

DATA SHEET

SKY12209-478LF: 0.9 to 4.0 GHz 40 W High Power Silicon PIN Diode SPDT Switch

Applications

- Transmit/receive switching and RF path switching in TD-SCDMA, WiMAX, and LTE base stations
- Transmit/receive and RF path switching in land mobile radios and military communication systems

Features

- High power handling: 40 W CW
- Low insertion loss: 0.3 dB typical
- High isolation: 42 dB @ 2.6 GHz
- Controlled with positive power supply
- Fast RF rise time: 40 ns typical
- Bias driver circuit available on request
- Small, QFN (16-pin, 4 x 4 mm) Pb-free package (MSL1, 260 °C per JEDEC J-STD-020)



Skyworks Green™ products are compliant with all applicable legislation and are halogen-free. For additional information, refer to *Skyworks Definition of Green™*, document number SQ04-0074.

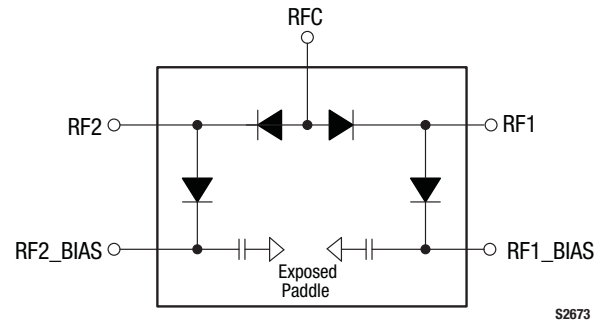


Figure 1. SKY12209-478LF Block Diagram

Description

The SKY12209-478LF is a high power handling, Single-Pole, Double-Throw (SPDT) silicon PIN diode switch with symmetrical switching paths from a single common port. The device operates over the 0.9 GHz to 4.0 GHz band. It features low insertion loss, excellent power handling, and superb linearity with low DC power consumption.

The SKY12209-478LF is well-suited for use as a high power transmit/receive and RF path switch in a variety of telecommunication systems such as WiMAX, TD-SCDMA, or LTE base stations.

The device is provided in a 4 x 4 mm, 16-pin Quad Flat No-Lead (QFN) package. A functional block diagram is shown in Figure 1. The pin configuration and package are shown in Figure 2. Signal pin assignments and functional pin descriptions are provided in Table 1.

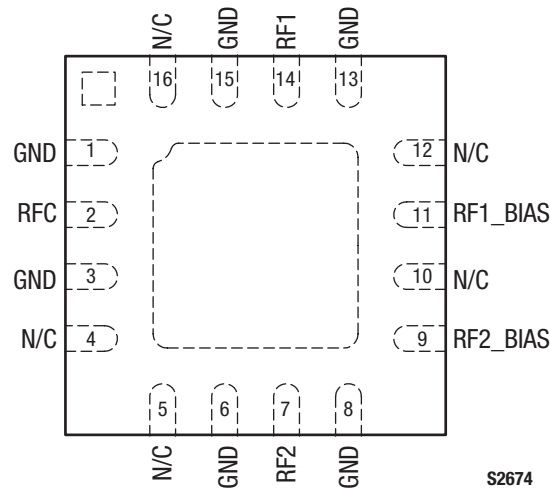


Figure 2. SKY12209-478LF Pinout – 16-Pin QFN (Top View)

Table 1. SKY12209-478LF Signal Descriptions

| Pin | Name | Description | Pin | Name | Description |
|-----|------|--|-----|----------|--|
| 1 | GND | Ground. Must be connected to ground using lowest possible impedance. | 9 | RF2_BIAS | RF ground port 2 and DC bias port |
| 2 | RFC | RF port and DC bias port | 10 | N/C | No connection |
| 3 | GND | Ground. Must be connected to ground using lowest possible impedance. | 11 | RF1_BIAS | RF ground port 1 and DC bias port |
| 4 | N/C | No connection | 12 | N/C | No connection |
| 5 | N/C | No connection | 13 | GND | Ground. Must be connected to ground using lowest possible impedance. |
| 6 | GND | Ground. Must be connected to ground using lowest possible impedance. | 14 | RF1 | RF port 1 and DC bias port |
| 7 | RF2 | RF port 2 and DC bias port | 15 | GND | Ground. Must be connected to ground using lowest possible impedance. |
| 8 | GND | Ground. Must be connected to ground using lowest possible impedance. | 16 | N/C | No connection |

Electrical and Mechanical Specifications

The absolute maximum ratings of the SKY12209-478LF are provided in Table 2. Recommended operating conditions are specified in Table 3. Electrical specifications are provided in Table 4 (28 V bias voltage) and Table 5 (5 V bias voltage).

Typical performance characteristics of the SKY12209-478LF are illustrated in Figures 3 through 10.

The state of the SKY12209-478LF is determined by the logic provided in Table 6. Table 7 provides the logic for use with the SKY12209-478LF Evaluation Board.

Power derating data is plotted against temperature in Figures 11 and 12. Equivalent circuit diagrams for transmit and receive are shown in Figure 13.

Table 2. SKY12209-478LF Absolute Maximum Ratings

| Parameter | Symbol | Minimum | Maximum | Units |
|--|------------------|---------|---------|--------------------|
| RF CW input power ($T_{\text{SUBSTRATE}} = 25\text{ }^{\circ}\text{C}$) | P_{IN} | | 60 | W |
| RF peak input power ($T_{\text{SUBSTRATE}} = 25\text{ }^{\circ}\text{C}$, RF burst width = 10 μs , RF burst repetition rate = 25 kHz) | P_{IN} | | 240 | W |
| Control port reverse voltage | V_{CTL} | | 200 | V |
| Control port forward current | I_{CTL} | | 200 | mA |
| Operating temperature | T_{OP} | -55 | +175 | $^{\circ}\text{C}$ |
| Storage temperature | T_{STG} | -55 | +200 | $^{\circ}\text{C}$ |
| Electrostatic discharge: | ESD | | | |
| Charged Device Model (CDM), Class 4 | | | 1000 | V |
| Human Body Model (HBM), Class 1C | | | 1000 | V |
| Machine Model (MM), Class B | | | 200 | V |

Note: Exposure to maximum rating conditions for extended periods may reduce device reliability. There is no damage to device with only one parameter set at the limit and all other parameters set at or below their nominal value. Exceeding any of the limits listed here may result in permanent damage to the device.

CAUTION: Although this device is designed to be as robust as possible, Electrostatic Discharge (ESD) can damage this device. This device must be protected at all times from ESD. Static charges may easily produce potentials of several kilovolts on the human body or equipment, which can discharge without detection. Industry-standard ESD precautions should be used at all times.

Table 3. Recommended Operating Conditions

| Parameter | Symbol | Min | Typical | Max | Units |
|---------------------------------------|------------------|-----|---------|-----|-------|
| Control port reverse voltage | V_{CTL} | 5 | 28 | 100 | V |
| Control port forward current (Note 1) | I_{CTL} | 20 | 50 | 100 | mA |

Note 1: Per each diode in forward conduction mode.

Table 4. SKY12209-478LF Electrical Specifications, Bias Voltage = 28 V (Note 1)
(T_{OP} = +25 °C, Characteristic Impedance [Z₀] = 50 Ω, EVB Optimized for 0.9 to 4.0 GHz Operation, Unless Otherwise Noted)

| Parameter | Symbol | Test Condition | Min | Typical | Max | Units |
|---|--|--|-----|---------|------|-------|
| Insertion loss, RFC to RF1 and RF2 ports | IL _{RFC-RF1} IL _{RFC-RF2} | RFC port P _{IN} @ pin 2 = 0 dBm: | | | | |
| | | 0.90 GHz | | 0.62 | | dB |
| | | 1.80 GHz | | 0.40 | | dB |
| | | 2.01 GHz | | 0.42 | | dB |
| | | 2.60 GHz | | 0.50 | 0.70 | dB |
| 3.50 GHz | | 0.65 | | dB | | |
| Isolation, RF1 to RF2 ports | ISO _{RF1-RF2} | RFC port P _{IN} @ pin 14 = 0 dBm: | | | | |
| | | 0.90 GHz | | 35 | | dB |
| | | 1.80 GHz | | 37 | | dB |
| | | 2.01 GHz | | 39 | | dB |
| | | 2.60 GHz | 40 | 46 | | dB |
| 3.50 GHz | | 36 | | dB | | |
| Isolation, RFC to RF1 and RF2 ports | ISO _{RFC-RF1} ISO _{RFC-RF2} | RFC port P _{IN} @ pin 2 = 0 dBm: | | | | |
| | | 0.90 GHz | | 35 | | dB |
| | | 1.80 GHz | | 37 | | dB |
| | | 2.01 GHz | | 39 | | dB |
| | | 2.60 GHz | 38 | 42 | | dB |
| 3.50 GHz | | 36 | | dB | | |
| Input return loss, RFC port | RL _{RFC} | RFC port P _{IN} @ pin 2 = 0 dBm: | | | | |
| | | 0.90 GHz | | 13 | | |
| | | 1.80 GHz | | 28 | | dB |
| | | 2.01 GHz | | 25 | | dB |
| | | 2.60 GHz | | 22 | | dB |
| 3.50 GHz | | 34 | | dB | | |
| 2 nd harmonic | 2fo | RFC port P _{IN} @ pin 2 = +30 dBm: | | | | |
| | | 0.90 GHz | | -80 | | dBc |
| | | 1.80 GHz | | -81 | | dBc |
| | | 2.01 GHz | | -82 | | dBc |
| | | 2.60 GHz | | -80 | | dBc |
| 3.50 GHz | | -81 | | dBc | | |
| 3 rd harmonic | 3fo | RFC port P _{IN} @ pin 2 = +30 dBm: | | | | |
| | | 0.90 GHz | | -92 | | dBc |
| | | 1.80 GHz | | -92 | | dBc |
| | | 2.01 GHz | | -95 | | dBc |
| | | 2.60 GHz | | -96 | | dBc |
| 3.50 GHz | | -93 | | dBc | | |
| 3 rd Order Input Intercept Point | IIP3 | RFC port P _{IN} @ pin 2 = +30 dBm/tone, Δf = 1 MHz, @ 2.6 GHz | | +76 | | dBm |
| Maximum CW input power | P _{IN_CW} | 0.9 to 3.5 GHz | | 40 | | W |
| Transmit RF switching time | t _{sw} | 10% to 90% RF rise time, repetition rate = 100 kHz, @ 2.6 GHz | | 40 | | ns |
| Thermal resistance (junction-to-case) | Θ _{JC} | | | 64.2 | | °C/W |

Note 1: Performance is guaranteed only under the conditions listed in this Table.

Table 5. SKY12209-478LF Electrical Specifications, Bias Voltage = 5 V (Note 1)
(T_{OP} = +25 °C, Characteristic Impedance [Z₀] = 50 Ω, EVB Optimized for 0.9 to 4.0 GHz Operation, Unless Otherwise Noted)

| Parameter | Symbol | Test Condition | Min | Typical | Max | Units |
|--|--|--|-----|---------|------|-------|
| Insertion loss, RFC to RF1 and RF2 ports | IL _{RFC-RF1} IL _{RFC-RF2} | RFC port P _{IN} @ pin 2 = 0 dBm: | | | | |
| | | 0.90 GHz | | 0.63 | | dB |
| | | 1.80 GHz | | 0.43 | | dB |
| | | 2.01 GHz | | 0.46 | | dB |
| | | 2.60 GHz | | 0.54 | 0.70 | dB |
| 3.50 GHz | | 0.63 | | dB | | |
| Isolation, RF1 to RF2 ports | ISO _{RF1-RF2} | RFC port P _{IN} @ pin 14 = 0 dBm: | | | | |
| | | 0.90 GHz | | 34 | | dB |
| | | 1.80 GHz | | 37 | | dB |
| | | 2.01 GHz | 40 | 38 | | dB |
| | | 2.60 GHz | | 46 | | dB |
| 3.50 GHz | | 36 | | dB | | |
| Isolation, RFC to RF2 and RF1 ports | ISO _{RFC-RF2} ISO _{RFC-RF1} | RFC port P _{IN} @ pin 2 = 0 dBm: | | | | |
| | | 0.90 GHz | | 33 | | dB |
| | | 1.80 GHz | | 36 | | dB |
| | | 2.01 GHz | 38 | 38 | | dB |
| | | 2.60 GHz | | 42 | | dB |
| 3.50 GHz | | 34 | | dB | | |
| Input return loss, RFC port | RL _{RFC} | RFC port P _{IN} @ pin 2 = 0 dBm: | | | | |
| | | 0.90 GHz | | 12 | | |
| | | 1.80 GHz | | 28 | | dB |
| | | 2.01 GHz | | 26 | | dB |
| | | 2.60 GHz | | 25 | | dB |
| 3.50 GHz | | 32 | | dB | | |
| 2nd harmonic | 2fo | RFC port P _{IN} @ pin 2 = +30 dBm: | | | | |
| | | 0.90 GHz | | -40 | | dBc |
| | | 1.80 GHz | | -51 | | dBc |
| | | 2.01 GHz | | -51 | | dBc |
| | | 2.60 GHz | | -51 | | dBc |
| 3.50 GHz | | -55 | | dBc | | |
| 3rd harmonic | 3fo | RFC port P _{IN} @ pin 2 = +30 dBm: | | | | |
| | | 0.90 GHz | | -51 | | dBc |
| | | 1.80 GHz | | -63 | | dBc |
| | | 2.01 GHz | | -68 | | dBc |
| | | 2.60 GHz | | -63 | | dBc |
| 3.50 GHz | | -63 | | dBc | | |
| 3rd Order Input Intercept Point | IIP3 | RFC port P _{IN} @ pin 2 = +30 dBm/tone, Δf = 1 MHz, @ 2.6 GHz | | +76 | | dBm |
| Maximum CW input power | P _{IN_CW} | 0.9 to 3.5 GHz | | 15 | | W |
| Transmit RF switching time | t _{sw} | 10% to 90% RF rise time, repetition rate = 100 kHz, @ 2.6 GHz | | 40 | | ns |
| Thermal resistance (junction-to-case) | Θ _{JC} | | | 64.2 | | °C/W |

Note 1: Performance is guaranteed only under the conditions listed in this Table.

Typical Performance Characteristics

(TOP = +25 °C, Characteristic Impedance [Z₀] = 50 Ω, EVB Optimized for 0.9 to 4.0 GHz Operation, Unless Otherwise Noted)

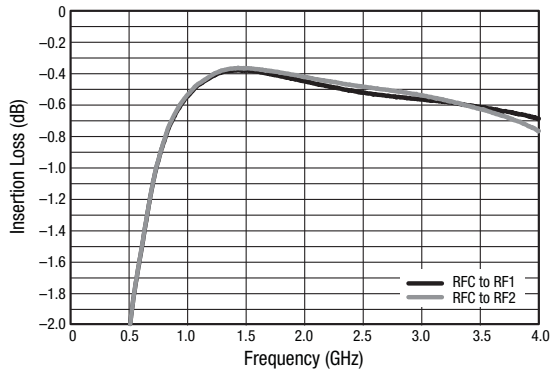


Figure 3. Insertion Loss vs Frequency
(V_{CTL} = 28 V, I_{CTL} = -50 mA)

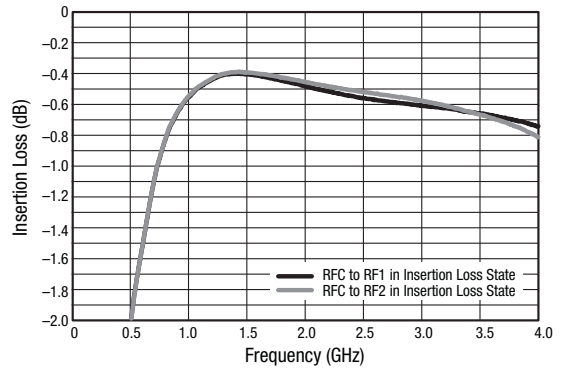


Figure 4. Insertion Loss vs Frequency
(V_{CTL} = 5 V, I_{CTL} = -50 mA)

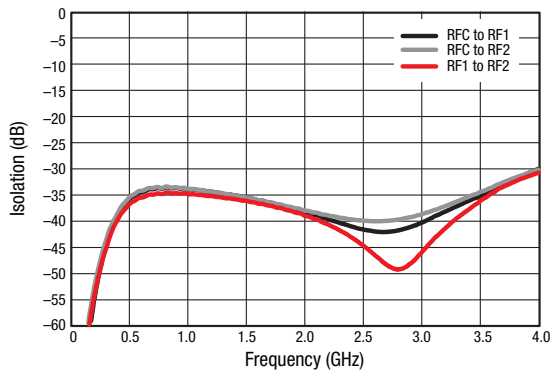


Figure 5. Isolation vs Frequency
(V_{CTL} = 28 V, I_{CTL} = -50 mA)

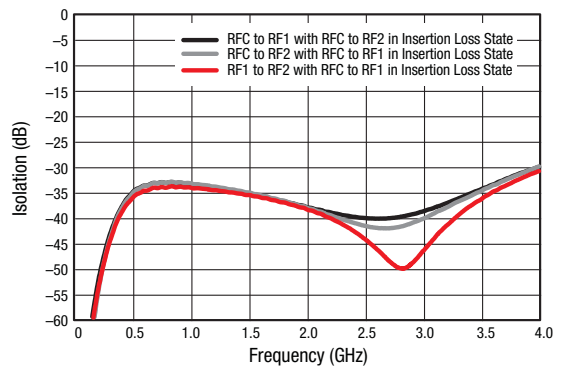


Figure 6. Isolation vs Frequency
(V_{CTL} = 5 V, I_{CTL} = -50 mA)

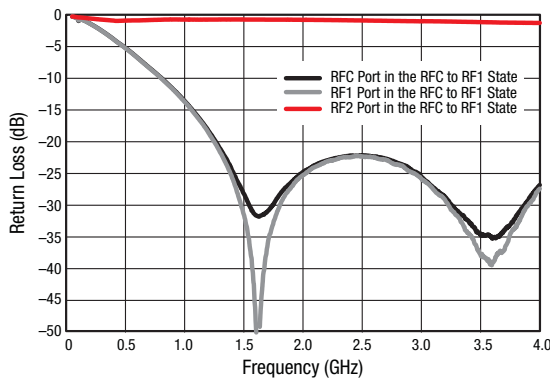


Figure 7. Return Loss vs Frequency
(V_{CTL} = 28 V, I_{CTL} = -50 mA)

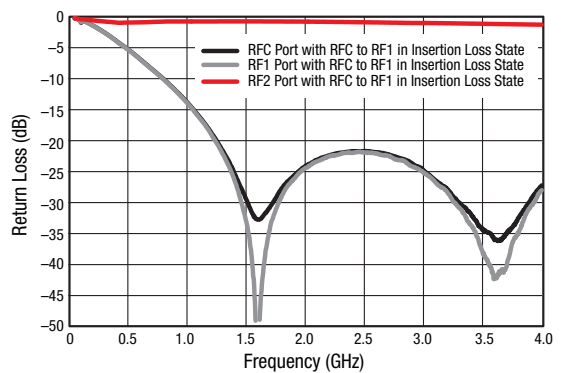


Figure 8. Return Loss vs Frequency
(V_{CTL} = 5 V, I_{CTL} = -50 mA)

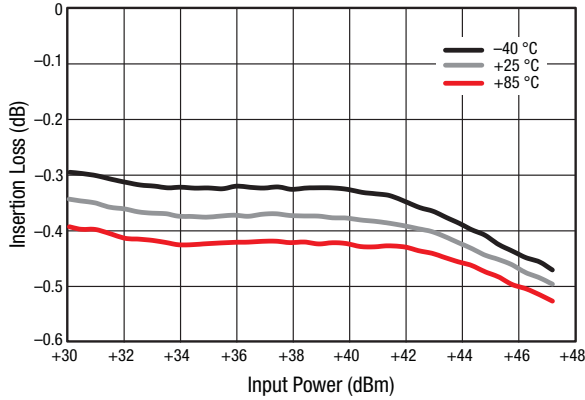


Figure 9. Insertion Loss vs CW Input Power
(f = 2.6 GHz, Evaluation Board Loss Included)

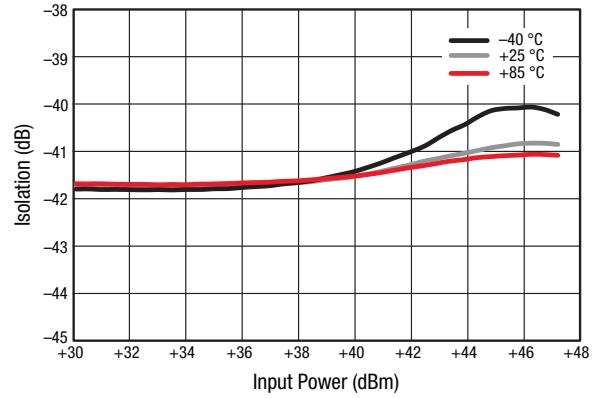


Figure 10. Isolation vs CW Input Power
(f = 2.6 GHz, Evaluation Board Loss Included)

Table 6. SKY12209-478LF Truth Table

| Path | | Control Conditions | | | | |
|-------------------------------------|--------------------------------------|--------------------------|--------------------------|---------------------------|---------------------|----------------------|
| RFC-to-RF2 Port (Pin 2 to Pin 7) | RFC-to-RF1 Port (Pin 2 to Pin 14) | RFC Port Bias (Pin 2) | RF2 Port Bias (Pin 7) | RF1 Port Bias (Pin 14) | RF2_BIAS (Pin 9) | RF1_BIAS (Pin 11) |
| Low insertion loss | High isolation | 1 V | -50 mA | 28 V | 28 V | -50 mA |
| High isolation | Low insertion loss | 1 V | 28 V | -50 mA | -50 mA | 28 V |

Table 7. SKY12209-478LF Evaluation Board Truth Table

| Path | | Control Conditions | | | | |
|--------------------|--------------------|----------------------|----------------------|----------------------|-----------------|-----------------|
| RFC-to-RF2 Port | RFC-to-RF1 Port | RFC Port Bias (V) | RF2 Port Bias (V) | RF1 Port Bias (V) | RF2_BIAS (V) | RF1_BIAS (V) |
| Low insertion loss | High isolation | 5 | 0 (ground) | 28 | 28 | 0 (ground) |
| High isolation | Low insertion loss | 5 | 28 | 0 (ground) | 0 (ground) | 28 |

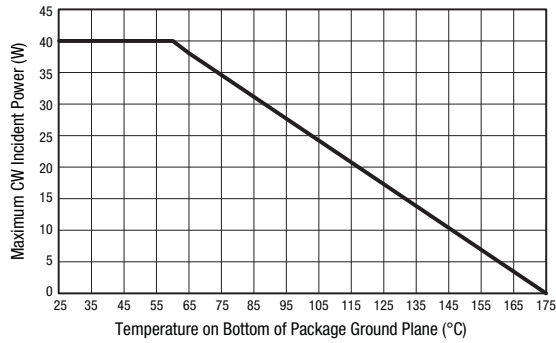


Figure 11. Power Derating, Maximum CW Incident Power (Insertion Loss = 0.2 dB) vs Temperature on Bottom of Package Ground Plane

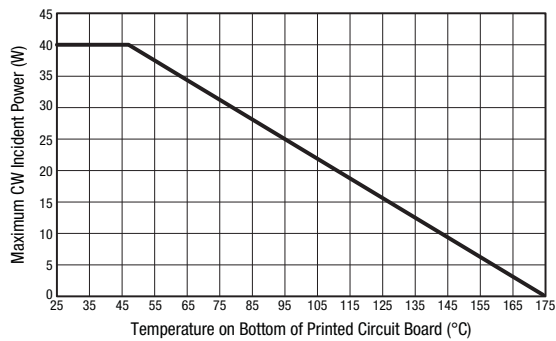


Figure 12. Power Derating, Maximum CW Incident Power (Insertion Loss = 0.2 dB) vs Temperature on Bottom of Printed Circuit Board

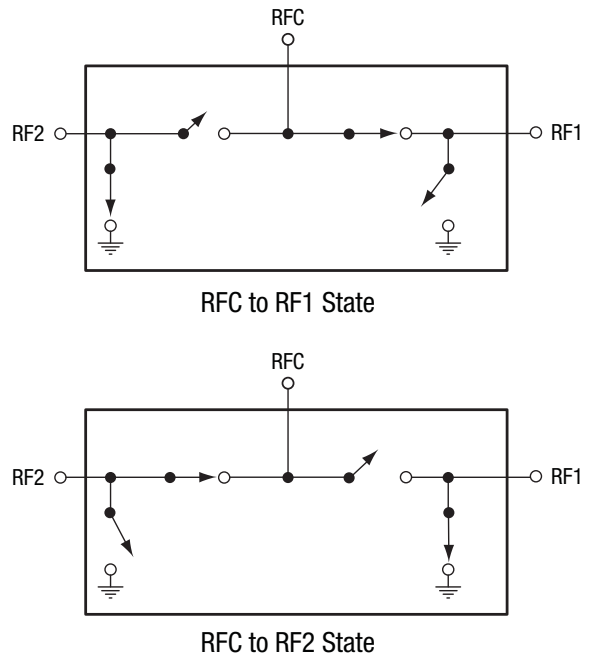
Evaluation Board Description

The SKY12209-478LF Evaluation Board is used to test the performance of the SKY12209-478LF PIN Diode SPDT switch. An assembly drawing for the Evaluation Board is shown in Figure 14. The layer detail is provided in Figure 15.

The SKY12209-478LF is designed to handle very large signals. Sufficient power may be dissipated by this switch to cause heating of the PIN diodes contained in the switch. It is very important to use a printed circuit board design that provides adequate cooling capability to keep the junction temperature of the PIN diodes below their maximum rated operating temperature.

As indicated in Figure 11, the x-axis temperature is referenced to the bottom of the QFN package. A printed circuit board with a very low thermal resistance and external heat sink design must be used to achieve the results shown in this Figure. The power derating curve with the x-axis temperature referenced to the bottom of the printed circuit board is provided in Figure 12.

The evaluation circuit is designed to facilitate control of the SKY12209-478LF SPDT switch with bias signals derived from positive voltages. The state of the PIN diodes within the



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Figure 13. SKY12209-478LF Equivalent Circuit Diagrams

SKY12209-478LF is controlled with 5 V applied to the RFC port and bias voltages of either 28 V or 0 V applied to the remaining bias inputs (RF1 and RF2 ports). The switch state circuit diagrams are shown in Figure 13.

The values of resistors R2 and R3 (refer to the schematic diagram in Figure 16), which are both nominally 540 Ω, together with the magnitudes of the voltages applied to the RF1 and RF2 ports, determine which of the two series of diodes is biased into conduction and how much current flows through the forward biased diode.

For example, to place the SKY12209-478LF into the RFC to RF1 low insertion loss state, 0 V is applied to the RF1 port (which forward biases the diode between pins 2 and 14), 28 V is applied to the RF2 port (which reverse biases the diode between pins 2 and 7), 0 V is applied to the RF2_BIAS port (which applies a forward bias through R3 to the diode connected between pins 7 and 9), and 28 V is applied to the RF1_BIAS port (which applies a forward bias through R2 to the diode connected between pins 14 and 11).

The values of R2 and R3 may be adjusted to accommodate other bias voltages. Resistance values of 540 Ω are selected to

produce approximately 50 mA of forward bias current in the diodes, which are forced into conduction when the bias source voltage is 28 V.

The component values shown in the Evaluation Board circuit diagram (Figure 16) were selected to optimize performance in the 0.9 to 4.0 GHz band.

Refer to Table 8 for the Evaluation Board Bill of Materials. Table 9 provides voltage, current, and resistor values for bias adjustments.

Package Dimensions

The PCB layout footprint for the SKY12209-478LF is shown in Figure 17. Typical case markings are noted in Figure 18. Package dimensions for the 16-pin QFN are shown in Figure 19, and tape and reel dimensions are provided in Figure 20.

Package and Handling Information

Instructions on the shipping container label regarding exposure to moisture after the container seal is broken must be followed. Otherwise, problems related to moisture absorption may occur when the part is subjected to high temperature during solder assembly.

The SKY12209-478LF is rated to Moisture Sensitivity Level 1 (MSL1) at 260 °C. It can be used for lead or lead-free soldering. For additional information, refer to the Skyworks Application Note, *Solder Reflow Information*, document number 200164.

Care must be taken when attaching this product, whether it is done manually or in a production solder reflow environment. Production quantities of this product are shipped in a standard tape and reel format.

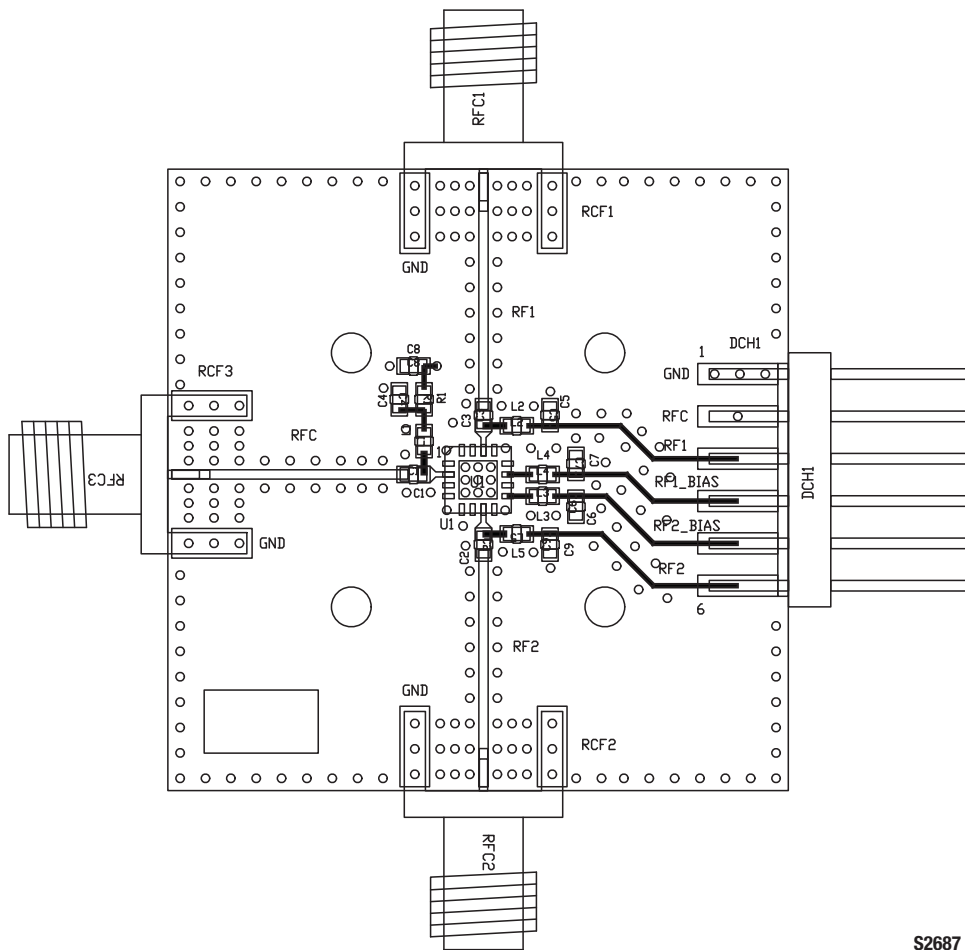


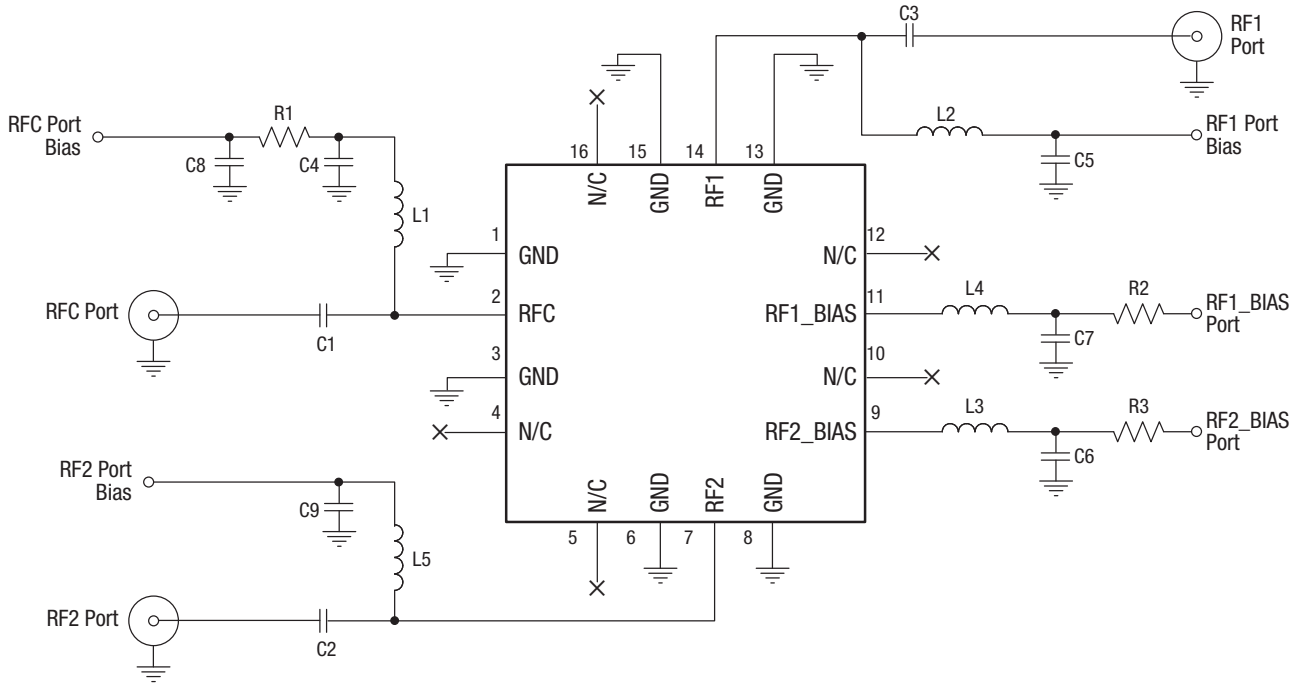
Figure 14. SKY12209-478LF Evaluation Board Assembly Diagram

| Cross Section | Name | Thickness (in) | Material |
|---|-------------------|----------------|---------------------|
|  | Top Soldermask | | |
|  | L1 | (0.0028) | Cu foil |
|  | Laminate | 0.012 ± 0.0006 | Rogers R04003C Core |
|  | L2 | (0.0014) | Cu foil |
|  | Laminate | (Note 1) | FR4 Prepreg |
|  | L3 | (0.0014) | Cu foil |
|  | Laminate | 0.010 ± 0.0006 | FR4 Core |
|  | L4 | (0.0028) | Cu foil |
|  | Bottom Soldermask | | |

Note 1: Adjust this thickness to meet total thickness goal of 0.062 ± 0.005 inches.

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Figure 15. Layer Detail Physical Characteristics



NOTE: The N/C pins (4, 5, 10, 12, and 16) are not internally connected, so they can be left open or grounded.

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Figure 16. Evaluation Board Schematic

Table 8. Evaluation Board Bill of Materials (Note 1)

| Component | Value | Size | Manufacturer | Mfr Part Number | Characteristics |
|--------------------------------|---------|------|--------------|-----------------|--------------------------|
| C1, C2, C3, C4, C5, C6, C7, C9 | 1000 pF | 0603 | TDK | C1608C0G1H102JT | COG, 50 V, ±5% |
| C8 | 1 μF | 0603 | TDK | C2012X7R1H104K | X7R, 50 V, ±10% |
| L1, L2, L3, L4, L5 | 22 nH | 0603 | Taiyo-Yuden | HK160822NJ-T | SRF, 1600 MHz, ±5% |
| R1 (Note 2) | 80 Ω | 0603 | Panasonic | ERJ-3GEYJ161V | 0.1 W, ±5% |
| R2, R3 (Note 3) | 540 Ω | – | – | – | Axial leaded (off board) |

Note 1: Component values selected are based on the desired frequency and bias level. Values may be adjusted for a specific response.

Note 2: Two 160 Ω resistors are combined in parallel to achieve a minimum power handling requirement and 80 Ω resistance.

Note 3: Evaluation Board does not include resistors R2 and R3. Operating at 28 V and 50 mA requires R2 and R3 resistors with a power dissipation greater than 1.35 W.

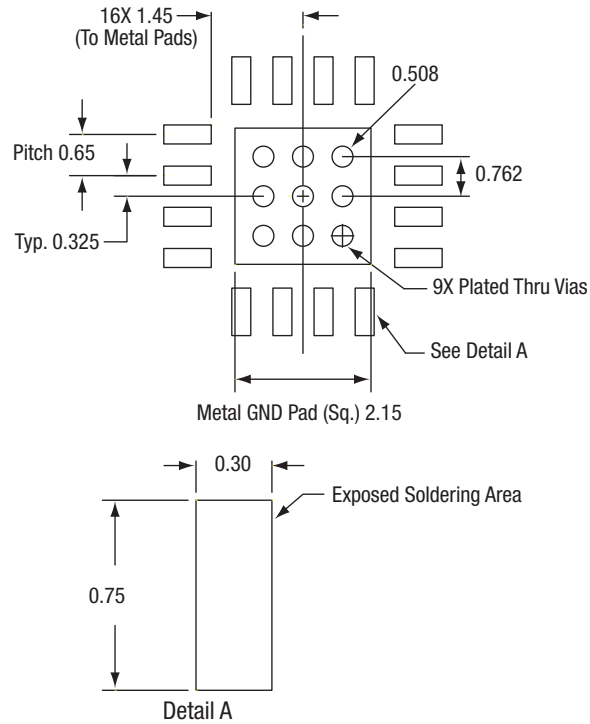
Table 9. Component Calculation Values

| Vs (V) | V _{DIODE} (V) | V _{RES} (V) | Current (A) | Resistance (Ω) | Power Dissipation (W) |
|--------|------------------------|----------------------|-------------|----------------|-----------------------|
| 28 | 1 | 27 | 0.05 | 540 | 1.35 |
| 28 | 1 | 27 | 0.02 | 1350 | 0.54 |
| 5 | 1 | 4 | 0.05 | 80 | 0.20 |
| 5 | 1 | 4 | 0.02 | 200 | 0.08 |

Notes: Vs = supply voltage; V_{DIODE} = voltage drop across the diode; V_{RES} = voltage drop across the resistor.

R2 and R3 values are calculated by $(V_s - V_{DIODE})/I$, where I is the desired bias current.

The power dissipation in R2 and R3 is calculated by $I \times (V_s - V_{DIODE})$. The resistor selected must be safely rated with a power greater than the dissipated power.



All measurements in millimeters

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Figure 17. SKY12209-478LF PCB Layout Footprint

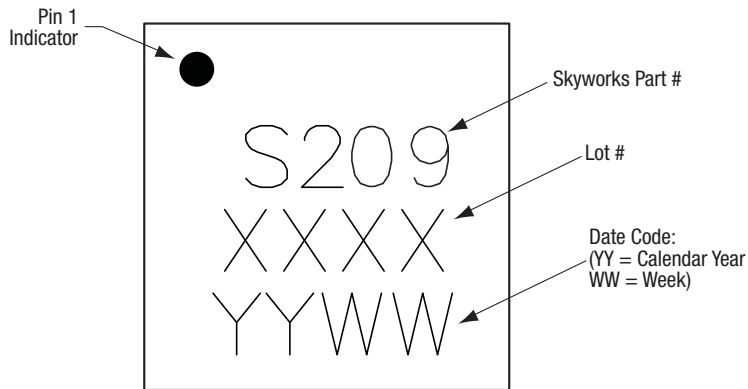
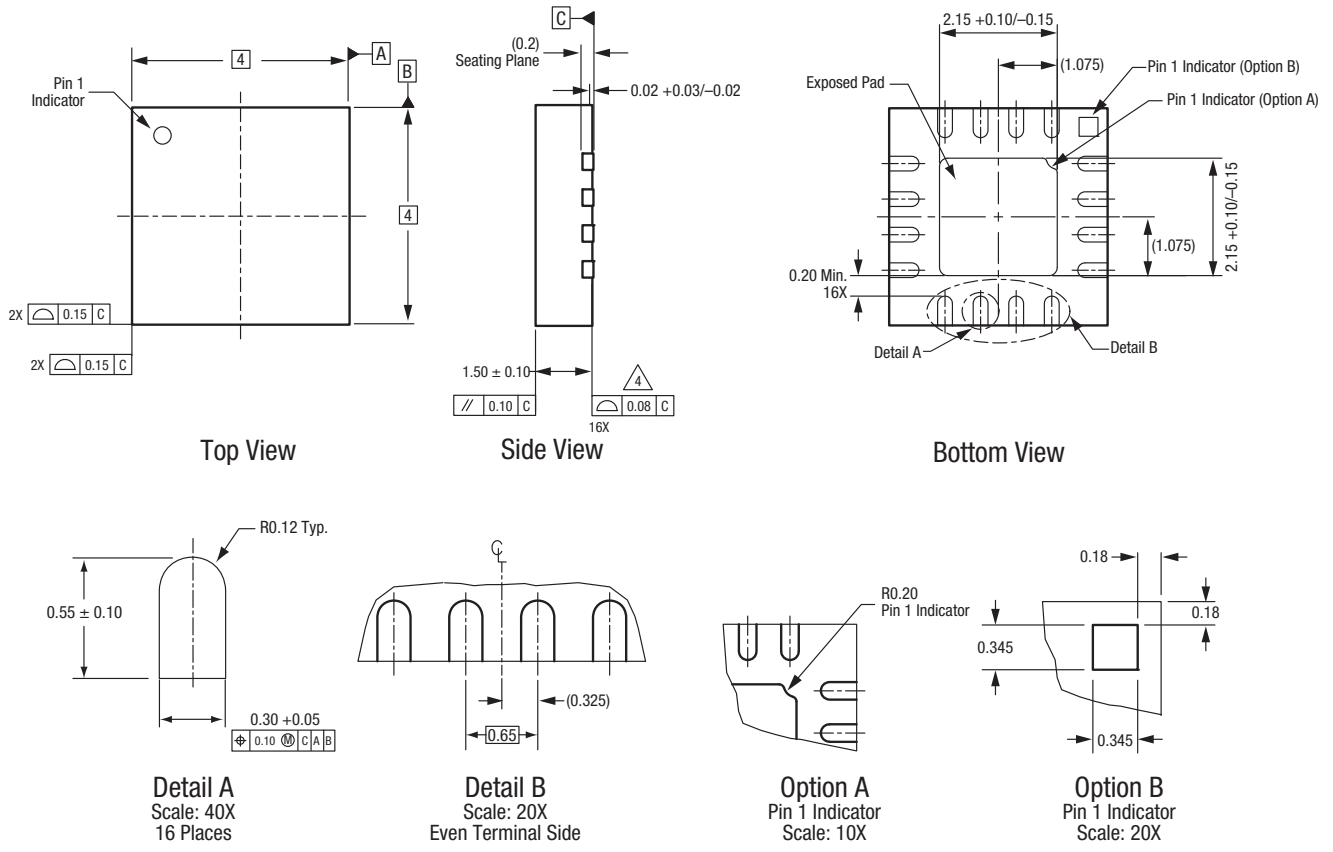


Figure 18. Typical Case Markings

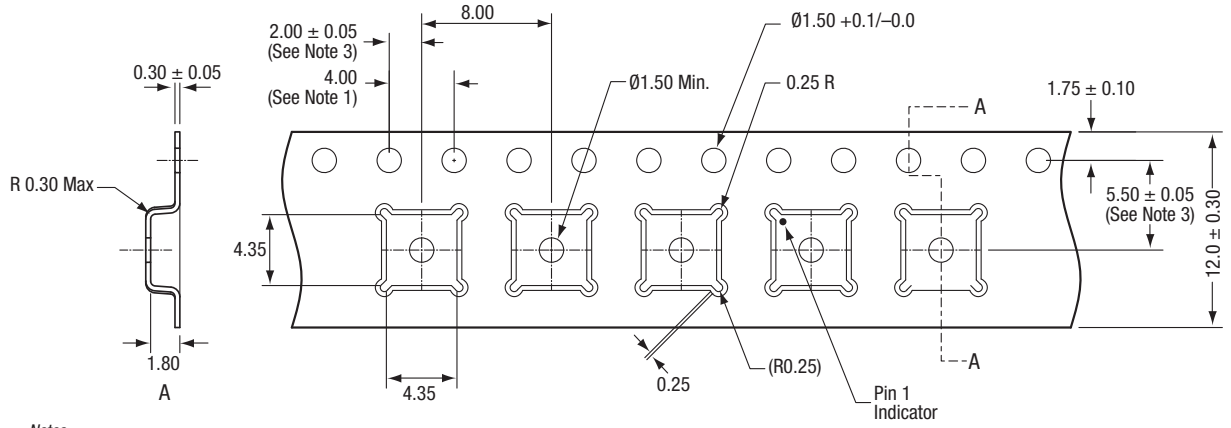


All measurements are in millimeters.
 Dimensioning and tolerancing according to ASME Y14.5M-1994.
 Coplanarity applies to the exposed heat sink slug as well as the terminals.
 Package may have option A or option B pin 1 indicator.

S2400a

Figure 19. SKY12209-478LF 16-Pin QFN Package Dimensions

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Notes:

1. Sprocket hole pitch cumulative tolerance: ± 0.2 mm
2. Carrier tape: black conductive polystyrene.
3. Pocket position relative to sprocket hole, measure as true position of pocket, not pocket hole.
4. Cover tape material: transparent conductive adhesive.
5. ESD surface resistivity must meet all ESD requirements of Skyworks, specified in GP01-D232.
6. All dimensions are in millimeters.

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Figure 20. SKY12209-478LF Tape and Reel Dimensions

Ordering Information

| Model Name | Manufacturing Part Number | Evaluation Board Part Number |
|--------------------------------------|---------------------------|------------------------------|
| SKY12209-478LF PIN Diode SPDT Switch | SKY12209-478LF | SKY12209-478LF-EVB |

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