

Top Considerations When Buying or Specifying an RF Switch

When choosing or specifying RF switches, all parameters must be considered simultaneously as they set the topology and circuit architecture of the switch.

Choosing the Right RF Switch

There are several characteristics to consider when determining the best RF switch for a design. The main parameters are the number of throws the switch has, how much power the switch must handle, the linearity requirements for the switch, the maximum insertion loss and minimum isolation between arms that is tolerable, and how the switch is packaged. All of these items are equally important and must be considered simultaneously.

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RF switches are used in many different ways in portable and infrastructure applications. Most often they are used to connect an antenna alternately to a transmitter and a receiver. An RF switch in a small plastic package is an attractive alternative to a larger, heavier, and more expensive passive circulator. RF gallium arsenide (GaAs) field effect transistor (FET) switches consume very little DC power and offer a very good “on” to “off” impedance ratio, making for low insertion loss and high isolation. Their low DC power consumption makes them ideal components for use in battery operated equipment. In addition to low loss and high isolation, there are several other parameters to consider when choosing an RF switch, such as how many throws are required, how much RF power will be passing through the switch and the linearity requirements of the system in which it is to be used. Finally, and equally important, is how the switch die is packaged.

Number of Throws

The first consideration is how many throws the switch needs to have. Will the switch be used for connecting a single antenna to a transmit port and a receive port? Then a single pole, two throw (SP2T) switch is required. Many RF systems cover multiple frequency bands that require different low noise amplifiers, one for each band. In such systems, a higher throw count switch is required. For example, in a quad band system there may be requirements for four different receive paths. In order to switch between the four different low noise amplifier chains, a single

pole four throw (SP4T) switch is required. If the same switch is to be used to connect multiple transmit paths in addition to the receive paths, then an even higher throw count is required. To connect two transmit paths and four receive paths to a single antenna, a single pole six throw (SP6T) is required.

Switch Topology

If a switch must handle both transmit power levels and receive power levels, the design of the switch is more complex and additional performance requirements are imposed upon on the switch. The switch needs to pass the RF signal without creating harmonics or distorting the signal. In addition to traditional single pole multi throw applications, GaAs RF transistors may be interconnected in many different ways to support a variety of system requirements, such as transfer switches, double pole double throw switches (e.g. for antenna diversity applications), and filter switches. Switches can be designed to be matched (absorptive) by incorporating terminating resistors, or without terminating resistors they can be configured to be either reflective “short” or reflective “open” when they are in their isolation state.

Power Handling

After the number of throws is determined, the next thing to consider when specifying a switch is how much RF power it must allow to pass through it, or prevent from passing through it. The power handling of the switch is specified by one or more of several different parameters, the most common of which is 1 dB compression point (P1dB), which is defined as either the input power (IP1dB) or output power (OP1dB) at which the insertion loss increases by 1 dB from its small signal value. The switch’s compression point is influenced by many factors, among which are: the wafer process used for the design, the design topology of the switch itself, the magnitude of the DC bias control voltage applied to the gates of the transistors, the frequency of the input signal, and the thermal properties of the package in which the die is packaged. The 1 dB compression point is best used as a figure of merit. The performance of the switch will become non-linear at input power levels several dB below the IP1dB point.

For lower power applications, say less than 20 dBm, the

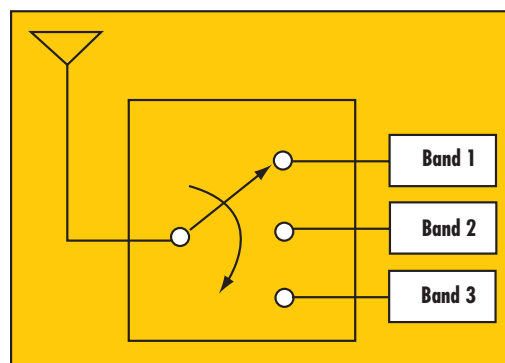


Figure 1. Typical SP3T switch used to switch between three different frequency bands.

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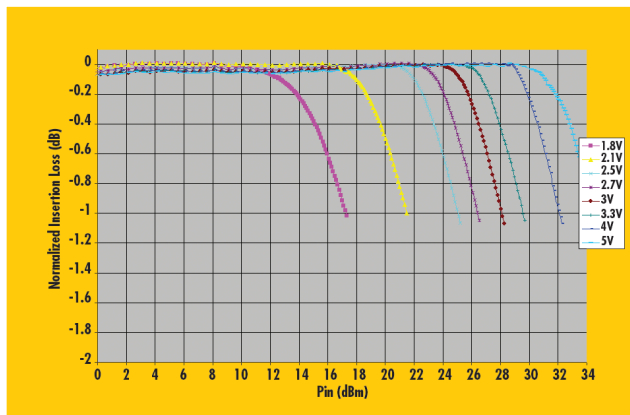


Figure 2. Typical compression curves vs. control voltage of SKY13314-378LF at 5.2 to 5.8 GHz.

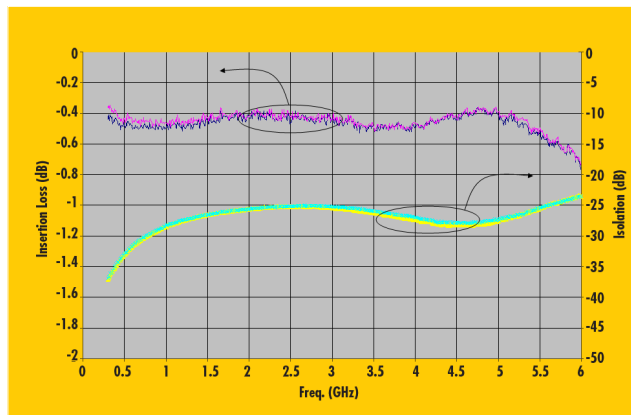


Figure 3. Typical insertion loss and isolation of SKY13320-374LF SPDT switch.

switch can be designed using single gate transistors. For medium power applications (less than 30 dBm), dual gate transistors can be used. For higher power applications (greater than 30 dBm), triple gate or a stack-up of FETs is required.

Linearity

More relevant parameters to specify for switches when it comes to linearity are parameters such as 2nd and 3rd harmonic generation, input third order intermodulation point (IIP3), or error vector magnitude (EVM). These parameters give a better indication as to whether the switch will meet system linearity and spurious emission requirements at the actual input signal levels which will be incident upon the switch in a system. Given specific linearity requirements, the magnitude of the control voltage available, the frequency of operation, the semiconductor wafer process, the switch topology and circuit design must be matched up to meet the linearity requirements.

Insertion Loss and Isolation

The insertion loss, isolation and return loss are key parameters when specifying a switch. The frequency at which they are specified determine the topology of the switch design. For low insertion loss and low isolation requirements, a series-FET-only design can be used. For higher isolation requirements, a series FET followed by a shunt FET (connected between the signal path and ground) is often used. Shunt depletion mode transistors that must operate with positive control voltage, must be DC-floated above ground. The value of the floating capacitor may be chosen to resonate with the bond wire and/or lead

inductance in series with the FET to maximize isolation at a particular frequency. For applications such as synthesizer switching in GSM infrastructure systems, isolation between switch arms must be on the order of 60 dB to prevent one synthesizer from pulling the other. The design of such a switch requires the use of more than one series/shunt section, in order to increase isolation. Unfortunately, the cascading of sections also inevitably increases the insertion loss. Terminating resistors are incorporated to make the switch absorptive in the isolation state, if required by the system design.

Die Size

Taking into account the number of throws, power handling and the requirements for loss and isolation, the size of the die necessary to achieve these parameters is determined. The size of the die and some of the performance requirements, especially power handling and isolation, dictate what package may be used for the switch.

The Package

Plastic encapsulated, lead-frame-based packaging is the most popular and most cost effective way to package an RF switch. The chip is epoxied onto a lead frame carrier with a conductive epoxy. The lead frame is most often made of copper and is then plated with a lead (Pb)-free matte tin (Sn) for easy assembly onto a printed circuit board. The die is wire bonded, typically with gold (Au) wire to make electrical connections to the appropriate leads of the package. The assembly is then overmolded with a "green", RoHS-compliant plastic encapsulant. The top surface of the plastic encapsulant is typically

marked to identify pin #1 and, if space permits, the switch's part number.

The package chosen impacts the performance and ease of use of the part. For higher power switches or switches that require exceptional grounding, the best packages to use are ones with exposed paddles. The exposed paddle provides the best thermal path to the system thermal mass for high power switches and the lowest inductance path to ground for high isolation switches. Packages as small as 1 x 1 millimeter (mm) are available and are becoming very popular for SPDT switches as commercial products become smaller. The tiny size of the 1 x 1 mm package limits the size of the die that may be used and the number of leads the package can have. Larger packages are required for switches with more throws or higher isolation requirements.

Conclusion

When choosing or specifying RF switches there are several characteristics to consider. The main parameters are the number of throws the switch has, how much power the switch must handle, the linearity requirements for the switch, the maximum insertion loss and minimum isolation between arms that is tolerable, and how the switch is packaged. These items all need to be considered simultaneously as they set the topology and circuit architecture of the switch.

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