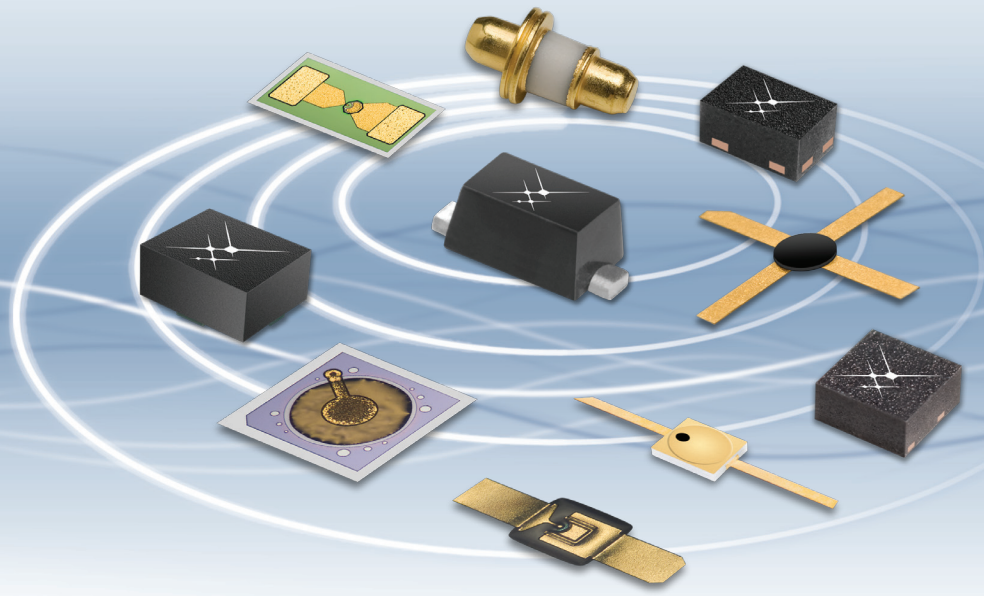
SKYWORKS®

BREAKTHROUGH SIMPLICITY®





RF Diode Design Guide

Skyworks Solutions

Skyworks Solutions, Inc. is an innovator of high reliability analog and mixed signal semiconductors. Leveraging core technologies, Skyworks offers diverse standard and custom linear products supporting automotive, broadband, cellular infrastructure, energy management, industrial, medical, military and mobile handset applications. The Company's portfolio includes amplifiers, attenuators, detectors, diodes, directional couplers, front-end modules, hybrids, infrastructure RF subsystems, mixers/demodulators, phase shifters, PLLs/synthesizers/VCOs, power dividers/combiners, receivers, switches and technical ceramics.

Headquartered in Woburn, Massachusetts, USA, Skyworks is worldwide with engineering, manufacturing, sales and service facilities throughout Asia, Europe and North America.

New products are continually being introduced at Skyworks. For the latest information, visit our Web site at **www.skyworksinc.com**. For additional information, please contact your local sales office or email us at **sales@skyworksinc.com**.

The Skyworks Advantage

- Broad front-end module and precision analog product portfolio
- Market leadership in key product segments
- Solutions for all air interface standards, including CDMA2000, GSM/GPRS/EDGE, LTE, WCDMA and WLAN
- Engagements with a diverse set of top-tier customers
- Analog, RF and mixed-signal design capabilities
- Access to all key process technologies: GaAs HBT, PHEMT, BiCMOS, SiGe, CMOS, RF CMOS and Silicon
- World-class manufacturing capabilities and scale
- Unparalleled level of customer service and technical support
- Commitment to technology innovation












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About This Guide

Proven Performance and Leadership

As a world-class supplier of RF microwave components for today's wireless communication systems, Skyworks continues to deliver the highest performance silicon and GaAs discrete products. Building on a proven legacy (which includes products developed at Alpha Industries prior to its merger with Conexant's Wireless Division to become Skyworks), these innovative solutions are manufactured using the most advanced processes, driven by decades of experience and industry leadership.

With market demands constantly changing, Skyworks is committed to expanding its microwave portfolio to meet a wider range of applications including radar, point-to-point, point-to-multipoint, cellular, military, space-based communications, and other wireless microwave functions. As always, all of our solutions are backed by world-class customer service, advanced manufacturing capabilities and leadership technology.

The Right Design Choice Starts Here

We invite you to review our complete catalog of packaged and unpackaged semiconductor diodes for specific RF and microwave applications. Products include silicon varactors, PIN, Schottky and GaAs Schottky diodes. Design engineers will find this guide especially useful in finding the key specifications for Skyworks' semiconductor products to easily select appropriate part numbers.

New products are continually being introduced at Skyworks. For the latest information, visit our Web site at **www.skyworksinc.com.** For additional information, please contact your local sales office or email us at **sales@skyworksinc.com.**

Innovation to Go™
Select products and sample/designer kits available for purchase online. **www.skyworksinc.com**

Skyworks lead (Pb)-free products are compliant to all applicable materials legislation. For additional information, refer to *Skyworks Definition of Lead (Pb)-Free*, document number SQ04-0073. Tin/lead (SnPb) packaging is not recommended for new designs.

Skyworks Green™ products are compliant to all applicable materials legislation and are halogen-free. For additional information, refer to *Skyworks Definition of Green™*, document number SQ04-0074.

Diode Product Portfolio Overview

Building on a proven legacy (including products developed at Alpha Industries prior to its merger with Conexant's Wireless Division to become Skyworks), our product portfolio includes PIN, Schottky, varactor and limiter diodes for a wide variety of microwave applications including WLAN, infrastructure, handset, SatCom (LNB/DBS-CATV), automotive, military, test and measurement, metering, medical, and RFID. Our discrete silicon and GaAs semiconductors are available as die, plastic packaged, surface mount technology (SMT) and ceramic hermetic packaged devices. Frequency ranges include HF, VHF, UHF, L, S, C, X, Ku, K, and Ka bands. Skyworks' diode products are manufactured using the most advanced processes and leadership technology. Table 1 shows diode solutions for market and application designs.

 Select Diodes Available from Stock for Prototype or High-Volume Production

Limiter Diodes—Core components for receiver protection applications

- Plastic Surface Mount Technology (SMT) Limiter Diodes
- Hermetic Ceramic Limiter Diodes
- Limiter Diode Chips

PIN Diodes—Superior building blocks for switch and attenuator applications

Switching Silicon PIN Diodes

- Plastic Surface Mount Technology (SMT) PIN Diodes
- Hermetic Ceramic PIN Diodes

PIN Diode Chips

- PIN Diode Wafers on Film Frame
- Beam-Lead PIN Diodes

Attenuator PIN Diodes

- Plastic Surface Mount Technology (SMT) PIN Diodes
- Hermetic Ceramic PIN Diodes
- PIN Diode Chips
- PIN Diode Wafers on Film Frame

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Visit our Web site for more information about our broad diode product offering.

Diode Products

Schottky Diodes—Designed for high-performance, high-volume and cost-sensitive mixer and detector applications

- Plastic Surface Mount Technology (SMT) Schottky Diodes
- Micro Surface Mount Silicon Schottky Mixer and Detector Diodes
- Hermetic Ceramic Schottky Diodes
- Schottky Diode Chips
- Schottky Diode Wafers on Film Frame
- GaAs Flip Chip Schottky Diodes
- Chip On Board Schottky Diodes
- Beam-Lead Schottky Diodes
- Beamless Schottky Diodes
- Epoxy Octo Ring Quad Schottky Diodes

Varactor Diodes—Ideal for VCO, VCXO, voltage controlled filters and phase shifter products

High Quality Factor (Abrupt) Varactor Diodes

- Plastic Surface Mount Technology (SMT) Abrupt Varactor Diodes
- Hermetic Ceramic Abrupt Varactor Diodes
- Abrupt Varactor Diode Chips

Wide Tuning Range (Hyperabrupt) Varactor Diodes

- Plastic Surface Mount Technology (SMT) Hyperabrupt Varactor Diodes
- Hermetic Ceramic Hyperabrupt Varactor Diodes
- Hyperabrupt Varactor Diode Chips

Table 1. Diode Solutions for Your Market and Application Designs

Market	Receiver Protector	Mixers	Frequency Control	Variable RF Filtering	Gain/Level Control	Switching	Detectors
Handset						•	•
Infrastructure	•	•	•	•	•	•	•
Automotive	•	•	•	•	•	•	•
CATV / Satcom		•	•		•	•	•
Smart Energy Solutions	•	•	•	•	•	•	•
Medical	•	•	•	•	•	•	•
Military	•	•	•	•	•	•	•
RFID	•	•	•		•	•	•
Test and Measurement	•	•	•	•	•	•	•
WLAN / WiMAX / WiFi						•	•

The Radio Transceiver

The radio transceiver block diagram, shown in Figure 1 in this design guide, represents the design approach that is taken for many different end uses, including cellular telephone base stations, land mobile radios, electronic countermeasure systems, portable two-way communications systems, avionics systems and more. There are many possible modifications to this block diagram; the system depicted below is meant to illustrate the components that may be in a radio.

The paragraphs that follow address each of the major sections of this transceiver which contains RF/microwave diodes. Simply locate the major component to be designed in this block diagram, turn to the page which covers the subsystem in greater detail, and discover the best Skyworks product(s) for your application.

The transceiver shown consists of two main subsystems: the transmitter and the receiver.

Learn More

The transceiver block diagram above represents multiple applications. Additional block diagrams are available on our Web site.

Block Diagrams

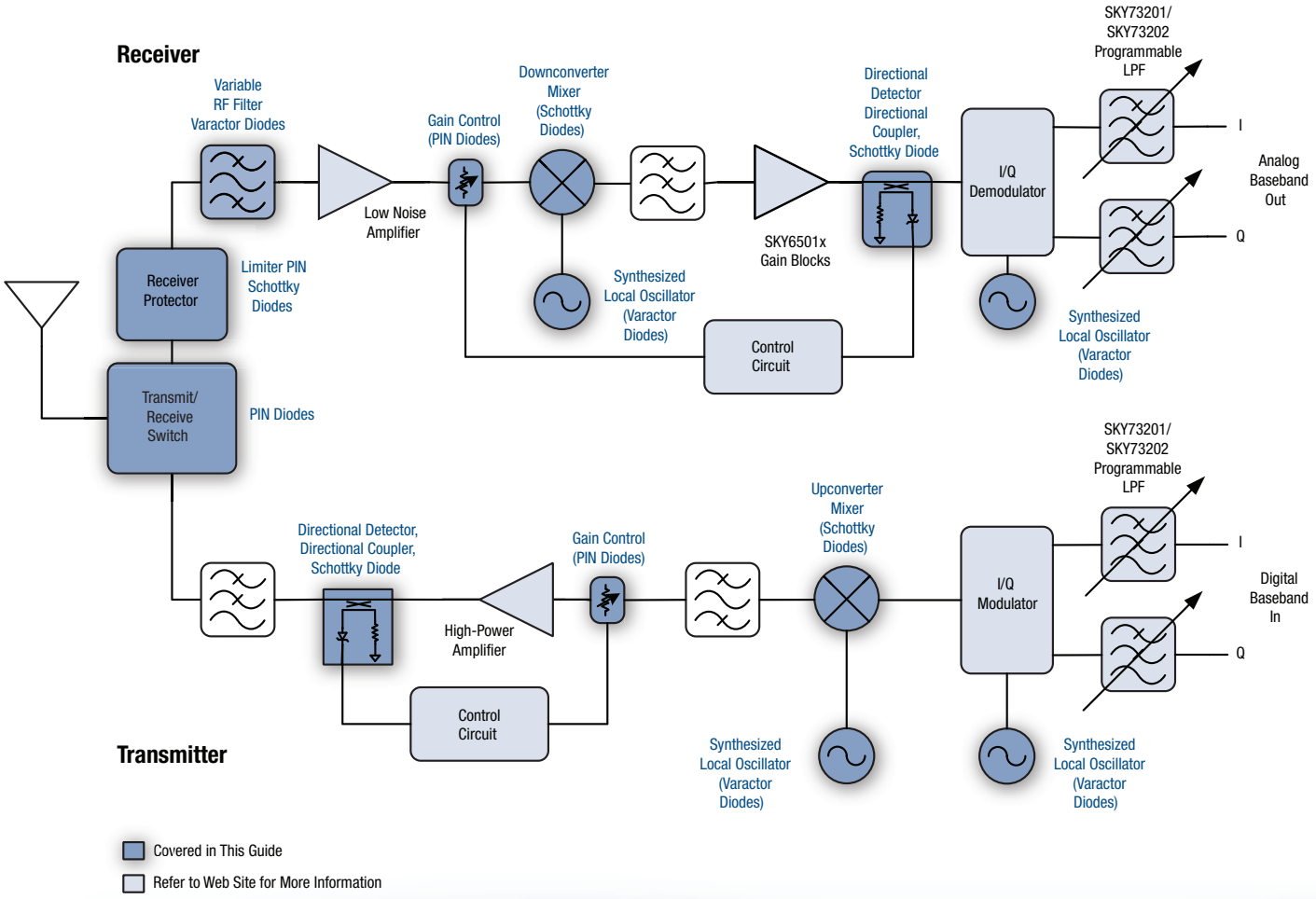


Figure 1. Radio Transceiver Block Diagram

The Transmitter

The transmitter processes and converts analog baseband signals to a higher frequency, analog signal which is radiated from the system antenna. A typical transmitter consists of low pass baseband antialiasing filters, an I/Q modulator, possibly an upconverter frequency mixer, a power amplifier subsystem and filtering. The power amplifier subsystem typically is comprised of a power amplifier, some means of measuring the output power of the power amplifier and a variable attenuator at the input of the power amplifier stages which is utilized to control the output power of the power amplifier subsystem.

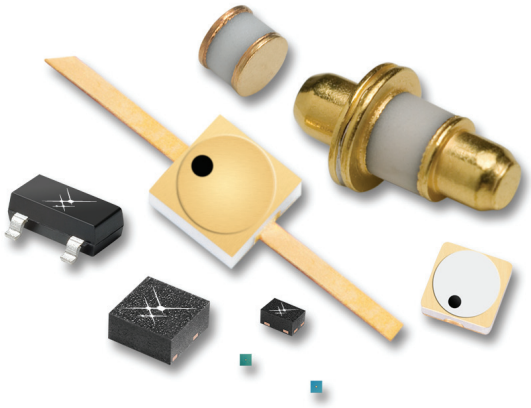
The Receiver

The receiver's function is the converse of the transmitter's function: a high-frequency signal is transduced by the antenna from electromagnetic energy propagated through free space to a voltage/current waveform. This signal is optionally applied to a receiver protector circuit, the output of which is filtered and applied to a low noise amplifier stage. The output of the low noise amplifier is applied to a variable attenuator which attenuates the amplitude of the signal under the control of a level detector which is downstream of the attenuator, to prevent overdriving the next stage, which is typically a downconverter frequency mixer. The low-frequency output of the mixer, often called the intermediate frequency, is selected by a filter and then amplified. The output of the amplifier is measured by a detector circuit, which controls the attenuator described above in order to maintain the optimum input signal level for the I/Q demodulator. The outputs of the I/Q demodulator are low pass filtered and then available to be digitized in a pair of analog-to-digital converters to produce the digital baseband output signals.

Both the transmitter and the receiver signal chains employ local oscillators which produce stable, low noise signals used as the reference frequency for frequency conversion, modulation or demodulation.

In this transceiver, the transmitter and receiver sections are connected to the common antenna via a switch, known as the transmit/receive or T/R switch. This function is typically utilized when the transmitter and the receiver operate at the same frequency. A three-port ferrite device known as a circulator may also be used in this position. If the transmit and receive frequencies are sufficiently different, this switch may be replaced with a filter structure known as a diplexer.

Receiver Protector



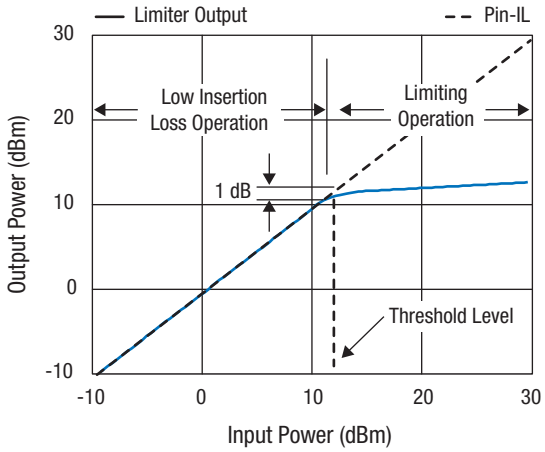


Figure 2. Output Power vs. Input Power for Single-Stage Limiter

The receiver protector function is performed by a specially processed PIN diode, known as a limiter diode. The PIN limiter diode can be described as an incident-power-controlled, variable resistor. In the case when no large input signal is present, the impedance of the limiter diode is at its maximum, thereby producing minimum insertion loss, typically less than 0.5 dB. The presence of a large input signal temporarily forces the impedance of the diode to a much lower value, producing an impedance mismatch which reflects the majority of the input signal power back towards its source.

The input power level at which the limiter diode's impedance starts to decrease in response to a large input signal amplitude is primarily determined by the diode's I layer thickness. The diodes which "turn on" at the lowest signal levels have the thinnest I layers. For example, the output power vs. input power characteristic for a very thin diode is shown in Figure 2. The function of limiter diodes in receiver protection circuits is shown in Figure 3. Table 2 shows Skyworks' limiter diode product offering.

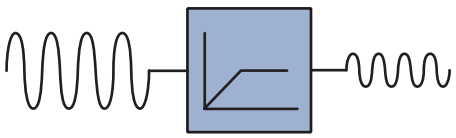


Figure 3. Limiter Diodes in Receiver Protectors Prevent Damage from Large Signals to Sensitive Receiver Components

Table 2. Limiter Diode Selection

Threshold Level (dBm)	I Layer Thickness (µm)	Insertion Loss at -10 dBm & 10 GHz (dB)	Maximum Series Resistance at 10 mA and 1 GHz (Ω)	Maximum Junction Capacitance (pF)	Maximum CW Input Power (dBm)	Maximum Peak Input Power (dBm)	Part Number
7	1	0.1	2.5	0.10	33	47	CLA4601
7	1	0.1	2	0.15	34.8	50	CLA4602
10	1.5	0.1	2	0.15	33	50	CLA4603
10	1.5	0.35 @ 1 GHz	1.5	1.0 (total)	30	50	SMP1330 (packaged only)
12	2	0.1	2.5	0.10	34.8	47	CLA4604
12	2	0.1	2	0.15	36	50	CLA4605
15	2.5	0.1	2	0.15	34.8	53	CLA4606
20	7	0.1	2	0.15	37.8	60	CLA4607
20	7	0.2	1.2	0.5	41.7	66	CLA4608
38	28	0.3	1.5	0.14	43	70	CLA4609

The circuit design for a single-stage limiter is shown in Figure 4. With a small input signal present, the diode presents a very large shunt impedance to the transmission line, so it produces very little insertion loss. The inductance of the RF choke is selected to also produce a very large shunt impedance. As the input signal gets larger, it forces charge carriers into the I layer of the diode, which reduces the diode's impedance. This reduction in impedance produces an impedance mismatch at the diode which reflects some portion of the input signal power.

This diode's impedance begins to decrease with only 10 mW incident power. Its impedance is sufficiently decreased to produce 1 dB of excess insertion loss at approximately 12 dBm. This level is known as its threshold level.

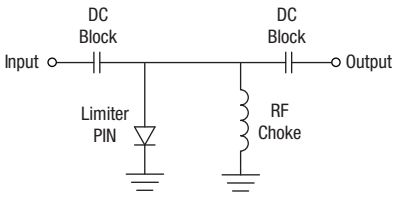


Figure 4. Typical Single-Stage Limiter Circuit

With a small incident signal, the diode appears to be a capacitive reactance in parallel with a large resistance. The values of these two components are determined by the physical design of the die. The major effect of the presence of these components in shunt with the transmission line is to increase small signal insertion loss.

When a large signal, larger in magnitude than the threshold level, is present the resistance of the equivalent circuit is significantly reduced and is forced to approach the minimum value. This minimum value of resistance is also determined by the physical design of the diode. The minimum value of resistance determines the maximum insertion loss, also known as isolation, that the diode can produce. Depending on signal frequency and the specific characteristics of the diode, isolation of 15 to 30 dB can be expected from a single stage.

Limiter diodes of different I layer thicknesses may be cascaded in order to produce a receiver protector that can withstand very large input power while allowing low flat leakage output power, as shown in Figure 5, typical two stage limiter circuit.

Limiter diodes are available as dice or in several package styles.

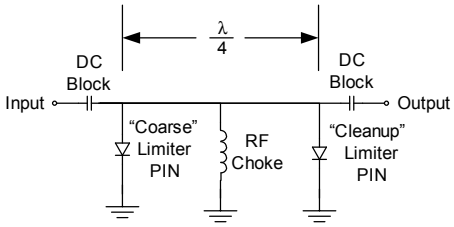


Figure 5. Multistage Limiter Circuit

Variable RF Filtering

Radio receiver systems must operate in environments high in electronic noise, so a bandpass filter is typically placed very near the receiver input.

This filter may simply reject out-of-band energy, such as broadband noise or blocking signals, but in some cases these filters are frequency-agile in order to improve receiver selectivity.

There are several ways to design a frequency-agile, electronically adjustable filter, including the use of tuning varactor (TVAR) diodes which are used to vary the resonant frequency of resonant structures comprising the filter under the control of an externally produced tuning voltage. Figure 6 shows a voltage tuned filter.

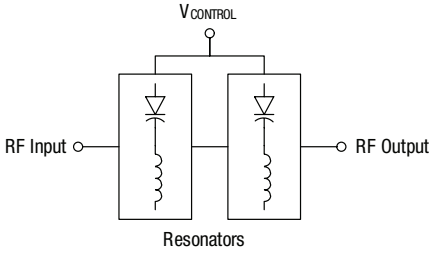


Figure 6. Voltage Tuned Filter

Learn More

Please refer to the "Local Oscillator" section of this guide for more information on the selection of tuning varactor diodes.

Mixers

Frequency conversion circuits are present in many receiver and transmitter architectures. The frequency mixer comprises one or more nonlinear impedance elements which are used to multiply a signal of interest by a reference signal, commonly known as the local oscillator (LO) signal, to produce signals at new frequencies. These frequencies include the sum of the signal of interest and the LO signal to produce an upconverted signal, and the difference of the LO signal and the signal of interest, producing a down-converted signal. Upconversion is generally used in transmit architectures while downconversion is generally found in receivers.

Schottky diodes produce a nonlinear relationship between current and voltage, that is, they present a nonlinear impedance. They can be used in several different circuit topologies as frequency up- or downconverters.

There are several categories of frequency mixer circuits. Some of the most commonly found mixer circuits are the doubly balanced mixer, the singly balanced mixer, the single-ended mixer and the subharmonic mixer. Each of these types of mixers may be found in a downconverter or in an upconverter. Some of the properties of these topologies are listed in Table 3.

There are several types of Schottky mixer diodes available. Silicon (Si) Schottky mixer diodes are available with low, medium and high barrier heights. Lower barrier heights are sensitive to lower power signals and typically require smaller LO power, while higher barrier heights can handle larger signals and typically produce less harmonic and intermodulation distortion. Consequently, downconverter mixers in receivers generally contain low or medium barrier Schottky diodes, while upconverters in transmitters contain medium- or high-barrier Schottky diodes.

Gallium arsenide (GaAs) Schottky diodes are similar in most respects to Si high-barrier Schottky diodes, with the exception that the higher carrier mobility of GaAs permits GaAs Schottky diodes to be used at much higher frequencies. Table 4 shows mixer topologies. Table 5 shows the LO drive level.

Learn More

Application Note
Mixer and Detector Diodes, document 200826

Mixer Products
Mixers may be comprised of Schottky diodes, field effect transistors or bipolar transistors. Additional information is available on our Web site.

Table 3. Mixer Types

Isolation LO to RF	Isolation LO to IF	Isolation RF to IF	LO Drive Level	Mixer Topology
High	High	High	High	Doubly-balanced
Moderate	Moderate	Moderate	Moderate	Singly-balanced
Low	Low	Low	Low	Single-ended
Low	Low	Low	Moderate to high	Subharmonic

Table 4. Mixer Topologies

Some typical circuits for each mixer topology are shown below.

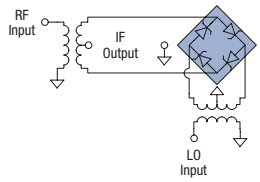
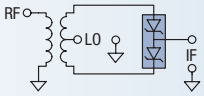
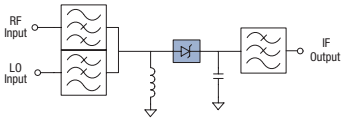
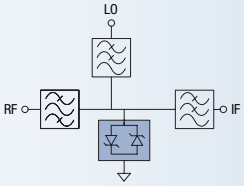
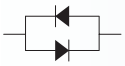
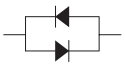
Topology	Typical, Simplified Schematic	Diode Configuration
Doubly Balanced		Ring Quad, Crossover Ring Quad, Dual Ring Quad
Singly Balanced		Series Tee, Reverse Series Tee
Single-Ended		Single
Subharmonic		Antiparallel Pair

Table 5. LO Drive Level

The LO drive power required for a mixer to function properly depends on the number of diodes in the mixer and their barrier height. These relationships are shown in the table below.

Configuration	Typical LO Drive Power Range (dBm)	Barrier Height	Base Part Number
Si Ring Quad 	10–14	Low	SMS3929, DMF3942, DMF3926
	13–20	Medium	SMS3930, DME3943, DME3927
	17–23	High	SMS3931, DMJ3944, DMJ3947, DMJ3937, DMJ3928
Si Crossover Ring Quad 	10–14	Low	SMS3926
	13–20	Medium	SMS3927
	17–23	High	SMS3928
Si Dual Ring Quad, Octoquad 	13–17	Low	DMF3938
	16–23	Medium	DME3939
	20–27	High	DMJ3940, SMS3940, DMJ3934
Si Crossover Dual Ring Quad 	13–17	Low	DMF3945
	16–23	Medium	DME3946
	20–27	High	SMS3940, DMJ3934
Si Series Tee, Reverse Series Tee 	0–6	Low	DMF3932, SMS1546
	3–10	Medium	DME3933
	7–13	High	Contact Factory
Si Single 	-3–3	Low	SMS7621
	0–6	Medium	Contact Factory
	6–13	High	Contact Factory
GaAs Single 	6–13	n/a	DMK2790
Si Antiparallel Pair 	10–16	Low	DMF2185, DMF2186, DMF2187
	13–20	Medium	DME2282, DME2283, DME2284, DME2838
	20–27	High	DMJ2303, DMJ2304, DMJ2246, DMJ2839
GaAs Antiparallel Pair 	20–27	n/a	DMK2308

Local Oscillator

Signal generation is required in modern radios and similar applications. Often, the frequency of the required signals must be electronically tunable as shown in the typical voltage controlled oscillator in Figure 7, whether to enable frequency agile systems or to enable very precise control of signal frequency and phase. The variable reactance most often used to permit this tunability is the voltage variable capacitance diode, known as the tuning varactor (TVAR) diode.

Tuning varactor diodes are processed so that the thickness of their depletion regions varies in a precise manner vs. reverse bias voltage, V_R. As V_R becomes larger, the depletion layer of the diode becomes thicker, thus reducing its junction capacitance. This characteristic is described by

$$C_J(V_R) = \frac{C_J(V_{reference})}{\left(\frac{V_R + \phi}{V_{reference} + \phi}\right)^{\gamma}}$$

where

$C_J(V_R)$ = Junction capacitance of the TVAR die at reverse bias voltage V_R

$C_J(V_{reference})$ = Junction capacitance of the TVAR die at an arbitrarily selected reference reverse bias voltage, $V_{reference}$

ϕ = Junction contact potential = 0.7 V for Si

γ = Capacitance slope exponent

The range of variation of a TVAR's junction capacitance is typically described by the ratio of capacitance measured at a small V_R and that measured at a larger V_R.

There are two general classes of TVARs: abrupt junction and hyperabrupt junction. The construction of the diode's cathode layers determines the category into which a diode falls and it determines the value of γ: abrupt junction varactors have $\gamma \leq 0.5$; and, γ is greater than 0.5 for hyperabrupt diodes. In addition, for abrupt junction diodes γ is constant with respect to reverse bias voltage. For Si hyperabrupt TVARs, γ varies vs. reverse bias voltage. Capacitance vs. reverse voltage plus contact potential for a hyperabrupt and an abrupt junction are shown in Figure 8.

The bandwidth capability of TVAR is determined by its capacitance range, which is often characterized by one or more ratios between capacitance at a low reverse voltage to capacitance at higher reverse voltages. At the upper limit, bandwidth (expressed as a ratio) is no greater than the square root of the capacitance ratio. In most circuit applications that contain fixed capacitances, bandwidth could be substantially less than this value. Unfortunately, there are no standard bias reverse voltages so comparing one TVAR against another can be tricky. Generally speaking, an abrupt junction device can produce a capacitance ratio of approximately 3:1 over the tuning voltage range 0 V to 30 V. Many hyperabrupt diodes can produce capacitance ratios of 10:1 or greater over the tuning voltage range of 0 V to 10 V.

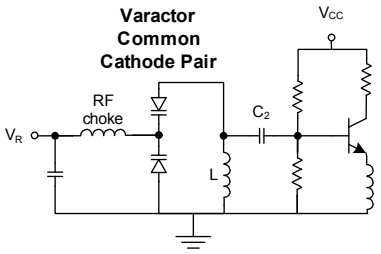


Figure 7. Voltage Controlled Oscillator

In hyperabrupt TVARs, there is an artifact of the ability to produce large capacitance ratios: larger series resistance. Some hyperabrupt tuning varactors might produce 3 Ω or 4 Ω series resistance, compared to 0.5 Ω or less for an abrupt junction device. This larger series resistance means that the wide bandwidth capability of the hyperabrupt TVAR must be weighed against its higher resistive loss and somewhat higher phase noise production as compared to an abrupt junction TVAR.

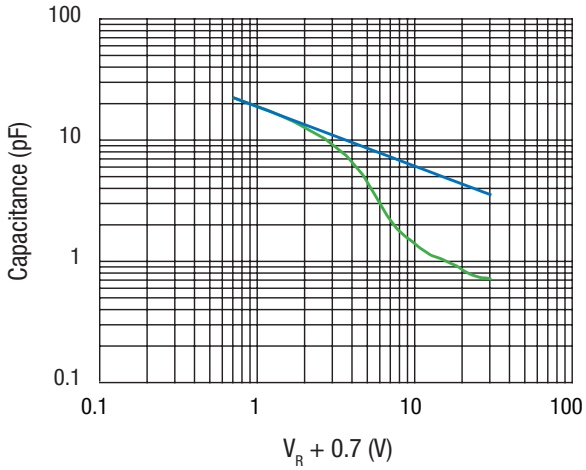


Figure 8. Capacitance vs. Reverse Voltage + Contact Potential – Abrupt and Hyperabrupt Junction Tuning Varactors

There are two primary selection criteria for TVAR applications: capacitance and capacitance ratio. In a given application, either of these criteria could be more important than the other. Figures 9A and 9B show the Skyworks TVAR product offering sorted by capacitance as measured with V_R = 3 V, along with the maximum rated capacitance ratio for each product. Figures 10A and 10B show these same data, but sorted by maximum rated capacitance ratio.

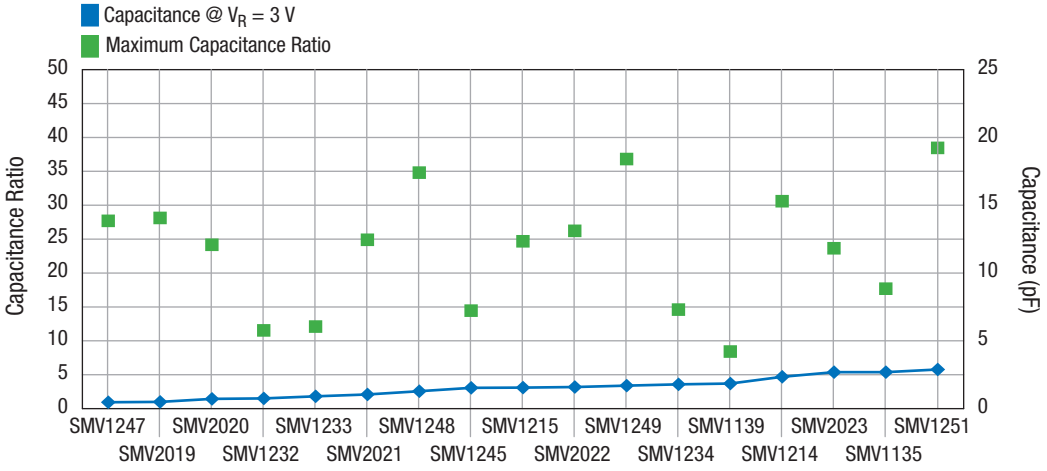


Figure 9A. Skyworks Solutions Tuning Varactors Sorted by Capacitance at V_R = 3 V

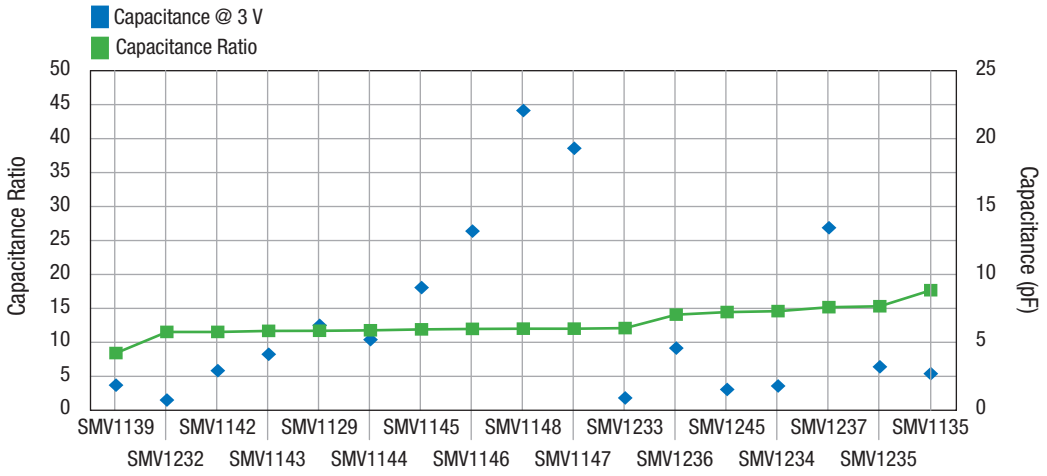


Figure 9B. Skyworks Solutions Tuning Varactors Sorted by Capacitance at V_R = 3 V

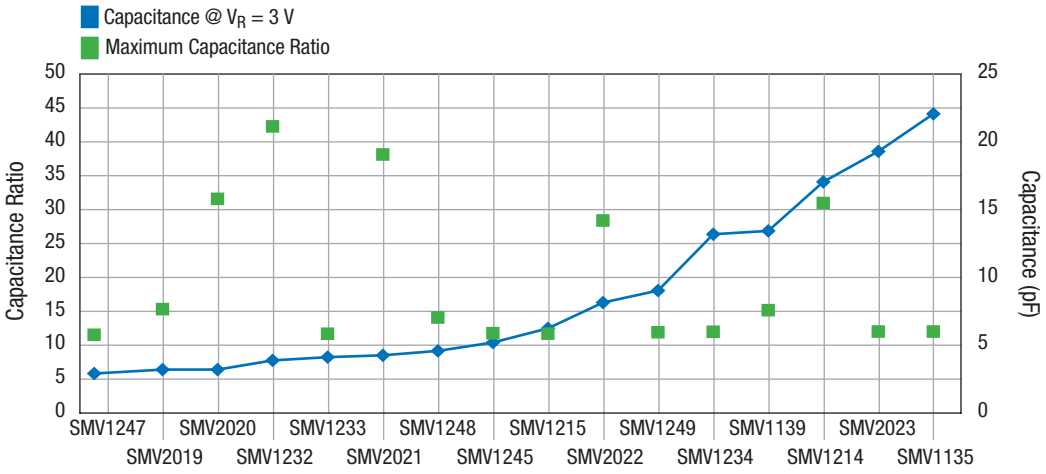


Figure 10A. Skyworks Solutions Tuning Varactors Sorted by Maximum Rated Capacitance Ratio

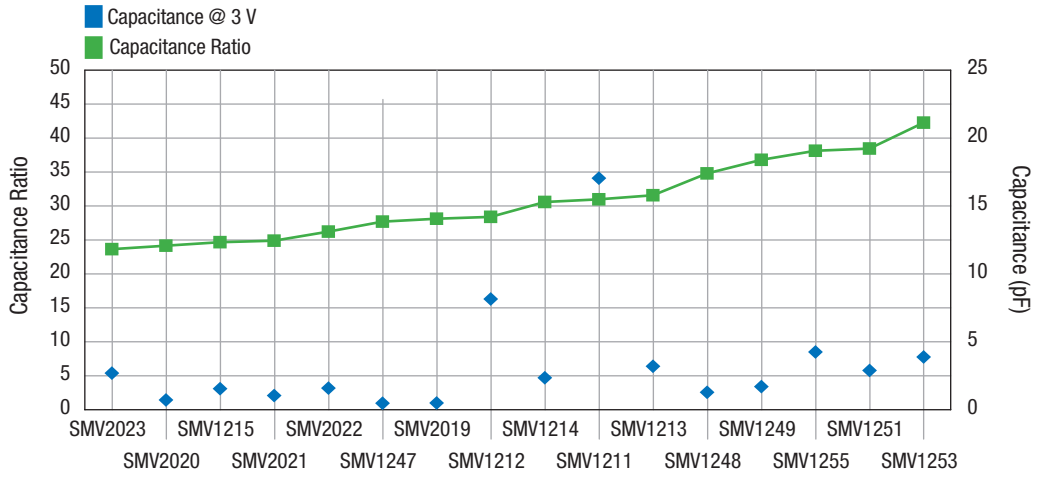


Figure 10B. Skyworks Solutions Tuning Varactors Sorted by Maximum Rated Capacitance Ratio

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Gain/Level Control

Signal levels must be controlled or adjusted to ensure that optimal signal levels are applied to several of the subsystems within the radio transceiver, or to ensure that the specified output power is transmitted from the system antenna. In RF circuits this is accomplished through the use of variable attenuators.

It is critical in most cases that the attenuators do not introduce distortion products into the signal path, so the linearity of their variable-impedance elements is of utmost importance. PIN diodes are highly linear devices and are frequently used in variable attenuator circuits.

There are several different attenuator circuits possible with PIN diodes, the simplest of which is a single device in shunt with a transmission line. A low-frequency control current is applied to the diode through an RF choke. The magnitude of the current along with the design of the PIN diode determine how much resistance the diode presents to the circuit. The impedance produced by the diode determines the amount of attenuation it produces as well. A well-designed attenuator PIN diode can produce several decades of variation in its resistance, over several decades variation in bias current. The series resistance vs. bias current curve for a typical attenuator PIN diode, SMP1307, is shown in Figure 11.

The disadvantage of the simple shunt PIN attenuator is that its input and output impedance varies. The performance of many circuits, such as voltage controlled oscillators, is degraded by a variable load impedance so a more sophisticated approach is necessary. There are several types of PIN diode attenuator circuits which offer constant input and output impedance even as their attenuation is varied over the range of 20 dB or more. Among these attenuator circuits are the π attenuator, the tee attenuator, the bridged tee attenuator and the hybrid coupler attenuator.

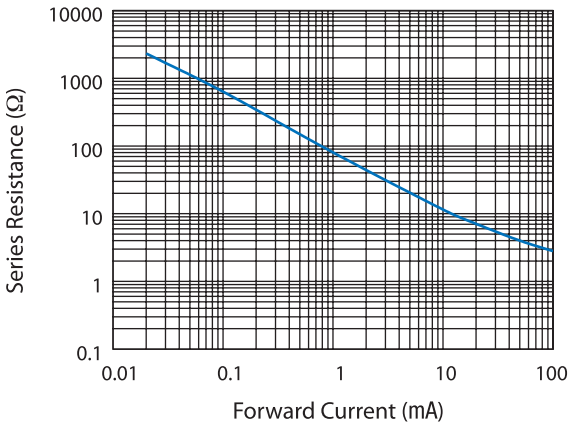


Figure 11. Series Resistance vs. Bias Current for SMP1307

The Pi Attenuator

The three PIN diodes in the π (pi) attenuator are arranged to resemble the letter "π": starting at the input of the attenuator there is a shunt diode, followed by a series diode and finally by a second shunt diode at the output side of the circuit as shown in Figure 12.

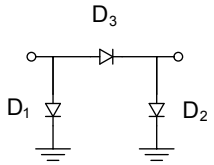


Figure 12. Simple π Attenuator

Identical bias currents are applied to shunt diodes D1 and D2. A different bias current is applied to series diode D3. The magnitudes of these bias currents are carefully controlled to produce diode resistances that maintain the input and output impedances of the circuit at the desired values as well as to produce the desired attenuation. The relationship of the individual diode resistances versus attenuation is shown in Figure 13, where the resistances of D1 and D2 are shown as "Shunt Diodes" and the resistance of D3 is shown as "Series Diode."

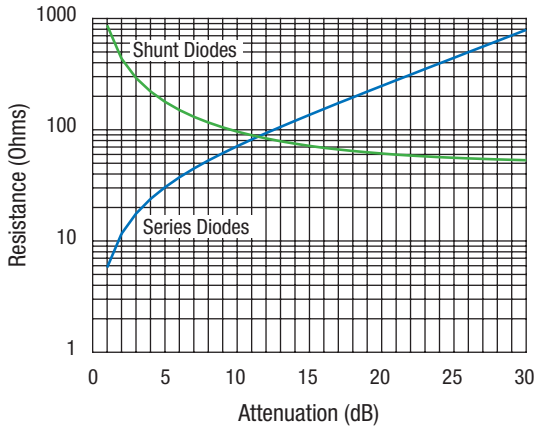


Figure 13. Series and Shunt Resistance vs. Attenuation—π Attenuator

A variation of the π attenuator is to include two diodes in the series arm of the attenuator. This simplifies the bias decoupling networks. This circuit is shown in Figure 14. In this circuit, diodes D1 and D3 comprise the series resistance, and diodes D2 and D4 are providing the shunt resistances.

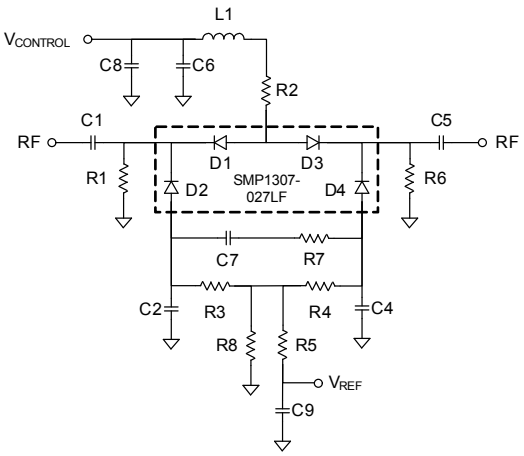


Figure 14. SMP1307-027LF π Attenuator Circuit

The Tee Attenuator

The three PIN diodes in the Tee attenuator are arranged to resemble the letter "T": starting at the input of the attenuator there is a series diode, followed a shunt diode and finally a second series diode at the output side of the circuit as shown in Figure 15.

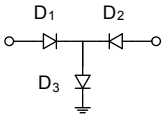


Figure 15. Tee Attenuator

In this circuit the combination of the resistances of the series diodes and shunt diode is carefully controlled to maintain constant input and output impedance while varying attenuation. This relationship is shown in Figure 16, where the resistance of D1 and D2 are shown as series diodes and that of D3 is shown as the shunt diode.

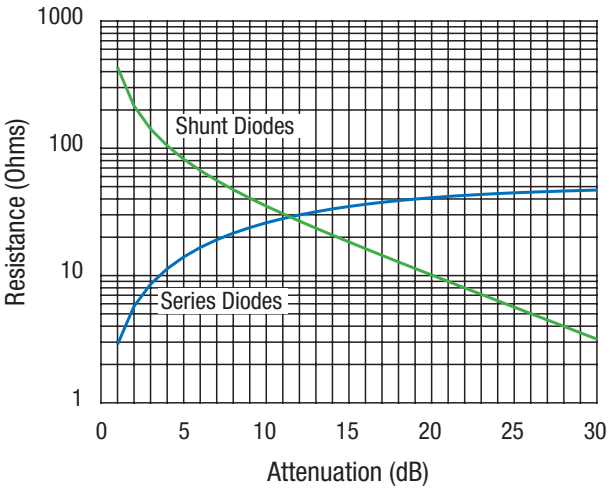


Figure 16. Series and Shunt Resistance vs. Attenuation—Tee Attenuator

Hybrid Coupler Attenuator

A very common form of variable attenuator is comprised of a hybrid coupler, with two of its ports terminated with PIN diodes, as shown in Figure 17.

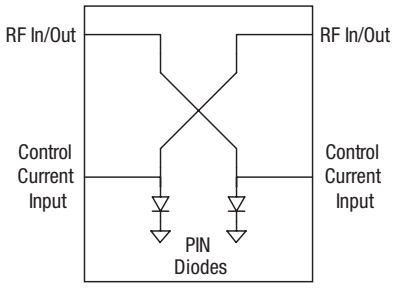


Figure 17. Hybrid Coupler Variable Attenuator

Maximum attenuation is achieved when the resistance of each of the PIN diodes exactly equals the impedance looking into the hybrid coupler ports which they terminate. This relationship is shown in Figure 18.

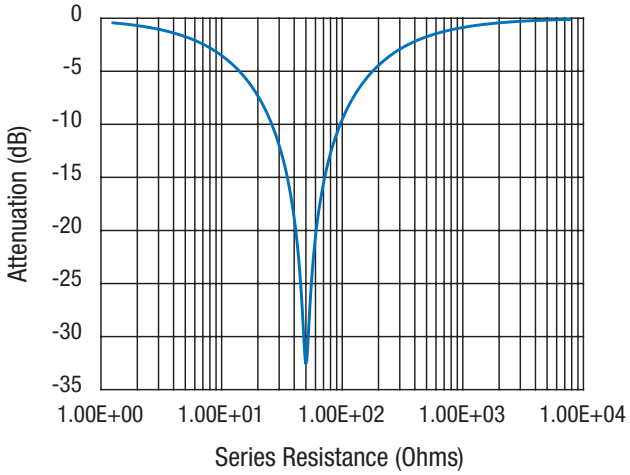


Figure 18. Hybrid Coupler Attenuator Attenuation vs. Diode Series Resistance (Z_0 = 50 Ω)

There are more PIN diode attenuator topologies which can be utilized. Please refer to the "Design with PIN Diodes" applicaton note on Skyworks' Web site for more information.

PIN diodes with thicker I layers typically produce less distortion than diodes with thinner I layers, so thicker diodes are typically more suitable for use in variable attenuator circuits. This comes at the expense of requiring larger bias currents to achieve a given resistance value. Table 6 shows Skyworks' attenuator diodes.

Table 6. Attenuator Diodes

Nominal Input 3rd Order Intercept (dBm)[1]	Nominal I Layer Thickness (µm)	Nominal Maximum Series Resistance (KΩ)	Minimum Series Resistance (mA)	Maximum Capacitance (pF)	Nominal Carrier Lifetime (ns)	Part Number
>50	175	3	3 @ 100	0.3 @ 30 V	1500	SMP1307-xxxLF
>43	100	2.5	2 @ 100	0.3 @ 30 V	1000	SMP1304-xxxLF
>38	50	1.8	1.5 @ 100	0.3 @ 30 V	700	SMP1302-xxxLF
>38	50	1.8	1.5 @ 100	0.2 @ 50 V	700	APD2220-000

1. Input third order intercept (IIP3) is dependent on several factors, including signal frequency, bias condition and attenuator topology. Values shown here refer to hybrid coupler attenuator toplogy, signal frequency equal to the center frequency of the hybrid coupler, with bias adjusted to produce minimum attenuation. IIP3 typically degrades by approximately 6 dB when attenaution is adjusted to maximum.

Learn More

Application Note
Design with PIN Diodes, document number 200312

PIN Diode Products for Attenuator Circuits

Switching

Signal routing in many radio architectures must be dynamic: a common antenna may be alternately connected to the transmitter and to the receiver signal chains; frequency agility or frequency hopping may be accomplished by selecting the output of one of two or more local oscillators; it may be advantageous to bypass a receiver low noise amplifier to prevent distortion and extend dynamic range when a large receive signal is present; and more.

The PIN diode's wide range of RF impedance (refer to Figure 19), coupled with the ability to produce very low distortion, make these excellent switching elements. With proper circuit and driver design PIN diodes can handle large power levels, of the order of several tens of Watts. Switches designed to handle more moderate power levels can switch in less than 100 ns with the right choice of diode and switch topology.

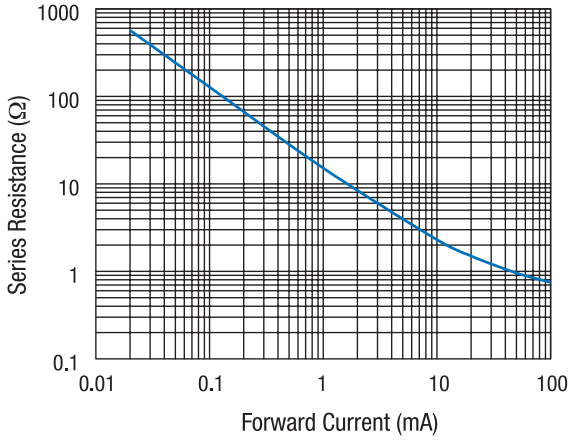


Figure 19. Series Resistance vs. Forward Bias Current—SMP1302

PIN Diode Switch Topologies

Multithrow PIN diode switches have been designed with up to 10 throws or more and with as few as a single throw. Insertion loss and isolation are both functions of the chosen switch topology as well as the properties of the PIN diodes which comprise the switch.

Most PIN diode switch topologies are reflective; that is, when they are in their isolation state they present either an RF open circuit or an RF short circuit to the transmission lines to which they are connected. Absorptive PIN diode switch topologies, which always present a very small return loss to their systems, are possible but are slightly more complex than reflective circuits.

PIN switch topologies consist of PIN diodes in series with their transmission path, in shunt with their transmission path, or both. Typically, multiple diode topologies are necessary to produce large isolation.

Single Pole Single Throw (SPST) PIN Switches

In the SPST PIN diode switch shown in Figure 20, the insertion loss of the switch is determined by the series resistance of the PIN diode when it is forward biased. The isolation is determined by the diode's capacitive reactance when it is reverse biased.

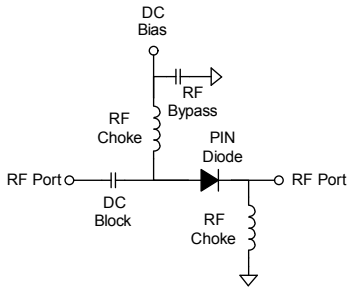


Figure 20. SPST with Series PIN Diode

In the SPST PIN diode switch shown in Figure 21, the insertion loss of the switch is determined by the diode's capacitive reactance when it is reverse biased. The isolation is determined by the series resistance of the PIN diode when it is forward biased.

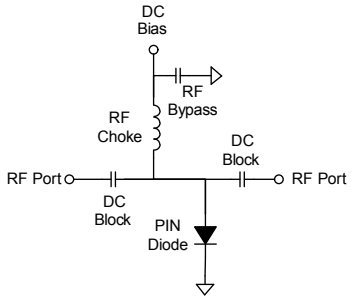


Figure 21. SPST with Shunt PIN Diode

In the SPST PIN diode switch shown in Figure 22, the insertion loss of the switch is determined by the series resistance of the series PIN diode when it is forward biased and the capacitive reactance of the shunt diode when it is reverse biased.

The isolation of this switch is determined by the series diode's capacitive reactance when it is reverse biased and the resistance of the shunt PIN diode when it is forward biased. This SPST topology can produce greater isolation than either of the single-diode topologies can produce.

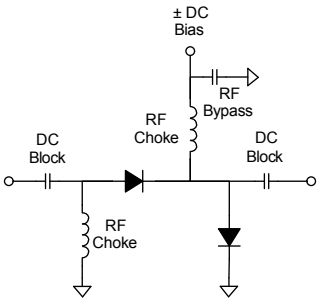


Figure 22. SPST with Series and Shunt PIN Diodes

Single Pole Double Throw (SPDT) PIN Switches

As is the case for the series PIN diode SPST, the isolation of either of the arms of the SPDT shown in Figure 23 is determined by the capacitive reactance of its series diode. Insertion loss is determined by the forward-biased series resistance of its PIN diode.

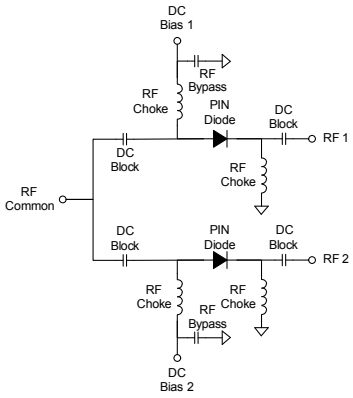


Figure 23. SPDT with Series PIN Diodes

The isolation of either arm of the SPDT comprising shunt PIN diodes, as shown in Figure 24, is determined by the forward-biased series resistance of its PIN diode. The insertion loss of either arm is determined by the capacitive reactance of its PIN diode.

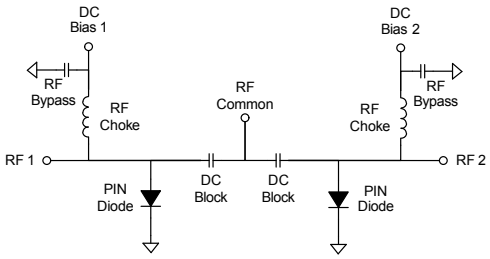


Figure 24. SPDT with Shunt PIN Diodes

The series-shunt diode SPDT topology shown in Figure 25 is widely utilized for applications in which higher isolation is required. In this topology, the series diode on the side of the switch which is intended to pass the signal is forward biased to produce low resistance, while the shunt diode on the same side of the switch is biased out of conduction so that it produces lowest capacitance in parallel with very large resistance. The insertion loss of this side of the switch is determined by the combination of the series resistance of the series diode and primarily by the capacitance of the shunt diode.

The diodes in the side of the switch which is intended to be in isolation are biased conversely to those in the insertion-loss side of the switch: the series diodes is biased out of conduction and the shunt diode is forward biased. The isolation of this side of the switch is mainly determined by the capacitance of the series diode and the resistance of the shunt diode.

Refer to "Design with PIN Diodes" application note on Skyworks' Web site for more information about the performance of each of these topologies.

PIN Diode Power Handling

With proper design, PIN diode switches can handle very large power signals. The important diode parameters for switches that must handle power levels higher than 1 W include the diode's voltage rating and thermal resistance. Other diode parameters, such as series resistance, capacitance and I layer thickness, are also contributing factors to the determination of maximum power handling.

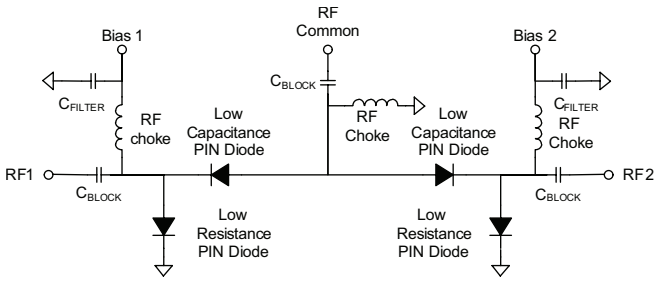


Figure 25. High Isolation Generic PIN SPDT

Thermal Resistance

A PIN diode is utilized as a variable impedance in switches. When the diode is forward biased, it presents a resistance to the circuit. This resistance will dissipate power. The dissipated electrical power is converted to heat as described by Joule's Law ($P = I^2R$). For good reliability, the junction temperature of the PIN diode must be kept as low as possible and must not exceed 175 °C, so the temperature of the diode's surroundings as well as its thermal resistance are critically important. The diode's junction temperature, T_J, is

$$T_J = T_A + P_D\theta_{JA}$$

where

T_A = Ambient temperature, typically expressed in °C

P_D = Power dissipated in the diode, in W

θ_{JA} = Thermal resistance of the media between the diode junction and the ambient environment, in °C/W

Thermal resistance is a very important consideration in power handling determination. The total thermal resistance is the sum of the thermal resistance of the die/package combination, typically denoted θ_{JC}, for thermal resistance from junction to "case" which is actually the terminals of the diode package, and the thermal resistance from the surface on or to which the diode is mounted, and the ambient environment, denoted as θ_{CA}. θ_{JC} is under the control of the semiconductor manufacturer, while the circuit designer's system design defines θ_{CA}.

Voltage Rating

The voltage rating of the PIN diode describes the absolute maximum voltage which can be impressed across the diode without driving it into avalanche breakdown. The sum of the peak RF voltage and the DC bias voltage must not exceed the voltage rating of the PIN diode. Table 7 shows Skyworks' PIN diode products.

Table 7. PIN Diode Selection

R_S @ 1 mA Nominal (Ω)	C_T @ V_R Nomimal (pF)	Nominal I Layer Thickness (microns)	Voltage Rating (V)	Available Package Styles	Base Part Number
0.90	1	8	50	Plastic	SMP1322
1	0.25	5	50	Chip, Ceramic	APD0520
1.2	0.25	15	200	Chip, Ceramic	APD1520
1.5	0.15	8	100	Chip, Ceramic	APD0810
1.5	0.2	5	50	Chip, Ceramic	APD0510
1.53	0.21	7	50	Plastic	SMP1340
1.90	0.3	8	50	Plastic	SMP1320
2	0.1	5	50	Chip, Ceramic	APD0505
2	0.1	8	100	Chip, Ceramic	APD0805
2	0.2	15	200	Chip, Ceramic	APD1510
2.60	0.25	15	100	Plastic	SMP1320
3.5	0.025	4	60	Beam Lead	DSM8100
3.5	0.18	10	50	Plastic	SMP1345
≤ 4 Ω @ 50 mA	0.02	6	20	Beam Lead	DSG9500
9.20	0.35	50	200	Plastic	SMP1352
16.20	0.3	50	200	Plastic	SMP1302

Detectors

Signal amplitudes or presence must be measured for proper operation of many systems. For example, the received signal strength is typically measured in a radio receiver in order to adjust automatic gain control circuits in order to maintain the desired output signal from the radio receiver. Many communications standards and legal regulations specify very tight requirements for the transmitted output power from a radio transmitter. Schottky detector diodes comprise the heart of these signal amplitude measurement systems.

The Schottky Junction

The Schottky diode junction is formed by plating a very pure metal, typically by evaporation or sputtering while under vacuum, onto a wafer that has been doped with either p-type or n-type dopant atoms. As soon as these materials are brought into contact and thermal equilibrium is established, their Fermi levels become equal. Electrons from the semiconductor lower their energy level by flowing into the metal. Charge accumulates at the interface, distorting the energy bands in the semiconductor. This creates an energy barrier, known as the Schottky barrier, which prevents more electrons from flowing from the n-type material into the metal without assistance from an external energy source of the correct polarity to elevate their energy above that of the Schottky barrier height. External energy of the opposite polarity increases the barrier height, thus preventing conduction.

One of the primary advantages of a Schottky junction compared to a p–n rectifying junction is that the Schottky junction operates with majority carriers only—there are no minority carriers, like those that are in the p–n diode, to slow the recovery time of the Schottky diode when a driving signal applied to the diode changes polarity from that which forward biases the diode to the opposite polarity. The Schottky diode's impedance changes virtually instantaneously with the change in polarity of the driving signal, thus enabling the Schottky to have very high rectification efficiency over a very wide frequency range.

Another significant advantage of the Schottky junction is that the forward voltage of the Schottky junction can be significantly lower than that of a comparable p–n junction, thus enabling the Schottky diode to be a more sensitive detector than a p–n diode.

The forward current vs. forward voltage curves for three different types of diodes are shown in Figure 26. Two of these diodes are Schottky junction devices, a low barrier height diode and a diode called a "zero bias detector" (ZBD) diode. The third diode is a typical p–n junction device. The ZBD diode has the lowest voltage for a given forward bias current of the 3 devices whose performance is shown in Figure 26. The low barrier height diode has a slightly higher forward voltage than that of the ZBD, while the p–n junction diode has forward voltage that is more than a factor of 3 greater than that of the ZBD.

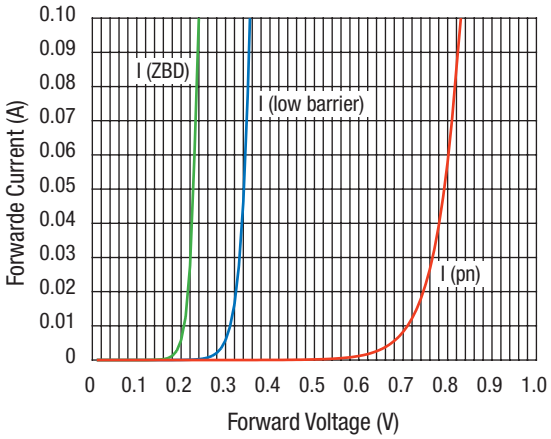


Figure 26. Typical Forward Current vs. Forward Voltage for a ZBD Schottky Diode, a Low Barrier Height Schottky Diode and a Si p–n Junction Diode

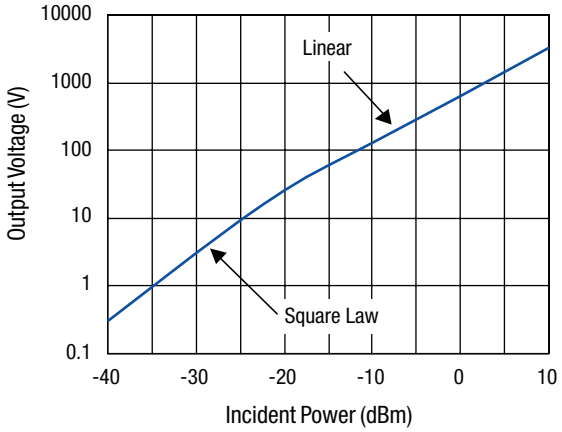


Figure 27. Typical Schottky Diode Detector Performance

Schottky Detector Parameters

Schottky diode detectors can operate over a very large input signal power range. The lower bound of this range is described by the diode's tangential signal sensitivity (TSS), which is defined as the input power level at which the Schottky diode's detected output signal to noise ratio is 8 dB. Typically, the lower the barrier height of the diode, the lower this minimum detectable signal level is. For Zero Bias Detector barrier height diodes, TSS is typically between -60 and -55 dBm. TSS is typically around -55 to -45 dBm for low barrier height Schottky diodes.

The transfer function of a Schottky diode detector is composed of two regions: the square law detection region and the linear detection region as shown in Figure 27. For small input signal levels, the detected output voltage is proportional to the square of the input signal voltage. For large input signal levels, the detected output voltage is linear with respect to the input signal voltage. The input signal level at which the transition from square law to linear response occurs is proportional to diode barrier height: a zero bias detector barrier diode produces this transition at a lower input signal level than does a low barrier height diode. Consequently, lowest barrier height diodes are most suitable for very small input signal levels but are less suitable for detection of larger signals than are diodes with higher barrier height.

Schottky Detector Circuit

The fundamental Schottky detector circuit is simply a half-wave rectifier, as shown in Figure 28. In this circuit, the incident RF signal voltage alternately forward biases and reverse biases the Schottky diode. The forward bias alternations charge the filter capacitor to a voltage that is proportional to the magnitude of the input signal.

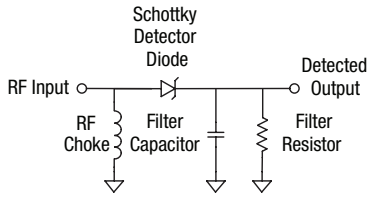


Figure 28. Schottky Diode Detector Circuit

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Visit our Web site for more information on Schottky Diode products for detector circuits.

Schottky Diode Products

Many other detector circuit configurations exist, most of which include multiple Schottky diodes, which produce a greater detected output voltage for a given input signal magnitude. For example, a voltage doubler detector circuit is shown in Figure 29.

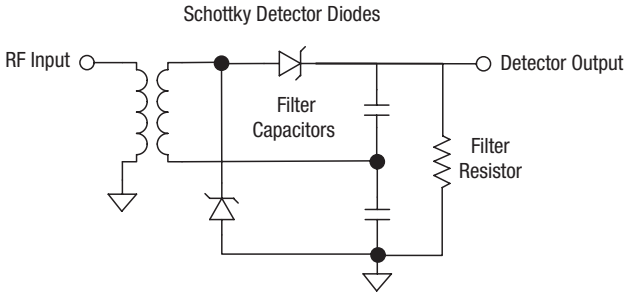


Figure 29. Schottky Diode Voltage Doubler Detector Circuit

Directional Detector

Many communications standards and government regulations require that a transmitter's output power meet tight requirements. These requirements might be to ensure that a maximum permitted output power is not exceeded, or in some cases the transmitted output power must fall between a minimum and a maximum value. In these systems it is important that the output power measurement in the transmitter not be corrupted by measurement of signal power that might be reflected from the radio's antenna. In such cases, a directional coupler is used to sample the transmitter's output power only.

The DD02-999LF (shown in Figure 30) integrates a directional coupler with a pair of Schottky diodes. One of the Schottky diodes performs signal detection, while the second diode acts as a temperature measurement device to enable external temperature compensation.

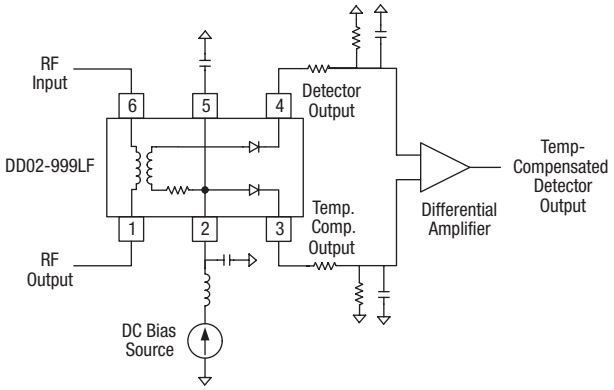


Figure 30. DD02-999LF Directional Detector with External Components

Table 8 shows Skyworks' Schottky detector diodes. Table 9 shows Skyworks' directional detector.

Table 8. Schottky Detector Diodes

Minimum Detectable Signal (dBm)	Barrier Height	Input Signal Frequency Range	Maximum Capacitance (pF)	Configuration	Base Part Number
-52	ZBD			Chip, ceramic packaged	CDC7630
-56	ZBD	Ku band	0.15	Chip, ceramic packaged	CDC7631
-60	ZBD	Up to 10 GHz	0.3	Single junction, common cathode pairs and series pairs, plastic packages	SMS7630
-60	ZBD	Up to 100 GHz	0.3	Single junction flip chip	SMS7630
-50	Low	Ku band	0.1	Chip, ceramic	APD0510
-50	Low	Ku band	0.15	Chip, ceramic packaged	CDB7620
-53	Low	Ku band	0.1	Chip, ceramic packaged	CDF7621
-53	Low	X band	0.3	Chip, ceramic packaged	CDF7623
-53	Low	Up to 10 GHz	0.3	Single junction, common cathode pairs and series pairs, plastic packages	SMS7621
-53	Low	Up to 100 GHz	0.18	Single junction flip chip	SMS7621
-52	ZBD	Ku		Beam lead, ceramic packaged	DDC2353
-56	ZBD	Ku		Beam lead, ceramic packaged	DDC2354
-50	Medium	K band	0.1	Beam lead, ceramic packaged	DDB2503
-50	GaAs	Up to 150 GHz	0.04–0.07	GaAs single junction flip chip	DMK2790
-48	Medium	Ku band	0.1	Beam lead, ceramic packaged	DDB2504
-47	Medium	S band	0.30–0.50	Beam lead, ceramic packaged	DME2127
-45	Medium	K band	0.1	Chip, ceramic packaged	CDE7618
-45	Medium	Ku band	0.15	Chip, ceramic packaged	CME7660
-45	Medium	K band	0.1	Beam lead, ceramic packaged	DME2458
-45	Medium	Ku band	0.05–0.15	Beam lead, ceramic packaged	DME2333
-45	Medium	S	0.3–0.5	Series pair, beam lead, ceramic packaged	DME2050
-40	High	X band	0.15	Chip, ceramic packaged	CDP7624
-40	High	K band	0.1	Beam lead, ceramic packaged	DDB2265

Table 9. Directional Detector

Input Power Level (dBm)	Input Frequency Range (MHz)	Package	Base Part Number
< 36	650–3000	SC-88	DD02-999LF

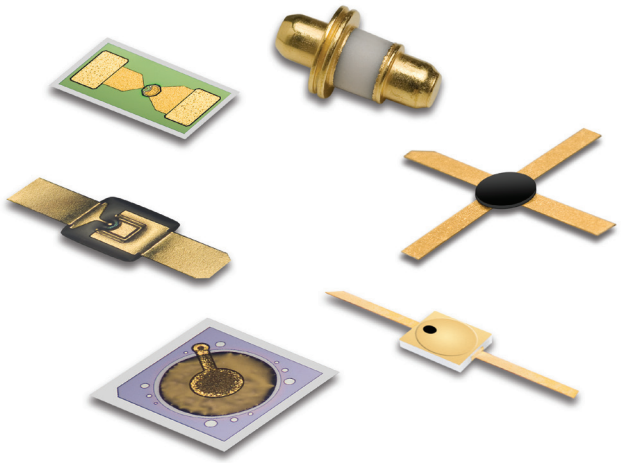
High-Performance/High-Reliability Semiconductor Discrete Devices

Wide Variety of Devices for High-Performance Applications

In addition to our plastic-packaged product offering, Skyworks also offers a variety of hermetic and epoxy packaged devices, as well as unpackaged dice and beam-leads, in various configurations for all your high-performance applications from low frequency to 100 GHz. For more information, please refer to Skyworks' complete catalog of packaged and unpackaged semiconductors, Semiconductor Discretes for RF-Microwave Applications, CAT501-09A. Table 10 shows devices for high-performance applications.

- Silicon Diodes: Limiter, PIN, Schottky, Varactor
- GaAs Schottky Devices
- Silicon Passive Devices: Fixed Attenuator Pads, MIS Chip Capacitors
- GaAs IC Switch Devices

When requested, Skyworks will perform JANTX level high-reliability testing on packaged devices in accordance with MIL-PRF-19500 and Element Evaluation on unpackaged dice and beam-lead devices in accordance with MIL-PRF-38534. Skyworks also offers lot approval services for sensitive circuits. For more information on screening and evaluation, please refer to High-Performance/High-Reliability Semiconductor Discrete Devices, BRO383.



Learn More

Brochure
High-Performance/High-Reliability Semiconductor Discrete Devices, BRO365

Table 10. Devices for High-Performance Applications

Application	T/R Switches	Mixers	Attenuators
Microwave	•	•	•
Military	•	•	•
Space	•	•	•
Jammers	•	•	•
Radar	•	•	•
Avionics	•	•	•

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- KIT606-10A Silicon Limiter Diode Chips
- KIT601-10A MIS Chip Capacitors for Hybrid Circuit Applications
- KIT605-10A GaAs Schottky Diode Flip Chips for Mixer and Detector Applications
- KIT619-10A Fixed Attenuator Pads (ATN3590)
- KIT604-10A Silicon PIN Beam-Lead Diodes for High-Frequency Switch Applications
- KIT603-10A Silicon PIN Diode Chips for Switch and Attenuator Applications
- KIT607-10A Silicon Schottky Diode Chips for Mixer and Detector Applications
- KIT609-10A Varactor Diodes for VCO, Phase Shifter and Filtering Applications
- KIT616-10A Varactor Diodes Hyperabrupt and Abrupt Chips for VCO and Phase Shifter Applications
- KIT615-09A RF Passive Devices
- KIT614-10A Diodes (SMT Limiter, PIN, Schottky, Varactor)
- KIT617-10A Smart Energy Solutions

Certifications

As an industry leader, Skyworks has demonstrated its quality leadership and strengthened its commitment to customer satisfaction through formal, third-party registration to ISO 9001, ISO/TS 16949, ANSI/ESD S.20.20, and ISO 14001.

ISO 9001

ISO 9001 is an internationally recognized Quality Management System standard that promotes customer satisfaction through continual improvement of the system's effectiveness. ISO 9001 provides a model for a Quality Management System which focuses on the effectiveness of the processes in a business to achieve desired results. The standard promotes the adoption of a process approach emphasizing the requirements, added value, process performance and effectiveness, and continual improvement through objective measurements.

ANSI/ESD S.20.20

ANSI/ESD S20.20 is a standard for the Development of an Electrostatic Discharge Control Program for Protection of Electrical and Electronic Parts, Assemblies and Equipment. The standard covers the requirements necessary to design, establish, implement, and maintain an Electrostatic Discharge (ESD) Control Program.

ISO/TS 16949

One of the major challenges facing today's manufacturers is that, even though there is a low failure probability for each individual component, the total failure probability for all parts combined may reach unacceptable levels. The ISO/TS 16949 standard answers this challenge by defining requirements focused on continual improvement, and the understanding of process interaction. It also creates an implementation framework for customer specific requirements, and includes clear requirements for development processes and techniques to prevent problems in the earliest possible stage of product development.

Jointly developed by International Automotive Task Force (IATF), ISO/TS 16949 is the automotive industry's international quality management system standard intended to answer the need for global consistency, continual improvement, and increased customer satisfaction. It is approved and released by the International Organization for Standardization (ISO).

ISO 14001

Through our Green Initiative™, we are committed to manufacturing products that comply with global government directives and industry requirements.



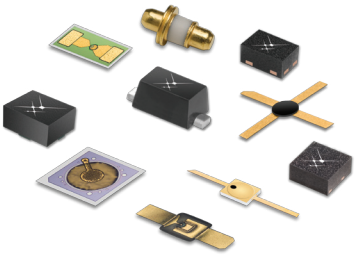
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Visit our Web site for more information on Skyworks' quality and environmental programs and initiatives.

Quality

Green Initiative™ and Sustainability

How to Select Diode Packages



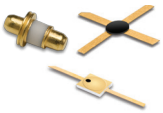
Skyworks diodes are available in several types of packages, as unpackaged dice or as unpackaged beam leads. In most cases the requirements of the end application will determine the optimal physical diode configuration.



Plastic Surface Mount Technology Packages

Plastic surface mount technology (SMT) packages are inexpensive and are compatible with modern pick-and-place assembly techniques, so they are optimal choices for high-volume, low-cost final product assemblies.

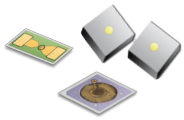
While careful attention has been paid to minimizing package parasitic reactances they are always present in such diode configurations. These parasitics, package capacitance and package inductance, inherently reduce the bandwidth over which a diode may be used. Plastic SMT packages also add thermal resistance to that of the die, thereby reducing the amount of power a diode can dissipate without exceeding its maximum rated operating junction temperature.



Ceramic-Metal Packages

Ceramic-metal packages offer several advantages over plastic packages: their parasitic inductances and capacitances are lower, sometimes as much as 75% lower, than that of the plastic SMT packages described above. Their thermal resistances are also much lower than that of the large majority of plastic SMT packages. Most ceramic packages used for diodes are capable of being hermetically sealed, thereby offering maximum protection to the die against environmental contaminants such as sodium (Na), water vapor, etc.

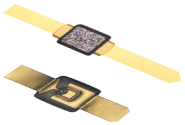
Such packages have two disadvantages compared to plastic SMT packages: they are typically more costly, and, they generally are not compatible with automated surface mount assembly.



(Packageless) Dice

Diode dice, sometimes known as chips, eliminate the parasitic reactances and thermal resistance of the package. This configuration produces the widest bandwidth of operation as well as maximal power dissipation capabilities.

Of course, the end user of diode dice must be capable of handling these tiny devices as well as performing die attach and wire bonding assembly techniques. The assemblies which contain dice must be protected from mechanical damage, especially to the fragile bond wires. Some devices are also available on film frame.



Beam-Lead Power Handling Diodes

Beam-lead diodes offer the highest frequency performance capability, due to the absence of a package and its associated parasitic reactances, and the reduction of series inductance that would be presented by a bond wire. Also, since no mechanical connection needs to be made to the terminals of the diode junction by the user, the diode junction area can be very small, thus reducing junction capacitance.

The metal beams of beam-lead diodes must be mechanically and electrically attached to the circuit in which they are used. This lead attach may be accomplished using thermocompression bonding or a combination of thermocompression and ultrasonic bonding referred to as "thermalsonic bonding," or beam attach may be done using conductive epoxy. Such assembly techniques are most frequently performed manually by skilled assemblers.

The only conduction paths for heat to flow out of the diode junction are through the metal beams, which have very small cross-sectional areas, so thermal resistance of beam-lead diodes is generally greater than 125 °C/W, sometimes substantially so. This limits the power dissipation of beam-lead diodes to relatively low power levels.

Application Notes

Please visit our Web site to access our technical documents, which include application notes and product briefs.

Category	Description	Document Numbers
General	Waffle Pack Chip Carrier Handling/Opening Procedure	200146
General	Quality/Reliability	200149
General	Solder Reflow Information	200164
General	Circuit Models for Plastic Packaged Microwave Diodes	200311
General	Diode Chips, Beam-Lead Diodes, Capacitors: Bonding Methods and Packaging	200532
GaAs Flip Chips	APN3001: Epoxy Die Attachment for GaAs Flip Chip Devices	200741
Limiter	PIN Limiter Diodes in Receiver Protectors	200480
Phase Shifter	A Varactor Controlled Phase Shifter for PCS Base Station Applications	200319
PIN	Design With PIN Diodes	200312
PIN	A Wideband General-Purpose PIN Diode Attenuator	200313
PIN	T/R Switch for IMT-2000 Handset Applications	200318
PIN	5–6 GHz Switch Using Low-Cost Plastic Packaged PIN Diodes	200321
PIN	A Wideband CATV Attenuator	200327
PIN	PIN Diode Basics	200823
Schottky	Level Detector Design for Dual-Band GSM-PCS Handsets	200324
Schottky	Mixer and Detector Diodes	200826
Schottky	Handling Precautions for Schottky Barrier Mixer and Detector Diodes	200840
Tuning Varactor	A Balanced Wideband VCO for Set-Top TV Tuner Applications	200314
Tuning Varactor	Varactor SPICE Models for RF VCO Applications	200315
Tuning Varactor	A Colpitts VCO for Wideband (0.95–2.15 GHz) Set-Top TV Tuner Applications	200316
Tuning Varactor	Switchable Dual-Band 170/420 MHz VCO for Handset Cellular Applications	200317
Tuning Varactor	VCO Design for WLAN Applications in the 2.4–2.5 GHz ISM Band	200320
Tuning Varactor	VCO Designs for Wireless Handset and CATV Set-Top Applications	200322
Tuning Varactor	Differential VCO Design for GSM Handset Applications	200323
Tuning Varactor	Dual-Band Switchable IF VCO for GSM/PCS Handsets	200325
Tuning Varactor	Low Phase Noise VCO Design for PCS Handset Applications	200326
Tuning Varactor	Varactor Diodes	200824

Product Briefs

Category	Description	Document Numbers
Diodes	Limiter Diodes Product Brief	BRO372
Diodes	GaAs Schottky Flip Chip Diodes Product Brief	BRO373
Diodes	PIN Beam-Lead Diodes Product Brief	BRO374
Diodes	Silicon PIN Diode Chips Product Brief	BRO375
Diodes	Silicon Schottky Diodes Product Brief	BRO376
Diodes	MIS Silicon Chip Capacitors Product Brief	BRO377
Diodes	Miniature 0402 Surface Mount Technology Diodes (PIN, Limiter, Schottky, Varactor)	BRO391
Diodes: PIN	SMP1302-085LF: Surface Mount PIN Diode for High-Power Switch Applications	SMP1302_085
Diodes: PIN, Schottky, Varactor	Select PIN, Schottky, Varactor Diodes Available From Stock for Prototype or High-Volume Production	BRO387

Packaging

Many of Skyworks' diodes are available in the package shown below. Please refer to individual data sheets for the availability of specific diode package combinations.

Part Number Suffix	Package Type	Actual Size	Package Dimensions (mm) (Lead Inclusive)*
-093, -096	0201 Micro Surface Mount Device (MSMD)		0.50 x 0.25 x 0.30
-060, -061	0201 Micro Surface Mount Device		0.60 x 0.30 x 0.27
-040	0402		1.00 x 0.60 x 0.46
-203	Hermetic Pill		1.27 x 1.40
-508, -517, -518	LGA		1.47 x 1.23 x 0.70
-079	SC-79		1.60 x 0.80 x 0.60
-219	Hermetic Pill		1.91 x 1.91 x 1.14
-085	QFN 2L (2 x 2) 1.7 mm Paddle		2.00 x 2.00 x 0.90
-086	QFN 2L (2 x 2) 1.7 mm Paddle		2.00 x 2.00 x 0.90
-087	QFN 2L (2 x 2)		2.00 x 2.00 x 0.90
-073, -074, -075, -076	SC-70		2.10 x 2.00 x 0.95
-001, -003, -004, -005, -006, -007, -39	SOT-23 3L		2.37 x 2.92 x 1.00
-015, -016, -017, -019, -020, -021, -022, -023, -026, -32	SOT-143		2.37 x 2.92 x 1.00
-011	SOD-323		2.52 x 1.25 x 1.04
-027, -72	SOT-23 5L		2.80 x 2.90 x 1.18
-321, -348, -350	QFN (3 x 3)		3.00 x 3.00 x 0.75
-207	Hermetic Ceramic Pill		5.08 x 2.18
-210	Hermetic Pill		5.7 x 3.15
-230	Epoxy Stripline		5.98 x 1.4 x 0.76
-232	Epoxy Stripline		5.98 x 3.69 x 0.76
-234, -235	Epoxy Stripline		5.98 x 5.98 x 0.76
-250, -251	Epoxy Stripline		8.12 x 2.54 x 1.27

*Dimensions indicated: lead tip to lead tip x body width x total thickness.

Part Number Suffix	Package Type	Actual Size	Package Dimensions (mm) (Lead Inclusive)*
-252, -253	Epoxy Stripline		8.12 x 5.33 x 1.27
-254	Epoxy Stripline		8.12 x 8.12 x 1.27
-255, -257	Epoxy Stripline		8.12 x 8.12 x 1.27
-220, -221	Hermetic Stripline		11.3 x 1.91 x 1.14
-224	Hermetic Stripline		11.3 x 11.3 x 1.14
-225	Hermetic Stripline		11.3 x 11.3 x 1.14
-222	Hermetic Stripline		11.3 x 6.6 x 1.14
-223	Hermetic Stripline		11.3 x 6.6 x 1.14
-240	Hermetic Stripline		11.52 x 2.64 x 1.18

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