PIN Switches and PIN Switch Drivers

1 Overview

RF and Microwave switches (RF switches) are used to direct RF and Microwave signals between a common port and a number of individual ports ranging from just a single port (Single Pole Single Throw – SPST) to many ports such as a SP6T (Single Pole Six Throw). The common port can be connected to either input signals as in the case of a common antenna or the input to switched filters, or as an output as might be the case to select a particular output from several filters. A common usage is that of a Transmit/Receive switch (T/R) in which the common port acts as the input to the receiver and the output of the transmitter, shown diagrammatically in figure 1a. Such usage puts constraints on the design as transmitters often handle high power whereas receivers require good low signal level performance and isolation from any high power from the transmitter. Figure 1b shows a multi-pole switch configured for a switched filter.

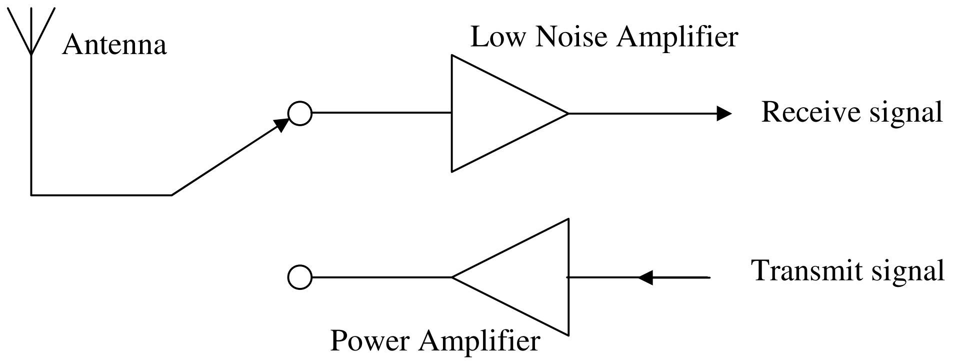


Figure 1a: SPDT switch used for T/R application

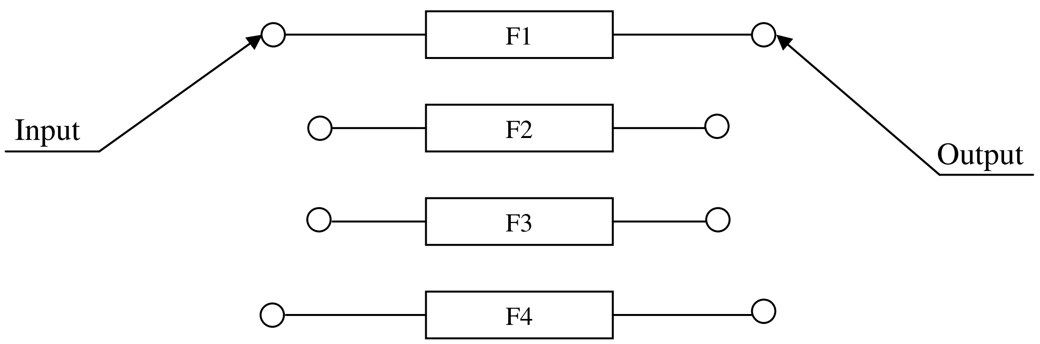


Figure 1b: SP4T Switches used in switched filter application

2 Switch Types

RF Switches can be classified by their capability. The three most often encountered types of switches are MMIC based switches, PIN switches and Coaxial (mechanical) switches all with their own characteristics that make them suitable for different applications:

MMIC	MESFET and HEMT based MMIC switches are suitable for relatively low power use (<circa 25dBm), have very fast switching time capability and consume very little power at relatively low voltages from the control electronics
PIN	PIN switches (also NIP switches) are capable of handling medium to high powers, have fast switching times but can consume more current from the control voltage and may require relatively high voltages depending on the RF power that they are required to handle.
Coaxial	These are mechanical switches used in applications where switching speed is not important such as test and measurement or where higher power is required.

Labtech Microwave standard offering of switches is in the PIN switch domain offering high isolation, low insertion loss, fast switching speed and mechanically robust construction for use in harsh environments such as ship borne or airborne systems.

3 PIN Switches

PIN (P–Intrinsic–N) diodes have an un-doped (Intrinsic) region of semiconductor sandwiched between highly doped P and N type contact regions and at high frequencies this behaves like a resistance that is inversely related to the DC bias current passing through the diode. When forward biased the resistance is very low and the diode acts like a short circuit; at high reverse bias the resistance is very high and the diode acts as an open circuit. By configuring these in a circuit through which RF signals pass, the diode can either pass or stop the RF signal.

Note that sometimes NIP diodes are used (N-Intrinsic-P). These have the P-type material rather than the N-type material bonded to the device case, for example, to allow the cathode to be mounted on a heatsink rather than the anode. This can be useful in some circumstances, for example to accommodate non conventional drive voltages.

PIN switches are generally broadband devices offering good performance from less than 1 GHz to more than 20 GHz. Performance trade offs can be made for narrower band applications but a lower limit of a few hundred MHz is dictated by the requirement to keep the PIN diode operating as a voltage controlled resistor. In low and medium power switches, an example of which is shown in figure 2, a typical configuration would consist of a series PIN diode followed by one or more shunt PIN diodes. By arranging suitable bias on the diodes the series diode is made very low resistance and the shunt diodes are made very high resistance and the circuit will pass the RF signal. If the opposite bias is applied such that the series diode is made very high resistance and the shunt diodes are

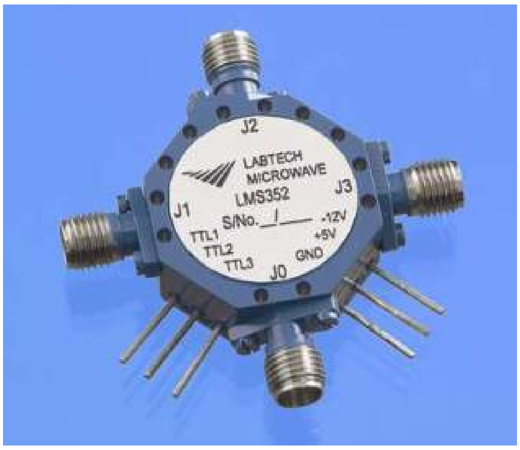


Figure 2: Example of Multiway (SP3T) PIN diode switch

made very low resistance the RF signal will not be passed through the circuit. These circuits are capable of low insertion loss and high isolation. By combining multiple circuits, switches with typically up to six selectable and one common port are readily manufactured. Beyond six ports, physically connecting the circuits together becomes difficult and alternative configurations are often used.

For higher power configurations the series diode can limit the power handling due to heat dissipation because it is not easy to mount the diode in such a way that the heat can be extracted from the diode. In these circumstances shunt only design are often used. However, this can limit the isolation since the series diode contributes significantly to this parameter.

Biasing the diodes is achieved from a switch driver; see section 5. In forward bias the diodes are in a high-level injection regime and a significant current level flows; typically 15-30 milli-amperes. The current is much less in the reverse bias direction. However, if significant powers are to be handled by the switch, the reverse bias must be high enough that the RF signal does not at any time begin to forward bias the diode and voltages in excess of 50V may be required for switches that handle powers in excess of 500W. Note that in general the switches may not be able to turn this power level on and off, so called hot switching. Under normal operation the RF power will be disabled before the switch is operated; cold switching.

Another consideration is switching speed. The switching speed, often defined as the time from the control voltage being 50% of its transition voltage until the RF signals is 90% or 10% of its final value can be very fast, typically <25ns for a medium power device. For high power devices this can be considerably longer because of the increased area of the PIN device to handle higher currents and the inability of the driver to remove the injected charge that resides in the intrinsic layer. For high power switches therefore, the switching time can be as high as 1µs although by applying suitable waveforms from the driver some speeding up of this circuit is often possible. However, fast switching speeds are not always desirable as the fast transient waveforms generated can be impressed on the RF signal which can affect other system performance. The compromise is dictated by the system designer but labtech can offer a range of switching speeds on many of its switches to accommodate individual requirements.

4 Switch configurations

Apart from the number of ports that a switch is designed to support, some applications require that unused ports are terminated so that they do not reflect any incident power. An RF connection made at one port of a switch is normally terminated by a load at the other port. The load may be an antenna, gain stage, filter, resistive load etc. However, any connections made to a switch port that is not connected through the switch will ordinary be reflected back along the feed line. This is undesirable in some instances and may be corrected by incorporating a load within the switch that is connected to any unconnected ports. This is shown diagrammatically in Figure 3. Such a switch is termed non-reflective or terminated.

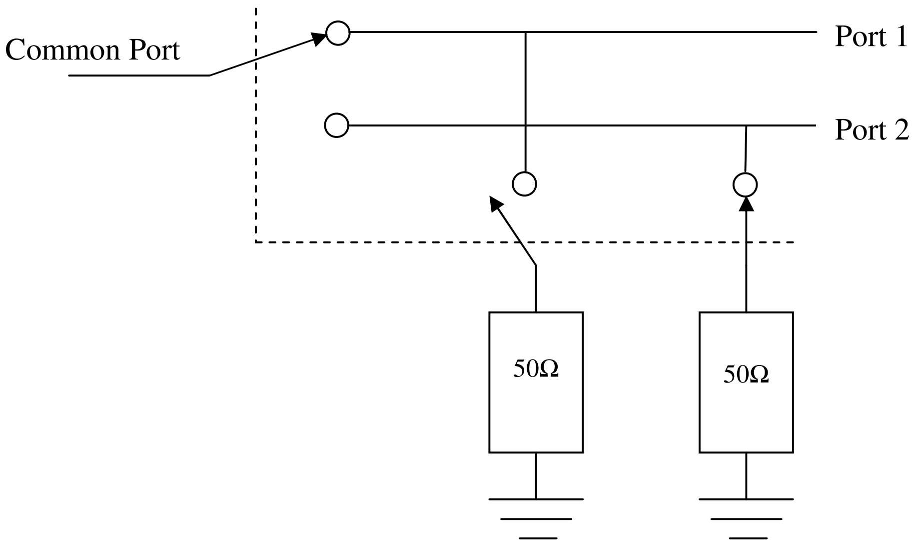


Figure 3: Terminated SPDT Switch

Labtech manufacture a range of standard configurations as indicated in Table 1. We have also manufactured many bespoke switch types for specific applications including multi-

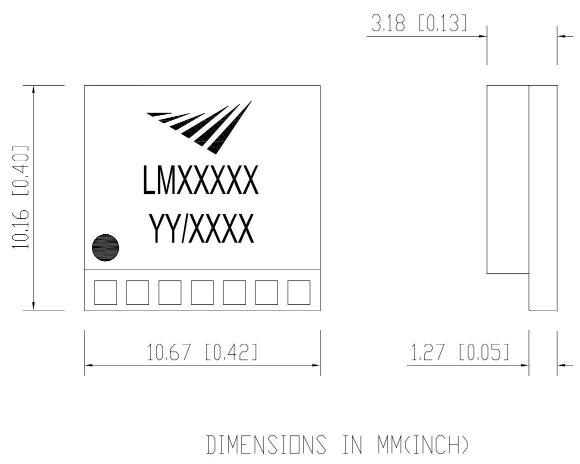
Table 1

Switch Type	Terminated or Reflective	Frequency options	Insertion loss	Isolation	Switching speed
SPST	R & T	0.5-2, 2-4, 4-8, 8-12, 12-18, 2-18 and 0.5-18GHz	0.6-2.2dB Max Depending on Bandwidth and isolation	40-80dB Min	From 25ns to 1us depending on requirement
SPDT	R & T				
SP3T	R & T				
SP4T	R & T				
SP5T	R				
SP6T	R				
SPDT	R	1.0-1.1GHz	0.8dB Max	45dB Min	1μs

way switching modules in which a number of inputs can be connected to a number of outputs in any desired order. Please contact Labtech microwave should you want a switch that does not conform to the standard offerings.

5 Switch Drivers

A range of PIN switch drivers have been designed to meet the demanding drive requirements of PIN diode microwave switches and offer small size, high power and selectable transition times to suit the application. Various arrangements are available to control from 2 to 6 channels. The switch driver includes an enhanced waveform function to improve the removal of stored charge within the PIN diodes enabling faster switching speeds to be obtained. The specification outlined below shows the typical parameters that characterise switch driver performance. For bespoke arrangements please contact Labtech Microwave.



Outline for Standard 2 Channel PIN Switch Driver

Table 2: Pin Functions

Pin	Function
1	Vee
2	Output 1
3	Input 1
4	Vcc
5	Gnd
6	Input 2
7	Output 2

Table 3: Logic

Input	Output Current Source
Hi (Vcc)	Hi (Vcc)
Lo (0V)	Lo (Vee)

Table 4: Absolute Maximum Ratings

Parameter	Min	Max	Units
Supply Voltage			
Vcc	-0.5	+6.5	Volts
Vee	-12.0	0.0	Volts
Vin	-0.5	+6.5	Volts
Temperature			
Operating	-40	+85	C
Storage	-65	+150	C

Typical Electrical Specification

Over the temperature range -55°C to +85°C. The specifications are per channel based on a two channel device.

Table 5: Operating Performance

Parameters	**Test Conditions**	**Min**	**Typ**	**Max**	**Units**
Operating Voltage Vcc Vee[1]		 3.5 -12	 - -	 5.5 -5.0	 Volts Volts
Input High	Vcc 4.5 to 5.5V	0.7*Vcc	-	-	Volts
Input Low	Vcc 4.5 to 5.5V	-	-	0.3*Vcc	Volts
Supply Current Icc Iee	 No Load current Vcc=12V,Vee =–12V (Per channel)	 - -	 - -	 +20 –14	 mA mA
Logic Input Current	Vcc=5.5V (Per input)	–1	-	+1	µA
Short Circuit Current[2] IOL IOH		 - -	 - -	 –8 40	 mA mA
Output Current Spike[3] ISPK+ ISPK-		 - -	 TBD TBD	 - -	 mA mA
Switching speed[4]	50% Input to 90% / 10% Output into PIN load T_High	 -	 10	 25	 ns

Notes:

1 Standard negative voltage range is from -12 to -5V. However, higher negative voltages of up to -100V can be accommodated by the design for use in other applications such as high power switches.

2 The short circuit current can be adapted to meet the requirements of the particular switching requirement.

3 A spike is provided to the available output current during the switching transient to charge/discharge the PIN diode capacitance to enable faster switching speeds.

4 Reference load for switching speed measurements is 3 x GC4271 + 1 x GC4951 PIN diodes.

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