{LIT} \text{ at } 25°C}$
5. Tracking is the percent error between Cell A and Cell B in each package.
$$\% \text{ Error (at 25°C)} = \left\{\left[\frac{R_a/R_b \text{ at } H}{R_a/R_b \text{ at } H_o}\right] - 1\right\} \times 100$$
6. Capacitance measurements made in the dark.

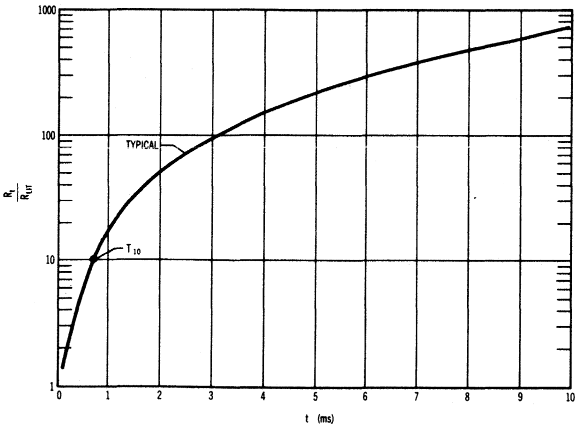


Figure 1. Response decay R_t/R_{LIT} vs. time.
R_{LIT} = lit resistance at H = 600 μW/cm², $\lambda = 0.65\ \mu$m
R_t = cell resistance at a time t after removal of illumination
R_t/R_{LIT} of Cell A in the package is typically within 15% of R_t/R_{LIT} of Cell B throughout the decay transient

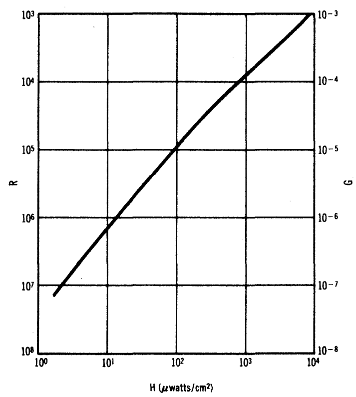
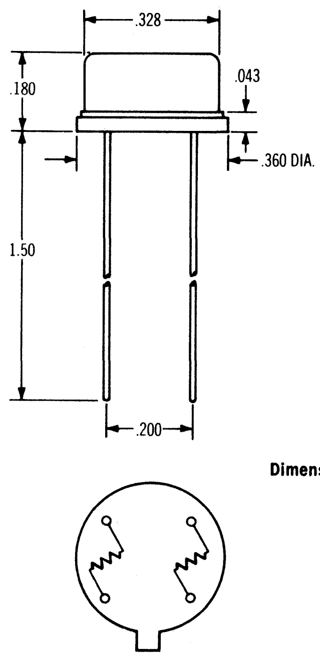


Figure 2. Resistance (R) and conductance (G) vs. irradiance (H) at $\lambda = 0.65\ \mu$m.

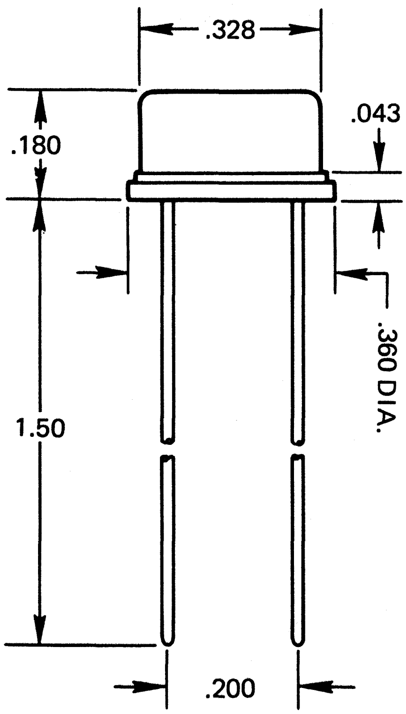


Dimensions in inches

HEWLETT PACKARD

TO-5 PHOTOCELL

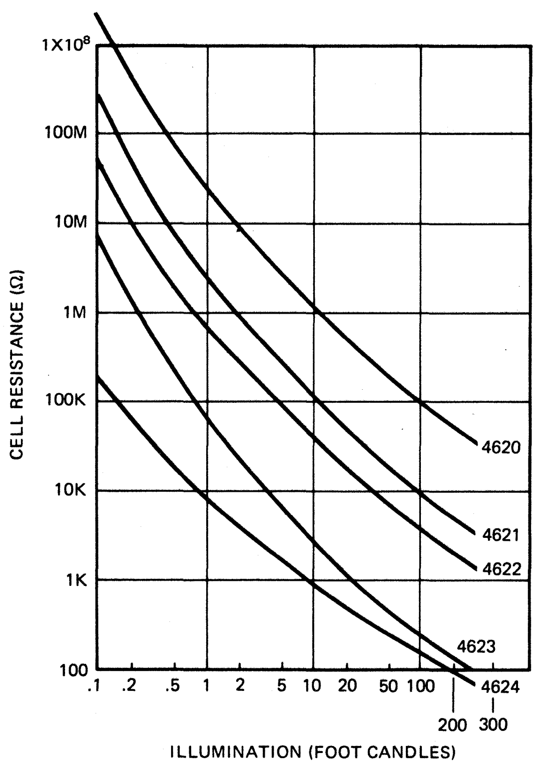
HP 5082-4620 series



LOW COST: $.89 Each (In 1000 Quantity)
HERMETICALLY SEALED TO-5 CASE
MAXIMUM POWER: 125 mW at 25°C
TEMPERATURE RANGE: −50°C to +65°C

HP Type	Resistance At 2 FC	Resistance At 100 FC[1]	Minimum Dark Resistance 5 sec After 2 FC	Maximum Peak Voltage	Peak Spectral Response
5082-4620	10 MΩ	100 kΩ	1000 MΩ	300 V	6550 Å
5082-4621	1 MΩ	10 kΩ	1000 MΩ	300 V	6550 Å
5082-4622	300 kΩ	4 kΩ	1000 MΩ	300 V	6550 Å
5082-4623	25 kΩ	225 Ω	100 MΩ	250 V	7250 Å
5082-4624	4 kΩ	150 Ω	10 MΩ	200 V	7250 Å

[1] Typical Resistance ±50%.
All measurements at 2854°K after 16 hours storage at 30 FC.

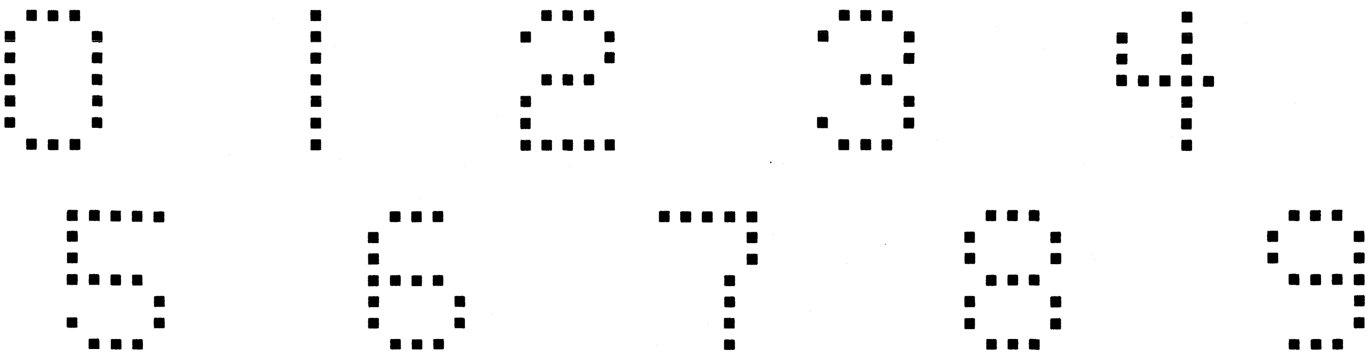


numeric displays

HEWLETT *hp* PACKARD

SOLID STATE NUMERIC INDICATOR

HP 5082-7000



The Hewlett-Packard Solid State Numeric Indicator is a rugged numeric display module providing solid state reliability for information presentation. Four input connections provide selection of the character set 0 through 9, using standard 8421 four-line negative logic BCD. A separate connection is provided to permit decimal point display from an external range switch. Character brightness is variable as a function of LED voltage over the range of 5 to > 50 footlamberts. Display power requirement is about ½ watt per character at the 50 fL brightness level.

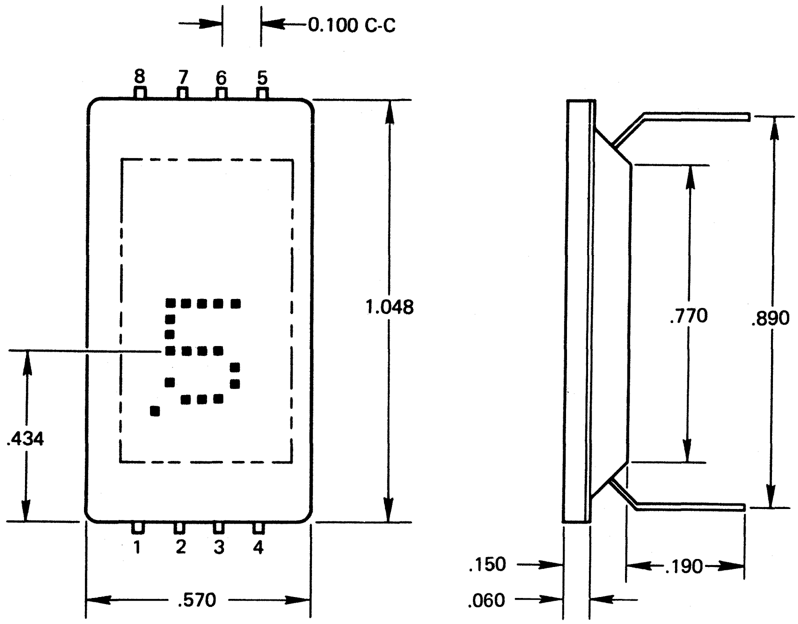
The small size of the module, with its self-contained switching logic, permits use where space is at a premium. The 0.25-inch high character is easily read at 8 feet and the Lambertian light-emitting surface provides extremely wide viewing angles (> 60° from the normal) with constant brightness independent of viewing angle.

DESCRIPTION

Power Supply: All power and logic inputs referred to common (ground).
IC Logic (Specified Voltage) ....5 V dc at 25 mA (typical)
LED (Light Emitting Diodes)
Specified Voltage ....1.6 to 4 V at 0 to 250 mA (typical)
Power Dissipation at 50 fL ....500 mW
Storage Temperature ....−55° to +85°C

TYPICAL CHARACTERISTICS

Peak Wavelength ....655 nm
Spectral Line Half Width ....30 nm
Character Response Time ("on" or "off") ....< 1 μsec



PIN
1 LOGIC 1
2 DECIMAL POINT
3 LED +
4 LOGIC 8
5 LOGIC 4
6 GROUND
7 LOGIC + (5VDC)
8 LOGIC 2

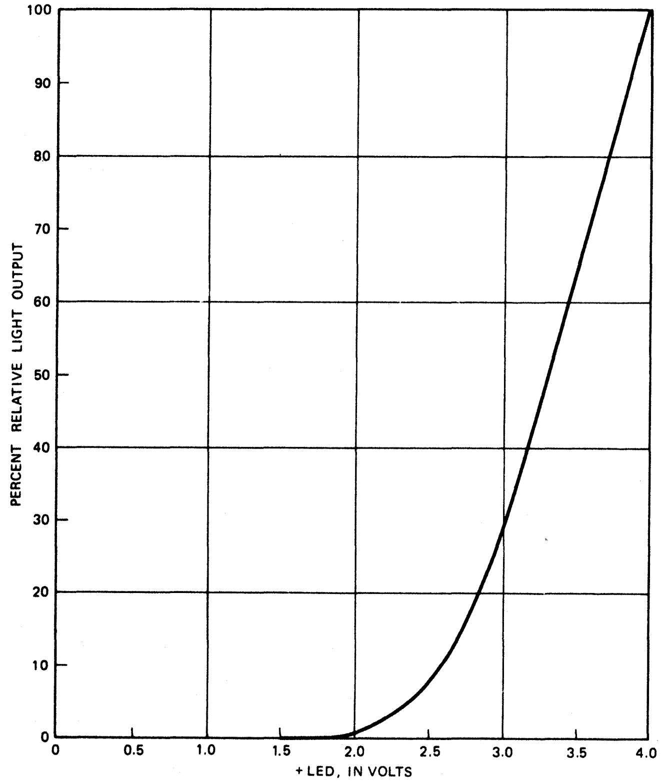


Figure 1. Brightness vs. LED voltage.

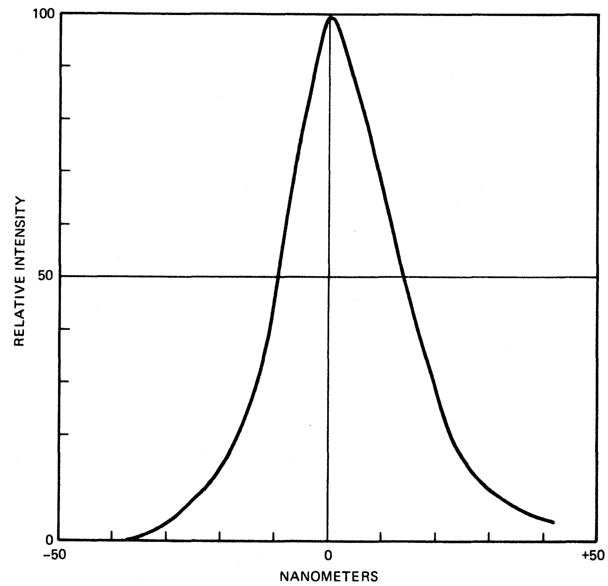


Figure 2. Light emitting diode brightness vs. header temperature at fixed current level.

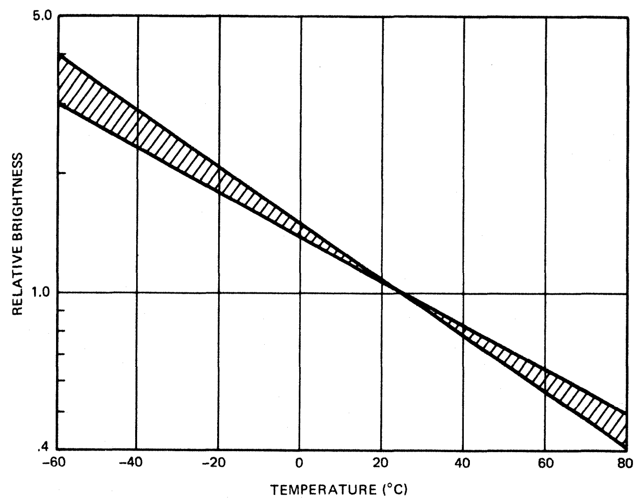


Figure 3. Spectral bandwidth of electroluminescent emission.

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