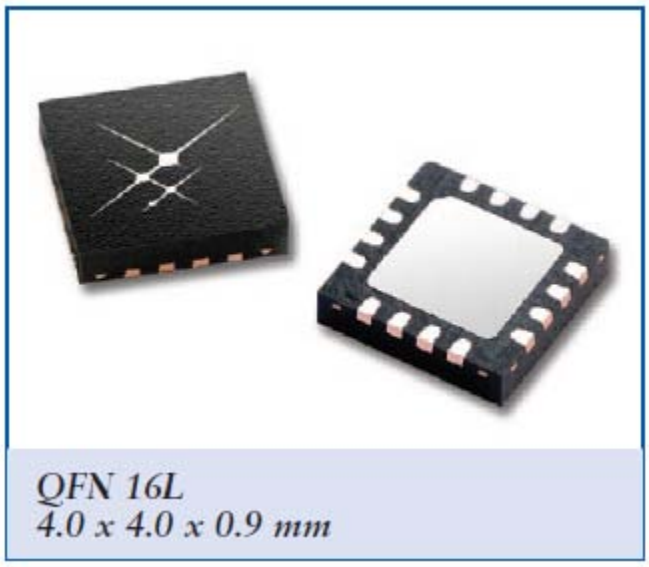
23rd ANNIVERSARY MPD MICROWAVE PRODUCT DIGEST

February 2012

50 W High Power Silicon PIN Diode SPDT Switch

By Rick Puente, Skyworks Solutions, Inc.

Radio transceiver designers have searched for a low cost solution to replace expensive mechanical switches and relays to direct high power transmit signals to the antenna and prevent that signal from entering the sensitive front end of the local receiver, while also allowing a low-loss connection between the antenna and the receiver. New low cost, solid state, PIN diode based switches, configured as transmit-receive (T-R) switches, perform this function.



A High Power Handling Solid State T-R Switch

The SKY12207-306LF SPDT switch utilizes a series, shunt diode pair and one series PIN diode to achieve high-power handling, 50 watts CW and 200 watts peak, low insertion loss of 0.4 dB typical and high isolation of >40 dB at 2 GHz. The switch can be used in many applications, but its primary application is as a transmit-receive failsafe switch in the frequency range of 0.9 to 4.0 GHz for WiMAX, TD-SCDMA or LTE base stations. The device is provided in a 4 x 4 x 0.9 mm, 16-pin Quad Flat No-Lead (QFN) package.

The internal circuitry of the SKY12207-306LF is shown in **Figure 1**. The circuit is a reflective, single pole double throw switch with asymmetrical sections. The RX side utilizes a low resistance single series diode and a shunt diode for low loss and high isolation. A small MIS chip capacitor connected to the shunt diode provides an AC-ground return. The TX side incorporates a single series diode capable of handling high RF power. These two ports are connected to a common antenna port labeled “ANT.”

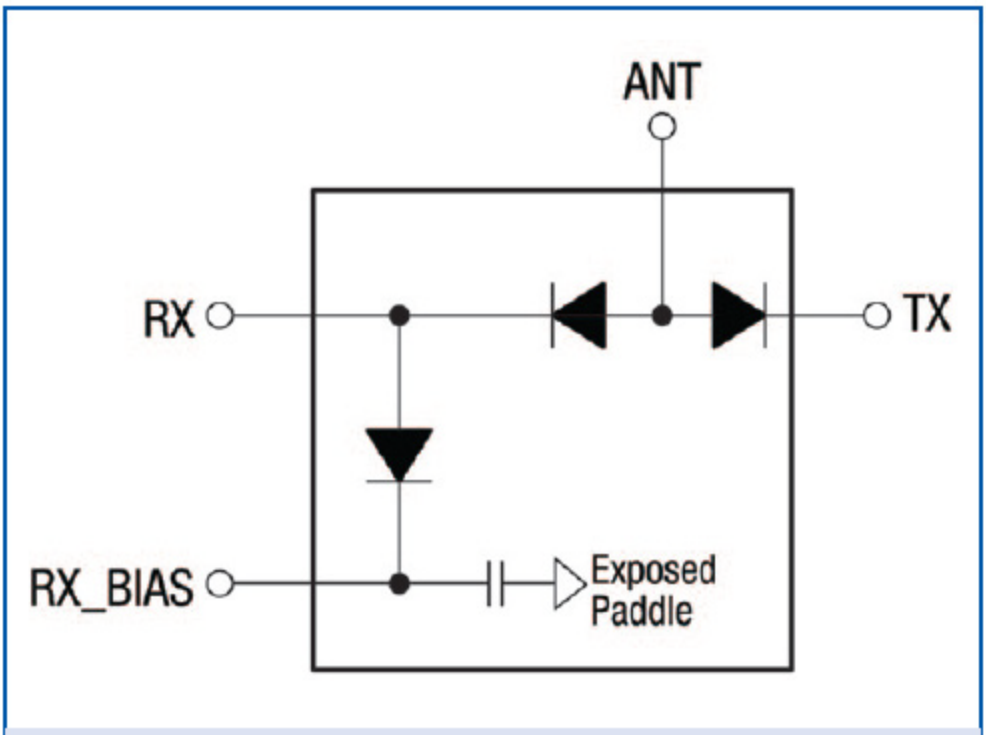
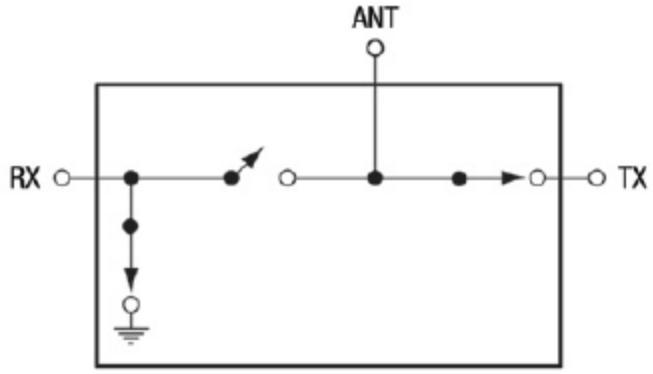


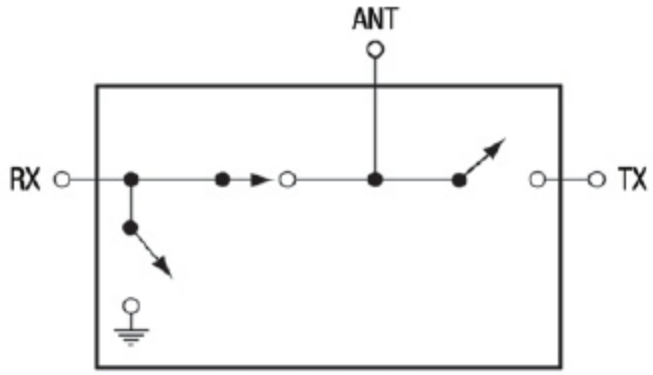
Figure 1: The SKY12207-306LF Circuit

This switch is operated in one of two discrete states as shown in **Figure 2**. In ANT-RX mode, the series diode on the RX side of the switch is forward-biased, resulting in low impedance and low insertion loss between the antenna port and the RX port. At the same time, the series TX diode and the RX_BIAS shunt diode on the RX side of the switch is in the reverse-bias state, which provides high impedance resulting in high isolation between the TX port and the antenna port.

In ANT-TX mode, the series diode on the TX side and the RX_BIAS shunt diode on the RX side of the switch is forward-biased, resulting in low impedance and low insertion loss between the antenna port and the TX port. At the same time, the series RX diode is in the reverse-bias state, which provides high impedance resulting in high isolation between the RX port and the antenna port.



Transmit State



Receive State

Figure 2: The SKY12207-306LF Switch States

Most new radio designs can only support positive value bias control. The SKY12207-306LF operates with either a 5V or 28V positive supply to provide the voltage differentials needed for reverse bias. Positive-forward currents are achieved by applying a positive voltage across external resistors R2 and R3. **Figure 3** shows the external-bias circuitry, which includes RF chokes, RF bypass and DC blocking capacitors for use in most applications.

In the ANT-TX mode, the low insertion loss state is produced by applying 50 mA of forward bias to the TX series diode and RX side shunt diode while the RX series diode is reversed biased with 28 V. In the ANT-RX mode, the low insertion loss state is produced by applying 50 mA of forward bias to the RX series diode while the TX and the shunt diode on the RX side are reversed biased with 28V.

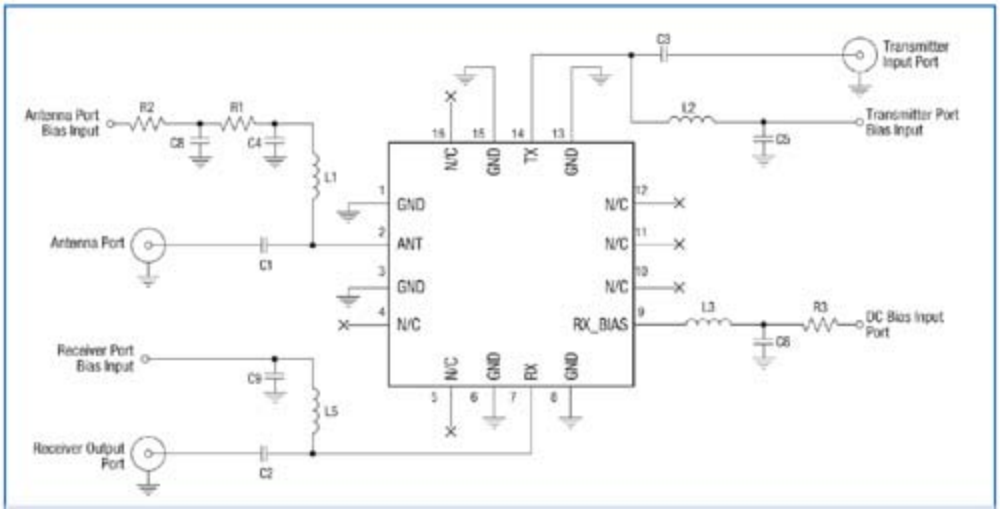


Figure 3: The SKY12207-306LF Schematic Circuit

When large signals are applied to a PIN diode, the RF electric field forces charge carriers into the I-layer, thereby reducing the diode's impedance. In other words, the resistance decreases as input power increases. A substantial reverse bias is applied to the PIN diode to hold the diode in its high-impedance state in the presence of RF voltages large enough to instantaneously apply forward voltage to the diode and possibly into conduction. The magnitude of reverse voltage required in a high-power switch depends on frequency, RF voltage and PIN diode I-region width. For the SKY12207-306LF switch at 50 watts incident power, 28 volts reverse voltage is specified. This was determined experimentally and conforms to theoretical analysis. The larger reverse bias voltage also reduces harmonic and intermodulation distortion produced by the nonconducting PIN diode.

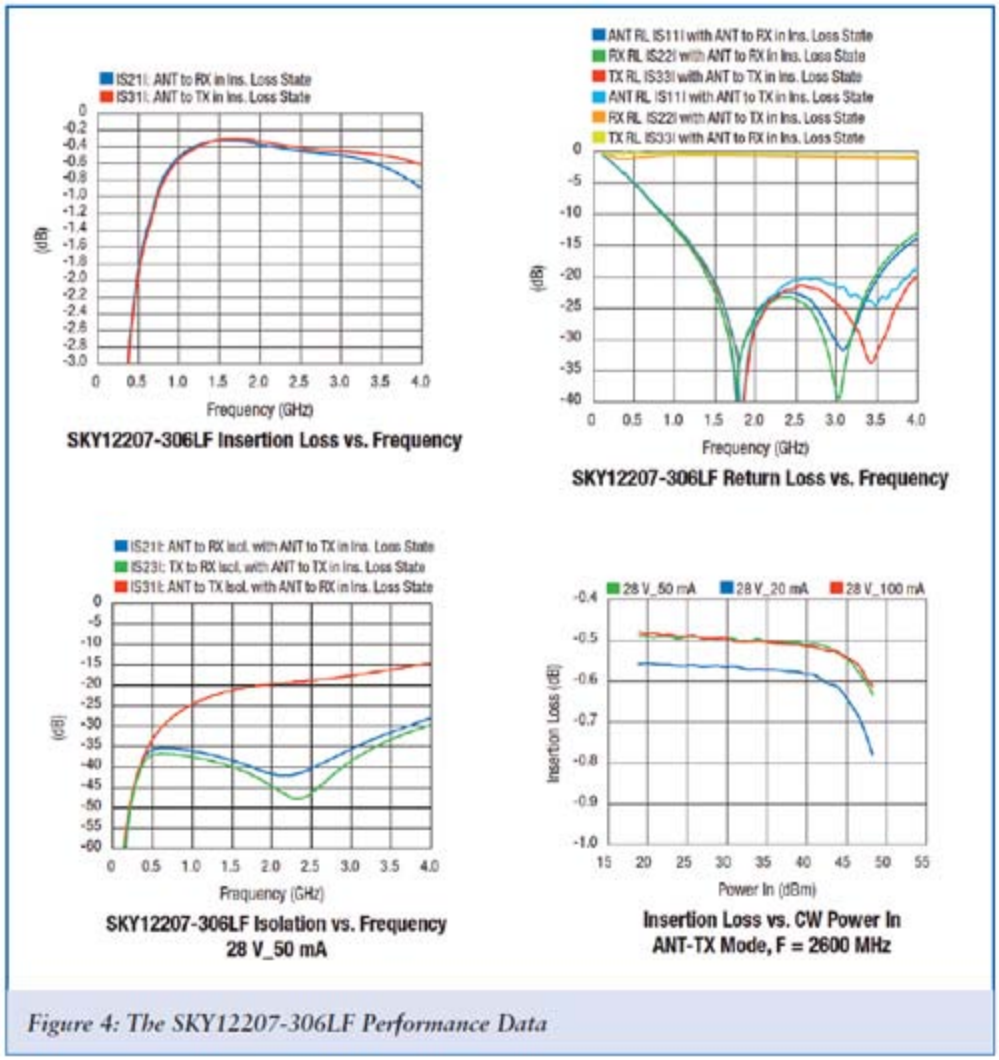


Figure 4: The SKY12207-306LF Performance Data

The SKY12207-306LF Performance

Table 1 indicates typical performance of the SKY12207-306LF. The data was taken at: TA = 25°C, Z0 = 50 Ohms.

Table 1: Typical Performance of the SKY12207-306LF

Switch State	Path		Control Conditions			
	Antenna-to-Receiver Port	Transmitter-to-Antenna Port	Antenna Port Bias Input	Receiver Output Port	Transmitter Port Bias Input	RX_BIAS Input
Receive	Low Insertion loss	High isolation	28 V	0 V (ground)	28 V	28 V
Transmit	High isolation	Low Insertion loss	28 V	28 V	0 V (ground)	0 V (ground)

Conclusion

Radio transceiver designers now have a low cost solution to replace expensive mechanical switches and relays. Skyworks Solutions has introduced the SKY12207-306LF, a solid state, high power, T-R switch which can handle 50 W CW, 200 W peak transmitter power operating from 0.90 to 4.0 GHz.

Also available from Skyworks Solutions is the SKY12208-306LF 50W, high power T-R switch, operating from 0.02 to 2.70 GHz. Samples are also available of the new SKY12210-478LF 100 Watt High Power SPDT switch, operating from 0.90 to 4.0 GHz, that addresses the higher power requirements of TDD-LTE within infrastructure applications.

References

1. Design with PIN Diodes, Skyworks' Application Note APN1002.
2. R. Caverly and G. Hiller, "Distortion in PIN Diode Control Circuits", IEEE Trans. on Microwave Theory and Techniques, vol. MTT-35, p. 492, May 1987.
3. R. Caverly and G. Hiller, Establishing the Minimum Reverse Bias for a PIN Diode in a High Power Switch, IEEE Trans. on Microwave Theory and Techniques, vol. MTT-38, p. 1938, Dec. 1990.