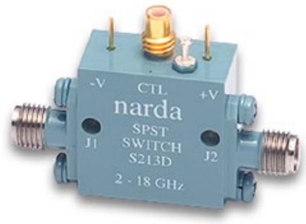
RF and Microwave PIN Control Products Application and Selection

A Guide to Help Designers Make the Best Selection When Specifying Switches, Attenuators and Limiters



- Fundamental PIN Diode Principles
- Primary Design Parameters
- Application Specific Considerations
- A Glossary of Key PIN Diode Terms

Introduction

RF and microwave components based on PIN diodes have been essential tools in the designer's toolkit for decades, and with good reason: their unique characteristics make them the best choice for a wide variety of control applications, such as switches, attenuators, phase shifters, limiters and modulators.

PIN diodes are fundamentally similar to standard diodes, but have an RF impedance that is determined by an externally supplied bias current. Their versatility makes them excellent building blocks in a wide variety of configurations within each product category, which allows diverse system requirements to be served. In short, the PIN diode enables all systems – from the least complex to the most sophisticated – to achieve their intended missions, while requiring very little space, power or cost.

There are many resources that provide both practical and theoretical information about PIN diode theory, characteristics and incorporation in modules and subsystem designs. However, practical information about choosing the proper PIN-diode-based product for a specific application is conspicuously absent. "RF and Microwave PIN Control Product Application and Selection" has been created to fill this void. It includes basic discussions of PIN diode characteristics, the most commonly used PIN-diode-based products, and the trade-offs encountered in designing products around them. The merits of various types of control products within a specific category (analog and digital attenuators, for example) are discussed as well.

PIN Diode Switches

Switches that control the path of RF power from very low frequencies through the low millimeter-wave range are the most common application for PIN diodes. The level of DC bias applied to the diode determines its impedance. In the case of a PIN diode mounted in series with a transmission line, when the bias changes the impedance from a low value to a high value, the circuit acts as a switch. That is, the switch is in the "on" state when forward biased (low impedance), and in the "off" state when zero or reverse biased (high impedance). The attenuation produced by the diode switch is called insertion loss (IL) when the switch is in the "on" state, and isolation when in the "off" state.

In a simple SPST PIN diode switch (Figure 1), the diode can be either series or shunt connected. The series-connected PIN diode configuration can provide reasonably low insertion loss over a multi-octave frequency range, but with lower power-handling capability. Design and fabrication are also simpler because no holes are required in the circuit board to mount shunt diodes.

In series diode switches, insertion loss is dependent on the series resistance of the PIN diode while isolation is primarily dependent on the junction capacitance. These parameters are determined by the forward bias current and reverse bias voltage, respectively.

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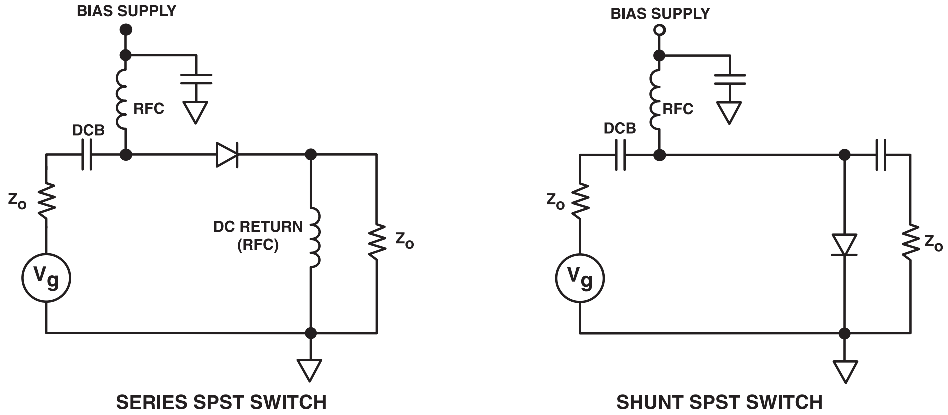

Figure 1

The shunt-connected PIN diode configuration optimizes high isolation and low loss across a wide frequency range (up to several octaves), and can handle higher power levels because the diodes are mounted directly to the housing. The shunt switch is "on" when the diode is zero or reversed biased, and off when forward biased (the opposite of the series switch).

The insertion loss of a shunt-connected diode at a given frequency is primarily dependent on its junction capacitance (C_j), while the isolation provided by the diode is dependent on its series resistance (R_s) when the diode is forward biased. A combination series-shunt topology is also used and provides very wideband performance, high speed and moderate power-handling ability and insertion loss.

Multi-throw switches can be configured in two ways to achieve improved performance. In the first method (Figure 2a), PIN diodes series-connected to the common junction and the diodes in the "on" port are forward-biased while the remaining diodes are reverse-biased. The result is a low-loss path for the "on" port and minimal loading by the "off" ports.

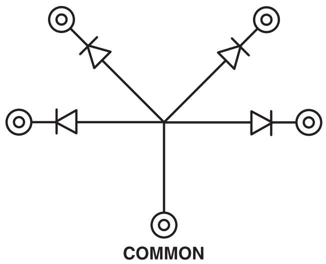

Figure 2a - Shunt Diodes Located Quarter Wave Length from Common Junction

In the second method (Figure 2b), shunt-connected PIN diodes are placed one-quarter wavelength from the common junction, and the selected diodes of the "on" port are reverse-biased while the "off" ports are forward-biased. The result in this case is an electrical short across each "off" transmission line, and the quarter-wavelength spacing transforms the shorts to open circuits at the junction. These techniques are optimized through prudent choice of transmission line impedances while keeping stray reactance low, resulting in a switch with acceptably low insertion loss and VSWR, and a 3:1 bandwidth.

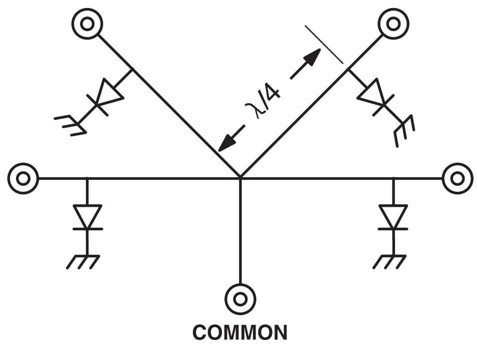

Figure 2b - Series Diodes at Common Junction

While it is possible to achieve isolation somewhat greater than 40 dB with a single PIN diode (either series or shunt-connected) at lower microwave frequencies, it is typically necessary at higher frequencies to increase the number of switch elements by using additional series-mounted and shunt-connected PIN diodes in each arm.

The isolation elements of a switch (series or shunt diodes) are usually spaced a quarter-wavelength apart. This results in a value of isolation 6 dB greater than the sum of the isolation that is provided by each pair of diodes. This structure can be repeated several times to achieve greater than 90 dB isolation.

Key PIN Diode Switch Parameters

Insertion loss, isolation, switching speed and power handling ability are typically the parameters used to describe switch performance. However, there are other key parameters.

Video Leakage

The spurious signals at the switch's RF ports when there is no RF signal present are collectively called video leakage. The switch driver produces these signals, specifically at the leading edge of the voltage spike provided for high-speed switching. There can actually be video spikes of ±10 Vdc present in a system with a 50 ohm impedance, although ±1.5 to ±3.0 Vdc is more common. Most of the RF energy in the video spike is below 200 MHz but in very high speed, broadband switches, there can be appreciable RF energy (-60 to -50 dBm) produced – as high as 1 GHz. High-pass filters can reduce the level of low-band video leakage components, but signals within the passband of the switch (in-band video leakage) cannot be filtered out. In-band video leakage can be reduced only by using a switch with a slower switching speed or by very carefully tailoring the drive waveform to suit the particular type of PIN diode being used.

Harmonics and Distortion

PIN diodes, like all diodes, are nonlinear in their response characteristics, and as a result produce harmonics and intermodulation distortion (IMD) products. Fortunately, these products are usually at very low levels in a PIN diode switch because the diodes themselves are either in a saturated, forward-biased condition or are reversed-biased. The minority carrier lifetime of the diode determines the level of IMD. A PIN diode switch's IMD performance is usually described by its third-order output intercept point (OIP). Good OIP performance for typical PIN switches ranges from +35 dBm to +45 dBm. The level of harmonics and IMD varies widely among devices, so it is important to read the manufacturer's specifications for these parameters for every model considered.

Minority Carrier Lifetime

This specification is very important from the perspective of both diode and circuit design. Carrier lifetime (T_L) is a property of the semiconductor material, and when the PIN diode is forward biased, injection of electrons and holes occurs from the N+ and P+ contacts respectively. These carriers have a finite lifetime, and the average time before they recombine is the carrier lifetime. Recombination takes place through interaction between the crystal lattice and impurities in the "I" region and P+ and N+ regions of the diode. The carrier lifetime in a PIN diode controls the switching speed, i.e., the time required to switch the diode from a low-impedance forward bias state to a high-impedance reverse bias state. This transition is the slower of the two transitions in a switching application since the driver circuit is attempting to remove stored charge from the PIN diode.

Switching speed and minority carrier lifetime are directly related. To visualize their interaction, it helps to examine the relationship of minority carrier lifetime and its forward and reverse current ratio (I_f/I_r) in the following equation:

$$T_{rr}=T_L \log (1 + I_f / I_r)$$

where

T_{rr} is the diode's switching speed (commonly referred to as "reverse recovery time"), and
T_L is the minority carrier lifetime

This equation describes the dependence of switching time on the minority carrier lifetime and the "I_f / I_r" ratio.

Switching Speed

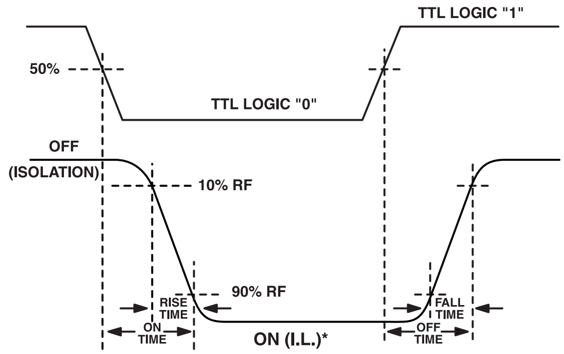

Figure 3 - Detected RF Power

a) Rise Time And Fall Time: These parameters, fundamental to many designs, are actually composed of several subsets, each one defining the time required for switching to take place between two states in the switch response (Figure 3). Rise time is defined as the period between full "off" and full "on," specifically from 10 percent of this condition to 90 percent of the square-law-detected RF power. Conversely, fall time is the period between 90 percent of full "on" to 10 percent of full "off." Rise time and fall time do not include driver propagation delays.

b) Switching Time (On Time and Off Time): The time lapse between 50 percent of the input control signal from the driver to 90 percent of the square-law-detected RF power when the device is switched from full "off" to full "on" is called the "on" time. The "off" time begins when the 50 percent point of control signal occurs, to the point when it achieves 10 percent of its square-law detected RF power and the unit is switched from full "on" to full "off." On and off times include driver propagation delays.

c) Modulating Switching Mode in Multichannel Switch: Mode when all the channels are in the isolation state and one of the channels is switching from "on" to "off."

d) Commutating Switching Mode in Multichannel Switch (Port-to-Port): Mode when two channels are switching simultaneously: one from "on" to "off" and another from "off" to "on." Switching time is the larger of the time for 1 port to go to 10 percent RF, and the other port to go to 90 percent RF.

For reflective switches, the switching time in the Commutation mode is typically slightly longer than in the modulation mode (5-10 ns).

For absorptive switches, Commutation time is dependent on switch topology. All series switches, and some series shunt switches, have Commutation times that are signigicantly longer than the Modulation Time. If Commutation switching time is required, please contact the factory.

ALL SPECIFICATIONS FOR SWITCHING SPEED IN THE NARDA CATALOG ARE FOR MODULATION SWITCHING SPEED.

Performance Trade-Offs

The design of any subsystem invariably requires trade-offs in one or more areas of performance. Optimizing a design for one performance parameter often occurs at the expense of another. Such is the case with PIN diode switches.

Power vs. Frequency

Junction capacitance can be reduced in order to ensure low loss at higher operating frequencies. For a given switching speed, junction capacitance can be lowered by decreasing the area of the diode. This increases the diode's thermal impedance, producing a reduction in power-handling ability.

Power vs. Switching Speed

To optimize power-handling ability, the diode's junction area must be large (hence lower thermal impedance). This increases the diode's junction capacitance, resulting in higher insertion loss, lower isolation (in a series switch configuration), and usually smaller bandwidths. To maintain low capacitance, the diode's "I" region thickness must be increased to compensate for the increase in capacitance caused by the increased junction area. The increased length of the "I" region raises the minority carrier lifetime, which increases switching speed. An added benefit of increasing the diode's junction area is a reduction in its forward-biased resistance, improving isolation in a shunt switch.

Frequency and Bandwidth

For a shunt configuration, the insertion loss (in dB) caused by the diode is given by:

$$10 \log [1+ 2 (Z_0 \pi F C_j) 2] \quad \textbf{for reverse bias}$$

As the diode's capacitance increases, the switch's insertion loss increases dramatically.

For a shunt configuration, the switch isolation in dB is given by:

$$20 \log \left[1+ \frac{Z_0}{2 R_s}\right] \quad \textbf{for forward bias}$$

where

Z_0 is the circuit's characteristic impedance

F is the RF frequency of interest

C_j is the diode's junction capacitance

R_s is the diode's forward-biased resistance

Reflective Switches

A reflective switch is one in which the incident power at the "off" port is reflected back to the source as a result of the impedance mismatch presented by the PIN diode. In contrast, an absorptive switch is designed to present a 50 ohm impedance in the "off" state, and to absorb incident power.

Typical reflective switches (Figure 4) include the previously described SPST series configuration, and an all-shunt arrangement, with its inherently higher power-handling ability and switching speed. The operating bandwidth of the switch is determined by the blocking capacitors selected, the bias circuitry and the diode's reverse-bias capacitance. Reducing the diode's shunt resistance increases isolation in this type of switch. This reduction is achieved either by increasing the current or decreasing the diode's overall resistance. In addition, by adding a fourth shunt diode, isolation can be increased, which is accompanied by an increase in insertion loss, but with little impact on power handling and switching speed.

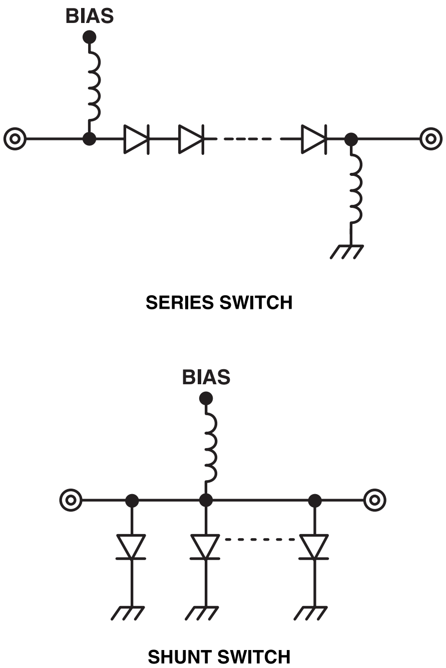

Figure 4 - Reflective SPST switch

Multi-Throw Reflective Switches

Taking this design to a multi-throw configuration (Figure 5), the low insertion loss at the "on" port must be isolated from the high insertion loss at the "off" port with a series PIN diode. Isolation at the "off" port is a function of frequency and diode capacitance, and isolation will increase as the capacitance of the series diode decreases. However, increased bandwidth (lower capacitance) comes at the expense of reduced power-handling ability. The number of throws can be extended in this type of switch, limited only by the diode's junction capacitance and the physical size limitations of the switch.

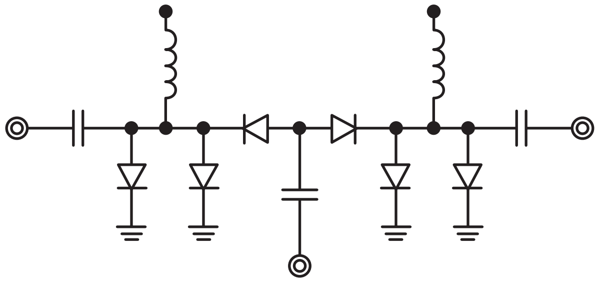

Figure 5 - Reflective SP2T Switch

Absorptive Switches

Multi-throw absorptive switches either employ the series-shunt or series with shunt termination approach (Figure 6). The required 50 ohm terminating impedance is achieved by the series combination of the diode and terminating resistance to ground. This type of termination has good high-frequency characteristics, but power-handling ability is limited by the ability of the diodes and resistors to dissipate RF power. In addition, absorptive switches typically exhibit somewhat slower switching speeds. These types of switches are usually not absorptive at their common port (in the "all-off" state) but can be made absorptive for special applications.

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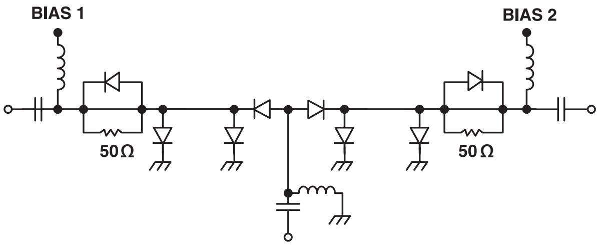
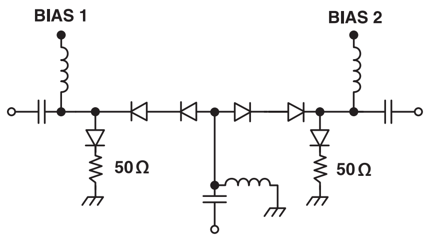


Series-Shunt SP2T, Absorptive



Series SPDT with Shunt Termination

Figure 6

Transmit/Receive (T/R) Switches

T/R switches are used to switch a single feedline between a transmitter and receiver and can benefit greatly from PIN diode switch technology. They are more reliable, faster and more rugged than their electro-mechanical counterparts. The basic T/R switch consists of a PIN diode connected in series with the transmitter and a shunt diode connected one-quarter wavelength away from the antenna in the direction of the receiver section (Figure 7). Of course, quarter-wavelength spacing is not practical at low frequencies, so quarter-wavelength lumped elements can be used instead. In T/R switches, the trade-off is between achieving low loss for the receiver path and high power-handling ability for the transmitter path.

When the switch transfers the feedline to the transmitter, each diode becomes forward biased. The series diode appears as a low impedance to the signal approaching the antenna, and the shunt diode shorts the receiver's antenna terminals to prevent overload. Transmitter insertion loss and receiver isolation are dependent on the diode resistance. In the receive condition, the diodes are zero or reverse-biased, and present a low (shunt) capacitance which creates a low-loss path between the antenna and receiver. The "off" (transmitter) port is isolated from this path by the high-impedance series diode.

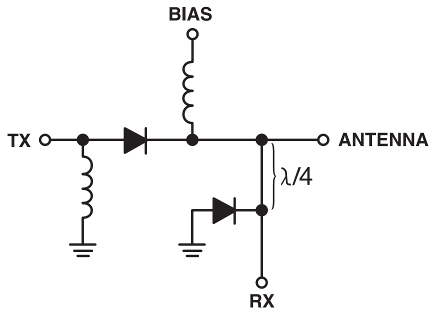


Figure 7 - T/R Switch

A Word on Drivers

A PIN diode switch will perform only as well as its driver allows. The driver must be capable of supplying the necessary reverse-bias voltage in order to achieve the desired diode capacitance, and must source or sink the bias currents required to drive the diodes to their rated forward-bias resistance. In addition, fast switching requires the transition time between driver output levels to be as short as possible. Relatively high voltage "spikes" are also required to remove charge from forward-biased diodes and speed up their switching time.

From the user's perspective, the important parameters are:

- Switching speed and repetition rate
- Number of switch throws
- Number of control lines (i.e., one line per throw or integral switch logic decoders)
- Logic sense (Ø = low-loss state is typical)
- Driver integral to switch assembly or mounted separately. High-speed switch driver circuits are usually built as hybrid (chip and wire) circuits to reduce size and increase speed, and are mounted next to the RF section.

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PIN Diode Attenuators

Introduction

PIN diode attenuators range from simple series connected or shunt-connected diodes acting as a lossy reflective switch to more complex structures that maintain a good input match across the full dynamic range of the attenuator. PIN diode attenuator circuits are used extensively in automatic gain control (AGC) and RF leveling applications.

Although other methods are available for providing AGC, such as varying the gain of the RF amplifier, the PIN diode approach results in lower power drain, less frequency pulling, and lower RF signal distortion. Lower attenuator distortion is achieved using diodes with thicker "I" regions and long carrier lifetimes.

In an attenuator, the resistance characteristics of the diode are exploited not only at their extreme high and low values as switches, but also at values in between. Thus, PIN diode attenuators tend to produce less distortion than amplifiers but more than switches. The resistance characteristic of a PIN diode when forward-biased depends on the "I" region thickness, carrier lifetime, and hole and electron mobilities. A PIN diode with a thin "I" region will operate at lower forward-bias currents than a PIN diode with a thick "I" region, but the latter diode will generate less distortion. Careful selection of diode "I" layer thickness can yield a good compromise between attenuator speed, distortion, linearity, and power-handling ability. In addition, it is easier to linearize the driver for thicker diodes.

Notes on Attenuator Performance

Understanding how the following parameters affect performance makes it easier to choose the best type of attenuator for a particular application.

Phase Shift and Attenuation

A PIN diode attenuator's phase shift varies as the attenuation level changes. This is a result of stray PIN diode reactance vs. bias level, or (in the case of a switched-bit attenuator) the different lengths of the transmission paths connecting the diodes that are being switched in or out. It can never be entirely eliminated. However, attenuators can be designed to reduce phase shift to a very low level, especially over narrow bandwidths.

IMD and Harmonics

Every PIN diode-based device generates some level of harmonics and intermodulation products because diodes are non-linear devices. In this regard, switched-bit attenuators outperform analog voltage variable attenuators (VVAs) because switched-bit attenuators are basically just PIN diode switches. That is, their diodes are biased either fully on or fully off.

Power-Handling Ability

An attenuator's power-handling ability is dictated by its design, bias conditions, and switching speed. Generally speaking, faster VVAs handle less power, especially at low frequencies. An attenuator's maximum operating power level is defined as the amount of power required to cause 1 dB attenuation compression. At or near the 1 dB compression point, the attenuator will produce its highest levels of IMD and harmonics. Generally, the faster diodes will handle less power at lower frequencies because of the compression point's dependence on "I" layer thickness. The attenuator's survival rating is dictated by the diodes' survival rating. As might be expected, attenuator power-handling specifications vary considerably and can be tailored to the needs of a specific application.

Monotonicity

This is a required attribute of any type of attenuator, regardless of the application. Without a monotonic attenuation relationship to the analog or digital control commands, the attenuator's accuracy and other characteristics can never be optimal. Non-monotonic behavior can be exhibited by switched-bit attenuators as a result of uncompensated internal VSWR interaction, and in digitally-controlled analog attenuators with errors in digital calibration toward the band edges.

Mean Attenuation

This parameter is the average of maximum and minimum values of attenuation over a given frequency range for a given control signal. It is of particular importance in wideband analog VVAs, as they typically have a parabolic attenuation vs. frequency response, and the minimum-to-maximum attenuation vs. frequency at higher levels can be as large as 5 dB in multi-octave designs.

Attenuation Flatness

The attenuation variation from the mean attenuation over a given frequency range for a given attenuation value is called attenuation flatness, and is expressed in dB.

Attenuation Accuracy

This parameter is the maximum deviation of the mean attenuation from the nominal value of the programmed attenuation, expressed in dB.

Total Attenuation Accuracy

This is the sum of the effects that together produce deviation from the set attenuation value, including the contribution of attenuation accuracy, frequency variation, and temperature.

Comparison of Attenuator Characteristics

Parameter	Switched-Bit	Digitally-Linearized Analog
Switching Speed	Very high (20 ns)	Moderate (>100 ns)
Attenuation Accuracy	High	Highest
Attenuation Flatness with Frequency	Best	Moderate
Power Handling	High	Moderate
Operating Frequency Bandwidth	Broad (2-3 octaves)	Moderate (1 octave)
Resolution	High (1 dB)	Highest (0.25 dB)
Calibration	Fixed	Selectable within unit
Cost	High	Moderate
Survival and Compression Power	High	Moderate

Digitally-Linearized Analog Attenuators vs Switched-Bit Attenuators

There are dozens of possible attenuator configurations, each one with its own unique characteristics that make it better suited for one application over another.

Digitally-Linearized Analog Attenuators

Other than switched-bit types, all attenuators are essentially analog devices. There are as many analog attenuator configurations as there are system applications that require them. This guide covers only digitally-linearized analog attenuators, shunt-mounted diode arrays, and switched-bit attenuators, because they are the most common and versatile types.

Typical VVAs contain from one to four shunt-mounted diodes (Figure 8a). Adjusting the bias current changes the resistance of the PIN diodes, reflecting more of the RF signal, which produces the desired attenuation.

This approach is similar to a reflective switch because it presents a poor match at the input and output ports. Most VVAs of this type are built in pairs and mounted between 3 dB hybrids (Figure 8b). The reflected RF power is absorbed by the termination at the hybrid's isolated port, presenting a good match at the VVA's input and output ports.

An analog driver/linearizer or a digital driver (D/A converter with EPROM) can then be used to calibrate and linearize the VVA's attenuation vs. control signal response.

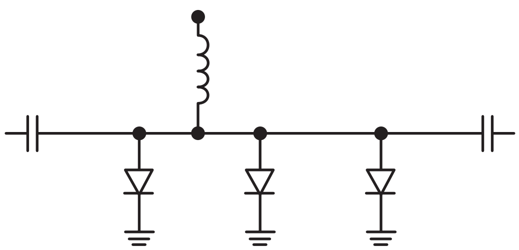


Figure 8a - Reflective

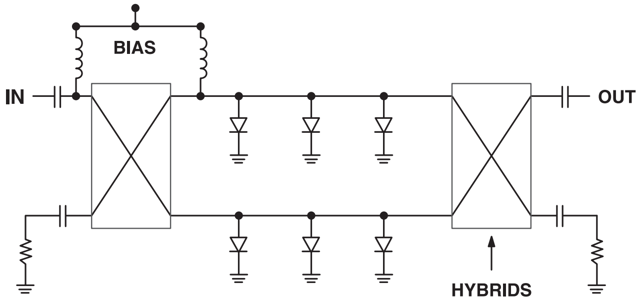


Figure 8b - Non-Reflective

Digitally-Controlled Switched-Bit Attenuators

When broadband, ultra-fast switching performance is needed, the digitally-controlled switched-bit attenuator is the only solution. It excels in attenuation accuracy and flatness over broad frequency ranges, and its switching speed is equivalent to a high-speed PIN diode switch (25 ns or better). Its only disadvantages are higher insertion loss and higher cost.

The digitally-controlled attenuator's topology is based on switching fixed attenuator pads in or out of the RF path using PIN diode SP2T switches. It uses one control bit per attenuator pad, and attenuation step size is determined by the lowest attenuator pad value. The total attenuation range is the sum of all the attenuator pads.

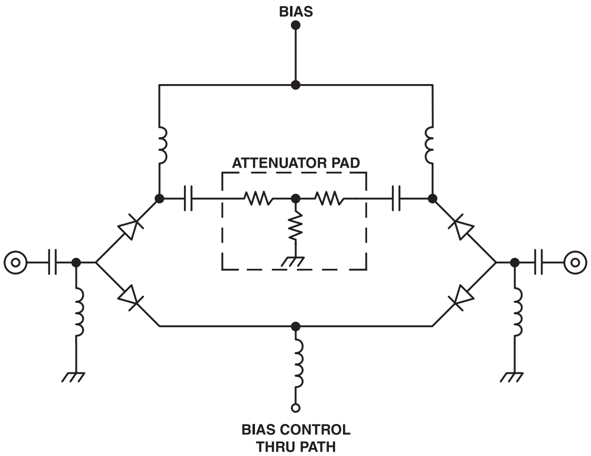


Figure 9

As stated earlier, attenuators are designed to match the requirements of specific applications. When the application requires fast switching speed combined with high power-handling ability (as in electronic warfare systems, for example), the switched-bit attenuator is the optimum choice (Figure 9). It employs one or more pairs of SP2T switches, with a low-loss connection between one pair of outputs, and a fixed attenuator between the other outputs. The diodes are switched between their forward-biased and reverse-biased states, which gives the attenuator higher switching speed.

The switched-bit attenuator achieves low, consistent VSWR performance throughout its dynamic range, and its power-handling ability (i.e., compression point and IMD) is also higher than that of an analog VVA because it uses PIN diode switches.

Of course, like all attenuator types, the switched-bit attenuator has some disadvantages. Its smallest attenuation step size at microwave frequencies is limited to about 0.5 dB because of VSWR interaction among the various high-loss and low-loss transmission paths and their associated bias circuits. This interaction also causes attenuation ripple, which can cause slight degradations in monotonicity. These errors are usually less than about ±0.5 dB.

Finally, the switched-bit attenuator is a comparatively complex RF circuit with more components, and is usually more expensive. These considerations aside, the high speed and power handling abilities of the switched-bit attenuator make it appealing for demanding applications.

Solid State PIN Control Products

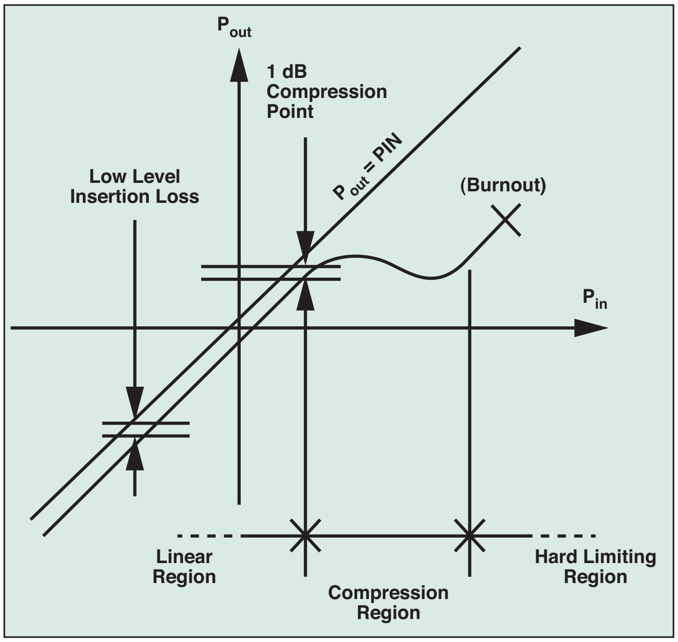
Limiters

Narda offers PIN diode based limiters supporting up to 500 W of pulsed power. The limiters can be supplied as stand alone devices, or as integrated assemblies that include the limiter and other microwave components such as: switches, attenuators, filters, amplifiers, etc.

Definition of Parameters

Input 1 dB Compression Point:

At the Input 1 dB compression point, the output power will start to compress and be 1dB below the value if it was linear.



Recovery Time:

The time period from the end of a high power pulse to the point where the insertion loss value has returned to within 3 dB of the quiescent loss state.

Spike Leakage:

After pulsed high power is applied, the limiter will momentarily pass significantly more power than when it is totally saturated. This power rise is seen as a spike on the leading edge of the leakage pulse. The rise time of the high power pulse and the turn-on time of the diode determine the spike's amplitude. The spike is defined by its energy content, i.e., in ergs.

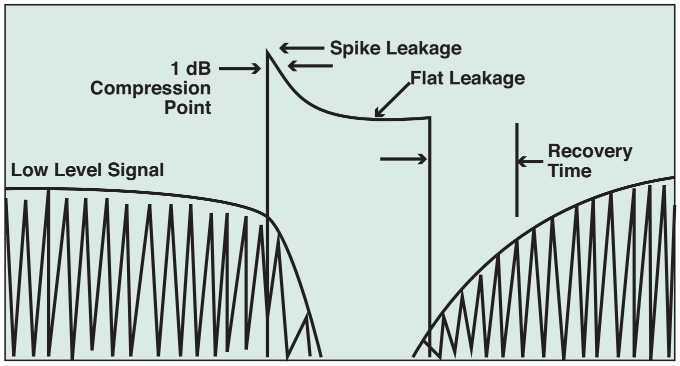
The formula for calculating the spike leakage is as follows:

$$\text{SPIKE LEAKAGE (ERGS)} = t_S \times P_S \times 10^7$$

where:

t_s = spike width at the half-power point in seconds

P_s = maximum spike amplitude in watts



Flat Leakage

The output signal that bleeds through a limiter under high input power conditons.

Power Handling

Two important considerations for defining the required power handling of a limiter are:

1. Peak Pulsed Power: for narrow pulses, equated to an equivalent CW power by multiplying the Peak Power by the Duty Cycle. For pulses exceeding 10 microseconds, Peak Power is considered CW.
2. Source VSWR: When it is fully turned on, the Limiter short circuits across the transmission line, and 90% incident power is reflected back towards the source.

Any mismatch at the source reflects power back toward the limiter, resulting in standing waves. In a correct limiter-source phase relationship, the maximum current point occurs at the input diode, causing the diode to dissipate a greater level of power than incident power. For a source VSWR of up to 2.0, an approximate maximum effective power can be achieved by multiplying the source VSWR by the incident power.

The following formula applies for source VSWRs over 2.0:

$$P_A = \frac{P_S}{[1 \pm (P_{FL} \times P_{FS})]^2}$$

where:

P_A = actual power

P_S = source power

P_{FL} = load (limiter) power factor 0.96 typical

P_{FS} = source power factor

Considerations in Using Limiters

- The difference between the flat leakage and the 0.1 dB compression point is typically between 10 and 13 dB, but may vary according to limiter type.
- There is usually noise generated following the point at which the limiter starts into compression, which can be at -10dBm. However, limiters can and usually do exhibit signs of compression at 0 dBm.
- Limiters dissipate approximately 8% of incident power as heat. Therefore, all limiters should be attached to a heatsink whose temperature does not exceed the maximum rated ambient temperature.
- Limiters are inherently broadband components. Band limitation results from DC return are required by some limiter designs. Limiters with bandwidths of up to 10:1 are relatively simple, while those with bandwidths exceeding 10:1 are progressively more complex and costly.

CAUTION! Limiters are NOT bidirectional components! They have a defined input and output; reverse installation will damage the component.

Glossary

Absorptive Device – A device in which the specified VSWR is maintained and all power is absorbed in the device during the high-loss state.

Accuracy/Linearity – In voltage-variable attenuators, the variation of the mean attenuation from the best straight line of attenuation vs. control signal transfer function.

Analog Attenuator – A unit in which attenuation level is controlled either by an applied current in a driverless unit or by a voltage in a unit with a driver. Attenuation level is continuously variable.

Attenuation Accuracy – The deviation of mean attenuation from the nominal attenuation value at a specified temperature (usually room temperature).

Bias – The control voltage or current signals supplied to a unit that provide proper operation for devices without integral drivers.

Carrier Suppression – The minimum ratio of carrier output power to the translated carrier output power in a phase shifter operated as a frequency translator.

Commutation – With all other ports set to isolation, one port is switched from insertion loss to isolation, while another port is switched from isolation to insertion loss. This specification applies only to multi-throw switches.

Digitally Controlled Voltage Variable Attenuator (VVA) – An analog attenuator with an integral driver in which control inputs are logic bits. Attenuation is not continuously adjusted, but is selected in steps. The steps are defined by the number of bits employed by the device, the maximum attenuation of the unit, and the logic levels applied to it.

Driver – The circuit used to convert analog or logic command signals to the bias conditions needed to execute control of active devices.

Fall Time – A measure of switching speed represented by the time between the 90 percent and 10 percent points of the detected RF power, when the unit is switched from insertion loss (on) to isolation (off).

Insertion Loss – The difference, measured in dB, between input power level and output power level when the unit is in a low-loss condition.

Solid State PIN Control Products

Isolation – The difference, measured in dB, between input power level and output power level when a unit is in a high-loss condition.

Mean Attenuation – The average attenuation over an attenuator's range of operating frequencies.

Modulation – With all other ports set to isolation, one port is repeatedly switched on and off.

Modulation Bandwidth – The maximum repetition rate at which a device can be switched.

Monotonicity – As the control input level is increased, the attenuation level continuously increases.

Off Time – A measure of switching speed represented by the time between the 50 percent point of input control pulse to the 10 percent point of detected RF power, when the unit is switched from insertion loss (on) to isolation (off).

On Time – A measure of switching speed represented by the time between the 50 percent point of input control pulse to the 90 percent point of detected RF power, when the unit is switched from isolation (off) to insertion loss (on).

Operating Frequency Range – The band of frequencies over which the product must operate and deliver specified performance.

Operating Power (Power Handling) – The maximum power over which a unit will achieve specified performance.

Operating Temperature Range – The temperature range over which a unit will achieve specified performance.

Phase and Amplitude Matching – The maximum range of values within which all phase or amplitudes are controlled over a specified frequency range. Usually referenced to one port and measured from port-to-port or unit-to-unit.

Phase Shift – The difference in electrical phase of a signal from the input of the device to its output. Measured as absolute insertion phase, or with respect to a given state.

Reflective Device – A device in which the incident power is reflected back to the source when the port is in the high-loss state.

Rise Time – A measure of switching speed represented by the time between the 10 percent and 90 percent points of the detected RF power, when the unit is switched from isolation (off) to insertion loss (on).

Sideband Suppression – The minimum ratio of any sideband output power to the translated carrier output power when a phase shifter is operated as a frequency translator.

Survival Power – The maximum RF power level to which a unit can be subjected without permanent performance degradation or failure. ***Cold switching only.***

Switching Speed – Either Modulation or Commutation. All specifications, unless otherwise noted, in the Narda catalog, are Modulation Switching Speed. See page 294.

Temperature Coefficient – The average rate of change in phase shift (degree phase shift/°C) or attenuation change (dB/°C) over the entire operating temperature range of the unit.

VVA Linearity – In a voltage-variable attenuator, the variation from straight-line attenuation vs. control signal level.