24th ANNIVERSARY MPD MICROWAVE PRODUCT DIGEST

October 2013

100W High Power Silicon PIN Diode SPDT Switches

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, high power handling, PIN diode based switches, configured as transmit-receive (T-R) switches, perform this function.

QFN 16 L 4.0 x 4.0 x 1.5 mm

High Power Handling Solid State T-R Switches

The SKY12210-478LF and SKY12212-478LF SPDT switches utilize a series, shunt diode pair and one series PIN diode to achieve high-power handling of 100 watts CW and 480 watts peak, low insertion loss of 0.4 dB typical and high isolation of >40 dB. Both switches can be used in many applications, but their primary application is as a transmit-receive failsafe switch.

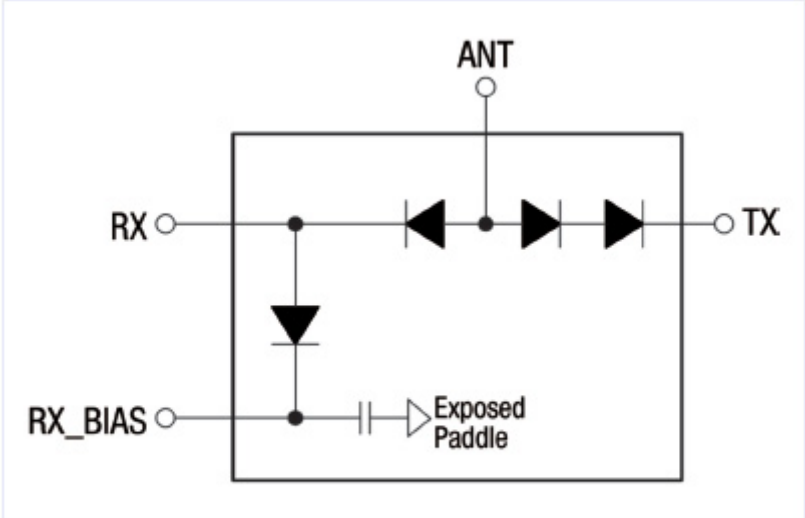

Figure 1: The SKY12210-478LF and SKY12212-478LF Circuit

The SKY12210-478LF operates in the frequency range of 0.9 to 4.0 GHz and is particularly useful in WiMAX, TD-SCDMA or LTE base station applications. The SKY12212-478LF operates in the frequency range of 0.02 to 2.7 GHz and is ideal for UHF, land mobile radios, public safety radios, and military communication system applications. Both devices are provided in a 4 x 4 x 1.5 mm, 16-pin Quad Flat No-Lead (QFN) package.

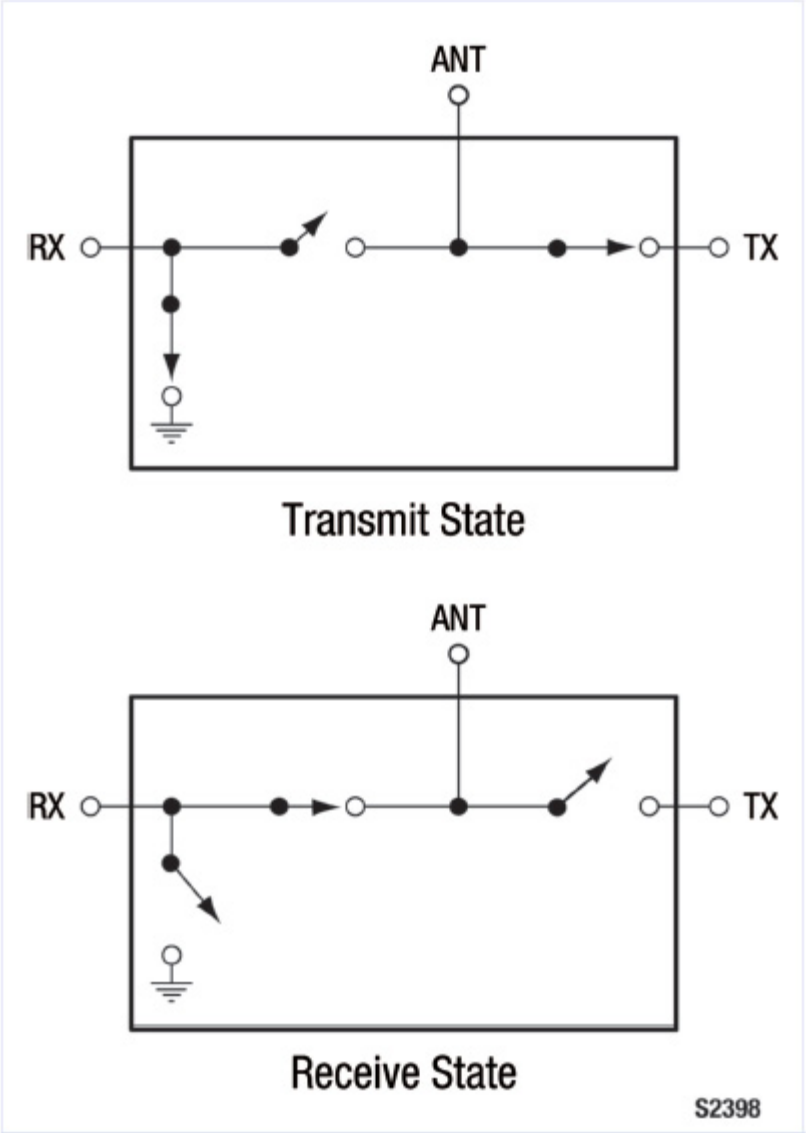

Figure 2: The SKY12210-478LF and SKY12212-478LF Switch States

The internal circuitry of both switches is shown in **Figure 1**. The circuit is a reflective, single pole double throw switch with asymmetrical sections. The common antenna port is labeled “ANT.” The TX side incorporates two series diodes capable of handling high RF power. 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, as well as RF tuning while the switch operates in the ANT-RX isolation state. The SKY12210-478LF is constructed with maximum ANT-RX isolation at 2 to 3.2 GHz, while the SKY12212-478LF operates with maximum ANT-RX isolation at 1.8 GHz and below.

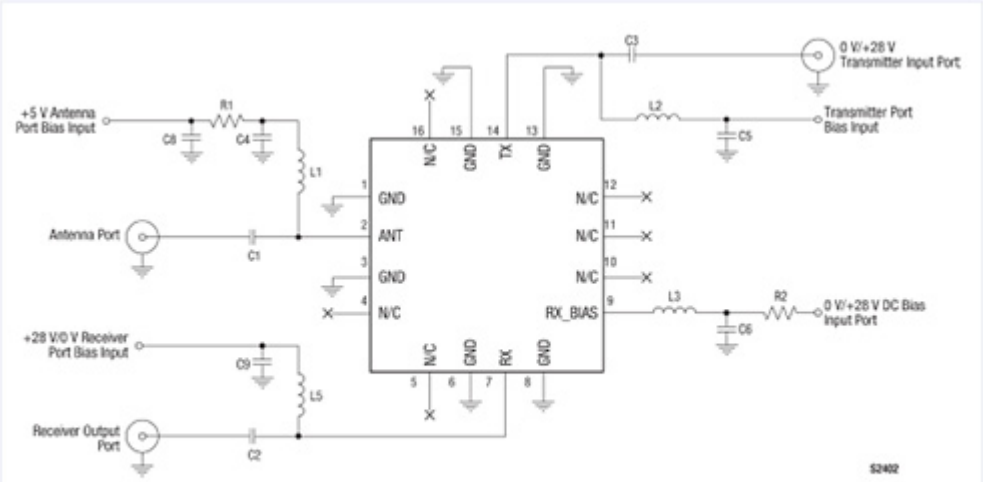

Figure 3: The SKY12210-478LF and SKY12212-478LF Schematic Circuit

Both switches are operated in one of two discrete switch 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.

Table 1: Part Switch Control Logic

Switch State	Path		Control Conditions			
	Antenna-to-Receiver Port (Pin 2 to Pin 7)	Transmitter-to-Antenna Port (Pin 14 to Pin 2)	Antenna Port Bias Input (Pin 2)	Nominal Receiver Output Port (Pin 7)	Nominal Transmitter Port Bias Input (Pin 14)	RX_BIAS Input (Pin 9)
Receive	Low Insertion Loss	High Isolation	1 V	-100 mA	28 V	28 V
Transmit	High Isolation	Low Insertion Loss	2 V	28 V	-100 mA	-100 mA

Table 2: Schematic Circuit Switch Control

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	5 V	0 V (ground)	28 V	28 V
Transmit	High Isolation	Low Insertion Loss	5 V	28 V	0 V (ground)	0 V (ground)

Most new radio designs can only support positive value bias control. The SKY12210-478LF and SKY12212-478LF operate with both +5 V and +28 V positive supplies 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. This circuitry defines the DC and RF performance of the switches. Component values and sizes can be found in the product data sheets.

In the ANT-TX mode, the low insertion loss state is produced by applying 100 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 100 mA of forward bias to the RX series diode while the TX series diode and the shunt diode on the RX side are reversed biased with 28 V. Table 1 indicates switching logic of the SKY12210-478LF and SKY12212-478LF part. For typical applications, 5 V is supplied at the ANT port resistor to set up the voltage differential needed to produce the current through the series diodes when in forward conduction mode, or a reverse bias state when the TX or RX pins are 28 V. Table 2 indicates switching logic of the SKY12210-478LF and SKY12212-478LF schematic circuit.

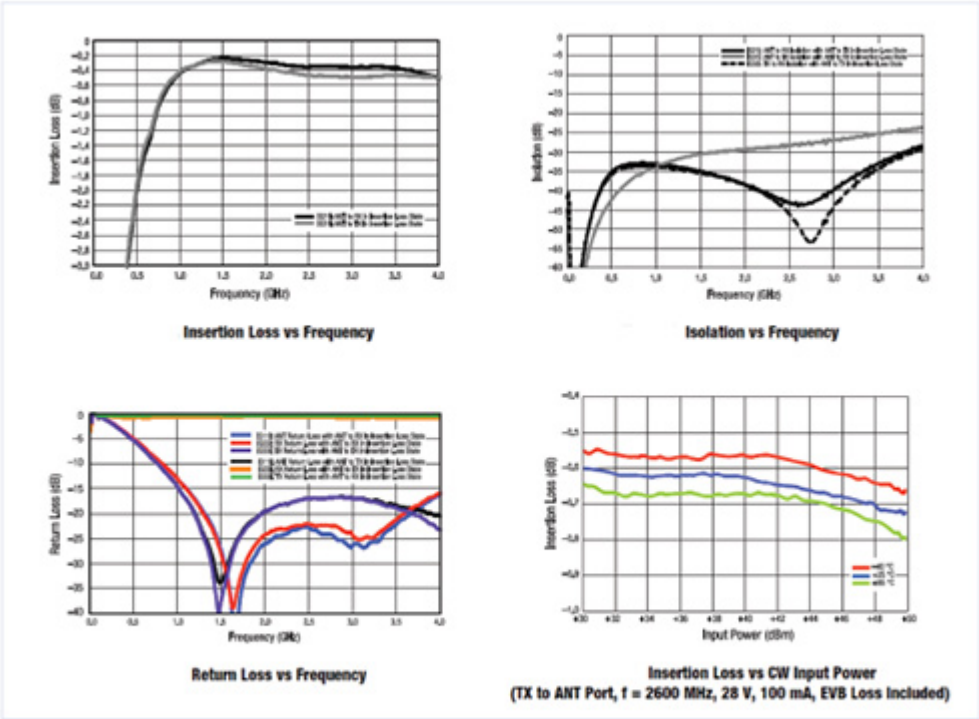

Figure 4: The SKY12210-478LF Performance Data

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 SKY12210-478LF and SKY12212-478LF at 100 watts incident power, 28 volts reverse voltage is specified. This value was determined experimentally and conforms to theoretical analysis. The large reverse bias voltage also reduces harmonic and intermodulation distortion produced by the reversed biased, "off state" PIN diode.

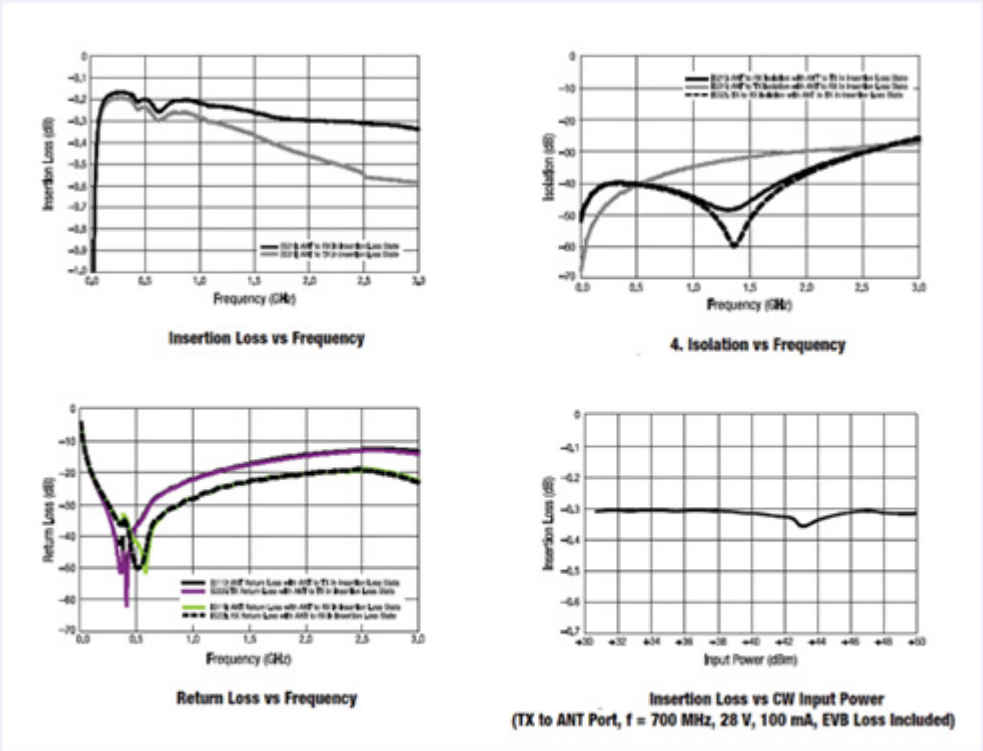

Figure 5: The SKY12212-478LF Performance Data

Figures 4 and 5 illustrate the typical performance characteristics of the SKY12210-478LF and SKY12212-478LF. The data was taken at: TA = 25°C, Zo = 50 Ohms.

Conclusion

Radio transceiver designers now have a low cost solution to replace expensive mechanical switches and relays. Skyworks Solutions has introduced the SKY12210-478LF and SKY12212-478LF solid state, high power, SPDT, T-R switches which can handle 100 W CW, 480 W peak transmitter power operating from 0.02 to 2.7 GHz or 0.9 to 4.0 GHz, respectively.

Also available from Skyworks Solutions is the SKY12207-478LF, 50 Watt, high power SPDT switch, operating from 0.9 to 4.0 GHz and the SKY12208-478LF, 50 Watt high power SPDT switch, operating from 0.02 to 2.7 GHz. These switches address lower power applications of base stations and infrastructure equipment. For our full lineup of Skyworks PIN diode switches and other products, please visit our website at www.skyworksinc.com.

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.

Skyworks Solutions, Inc.
www.skyworksinc.com
Email this article to a friend!