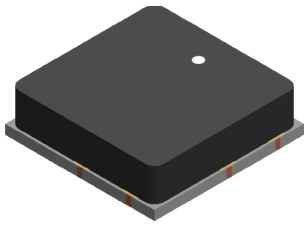
SP3T PIN Diode Switch

MSW310x-310
Rev. V3

Features

- Wide Frequency Range: 50 MHz to 4 GHz, in 2 bands
- Surface Mount SP3T Switch in Compact Outline: 8 mm L x 5 mm W x 2.5 mm H
- Higher Average Power Handling than Plastic Packaged
- MMIC Switches: 158 W CW
- High RF Peak Power: 500 W
- Low Insertion Loss: 0.45 dB
- High IIP3: 65 dBm
- Operates From Positive Voltage Only: 5 V & 28 V to 125 V
- RoHS* Compliant



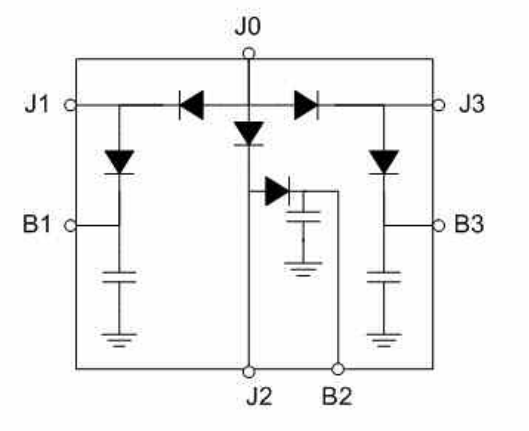
CS310

Description

The MSW3100-310 (50 MHz - 1 GHz) and MSW3101-310 (400 MHz - 4 GHz) series of surface mount silicon PIN diode SP3T switches can be used for high power transmit/receive (TR) symmetrical switching or active receiver protection. These switches are manufactured using a proven hybrid manufacturing process incorporating high voltage PIN diodes and passive devices integrated on a ceramic substrate. These low profile, compact, surface mount components offer superior small and large signal performance compared to that of MMIC devices in QFN packages. The SP3T switches are designed in a symmetrical topology to enable switched RF port to be used as the high-input-power -handling port, to minimize insertion loss and to maximize isolation performance. The very low thermal resistance (<25ºC/W) of the PIN diodes in these devices enables them to reliably handle RF incident power levels of 50 dBm CW and RF peak incident power levels of 57 dBm in cold switching applications. The thick I layers of the PIN diodes (>100 µm), coupled with their long minority carrier lifetime (>2 µs), produces input third order intercept point (IIP3) greater than 65 dBm.

These MSW310x-310 Series SP3T switches are designed to be used in high average and peak power switch applications, operating from 50 MHz to 4 GHz in two bands, which utilize high volume, surface mount, solder re-flow manufacturing. These products are durable and capable of reliably operating in military, commercial, and industrial environments.

Functional Schematic



Ordering Information

Part Number	Package
MSW3100-310-T	tube
MSW3100-310-R	250 or 500 piece reel
MSW3100-310-W	Waffle pack
MSW3101-310-T	tube
MSW3101-310-R	250 or 500 piece reel
MSW3101-310-W	Waffle pack
MSW3100-310-E	RF evaluation board
MSW3101-310-E	RF evaluation board

* Restrictions on Hazardous Substances, compliant to current RoHS EU directive.

MSW3100-310 Electrical Specifications: T_A = +25°C, P_{IN} = 0 dBm, Z_0 = 50 Ω

Parameter	Test Conditions	Units	Min.	Typ.	Max.
Frequency	—	MHz	50	—	1000
Insertion Loss	Bias State 1: port J0 to J1 Bias State 2: port J0 to J2 Bias State 2: port J0 to J3	dB	—	0.4	0.6
Return Loss	Bias State 1: port J0 to J1 Bias State 2: port J0 to J2 Bias State 2: port J0 to J3	dB	18	20	—
Isolation	Bias State 1: port J0 to J1 Bias State 2: port J0 to J2 Bias State 2: port J0 to J3	dB	50	53	—
CW Incident Power[1]	Source & Load VSWR = 1.5:1	dBm	—	—	50
Peak Incident Power[1]	Source & Load VSWR = 1.5:1 Pulse Width = 10 µs, Duty Cycle = 1%	dBm	—	—	57
Switching Time[2]	10% -90% RF Voltage, TTL rep rate = 100 kHz	µs	—	2	3
Input IP3	F1 = 500 MHz, F2 = 510 MHz P1 = P2 = 10 dBm Measure on path biased to low loss state	dBm	60	65	—

MSW3101-310 Electrical Specifications: T_A = +25°C, P_{IN} = 0 dBm, Z_0 = 50 Ω

Parameter	Test Conditions	Units	Min.	Typ.	Max.
Frequency	—	MHz	400	—	4000
Insertion Loss	Bias State 1: port J0 to J1 Bias State 2: port J0 to J2 Bias State 2: port J0 to J3	dB	—	0.6	0.8
Return Loss	Bias State 1: port J0 to J1 Bias State 2: port J0 to J2 Bias State 2: port J0 to J3	dB	14	15	—
Isolation	Bias State 1: port J0 to J1 Bias State 2: port J0 to J2 Bias State 2: port J0 to J3	dB	32	34	—
CW Incident Power[1]	Source & Load VSWR = 1.5:1	dBm	—	—	50
Peak Incident Power[1]	Source & Load VSWR = 1.5:1 Pulse Width = 10 µs, Duty Cycle = 1%	dBm	—	—	57
Switching Time[2]	10% -90% RF Voltage, TTL rep rate = 100 kHz	µs	—	2	3
Input IP3	F1 = 500 MHz, F2 = 510 MHz P1 = P2 = 10 dBm Measure on path biased to low loss state	dBm	60	65	—

1. PIN diode DC reverse voltage to maintain high resistance in the OFF PIN diode is determined by RF frequency, incident power, and VSWR as well as by the characteristics of the diode. The minimum reverse bias voltage values are provided in this datasheet. The input signal level applied for small signal testing is approximately 0 dBm.
2. Switching Speed (50 % TTL – 10/90 % RF Voltage) is a function of the PIN diode driver performance as well as the characteristics of the diode. An RC "current spiking network" is used on the driver output to provide a transient current to rapidly remove stored charge from the PIN diode. Typical component values are: R = 50 to 220 Ω and C = 470 to 1,000 pF.

Truth Table

Port J0 - J1	Port J0 - J2	Port J0 - J3	Bias: J1	Bias: J2	Bias: J3	Bias: B1	Bias: B2	Bias: B3	Bias: J0
Low Loss	Isolation	Isolation	0 V, -100 mA	+27 V, +25 mA	+27 V, +25 mA	+27 V, 0 mA	0 V, -25 mA	0 V, -25 mA	+5 V, +100 mA
Isolation	Low Loss	Isolation	+27 V, +25 mA	0 V, -100 mA	+27 V, +25 mA	0 V, -25 mA	+27 V, 0 mA	0 V, -25 mA	+5 V, +100 mA
Isolation	Isolation	Low Loss	+27 V, +25 mA	+27 V, +25 mA	0 V, -100 mA	0 V, -25 mA	0 V, -25 mA	+27 V, 0 mA	+5 V, +100 mA

RF Bias Network Component Values

Part #	Frequency (MHz)	Inductors	DC Blocking Capacitors	RF Bypass Capacitors
MSW3100-310	50 - 1000	4.7 µH	0.1 µF	0.1 µF
MSW3101-310	400 - 4000	82 nH	22 pF	270 pF

Minimum Reverse Bias Voltage[3]: P_{INC} = 125 W CW, Z_0 = 50 Ω with 1.5:1 VSWR

Part #	20 MHz	100 MHz	200 MHz	400 MHz	1 GHz	4 GHz
MSW3100-310	125 V	25 V	85 V	55 V	28 V	N/A
MSW3101-310	N/A	N/A	125 V	85 V	55 V	28 V

3. N/A denotes the switch is not recommended for that frequency band.

The minimum reverse bias voltage required to maintain a PIN diode out of conduction in the presence of a large RF signal is given by:

$$|V_{DC}| = \frac{|V_{RF}|}{\sqrt{1+\left[\left(\frac{0.0142 \times f_{MHz} \times W_{mils}^2}{V_{RF} \times \sqrt{D}}\right) \times \left(1+\sqrt{1+\left(\frac{0.056 \times V_{RF} \times \sqrt{D}}{W_{mils}}\right)^2}\right)\right]^2}}$$

Where:

$|V_{DC}|$ = magnitude of the minimum DC reverse bias voltage
$|V_{RF}|$ = magnitude of the peak RF voltage (including the effects of the VSWR)
F_{MHz} = lowest RF signal frequency expressed in MHz
D = duty factor of the RF signal
W_{MILS} = thickness of the diode I layer, expressed in mils (thousands of an inch)

R. Caverly and G. Hiller, —Establishing the Minimum Reverse Bias for a PIN Diode in a High Power Switch, IEEE Transactions on Microwave Theory and Techniques, Vol.38, No.12, December 1990

Absolute Maximum Ratings

Parameter	Conditions	Absolute Maximum
Forward Current	J1, J2, J3 port B1, B2, B3 port	250 mA 150 mA
Reverse Voltage	J1, J2, J3 port B1, B2, B3 port	200 V
Forward Diode Voltage	I_F = 250 mA	1.2 V
CW Incident Power Handling[4]	J0, J1, J2, J3 port Source & Load VSWR = 1.5:1, T_C = 85°C, cold switching	50 dBm
Peak Incident Power Handling[4]	J0, J1, J2, J3 port Source & Load VSWR = 1.5:1, T_C = 85°C, cold switching, Pulse Width = 10 µs, Duty Cycle = 1%	57 dBm
Total Dissipated RF & DC Power[4]	T_C = 85°C, cold switching	5 W
Junction Temperature	—	+175°C
Operating Temperature	—	-65°C to +125°C
Storage Temperature	—	-65°C to +150°C
Assembly Temperature	t = 10 s	+260°C

4. Backside RF and DC grounding area of device must be completely solder attached to the RF circuit board vias for proper electrical and thermal circuit grounding.

Nominal Operating Conditions

Parameter	Conditions	Value
Forward Current	J1, J2, J3 port B1, B2, B3 port	200 mA 100 mA
Reverse Voltage	J1, J2, J3 port B1, B2, B3 port	125 V
CW Incident Power Handling	J0, J1, J2, J3 port Source & Load VSWR = 1.5:1, T_C = 85°C, cold switching	48 dBm
Peak Incident Power Handling	J0, J1, J2, J3 port Source & Load VSWR = 1.5:1, T_C = 85°C, cold switching, Pulse Width = 10 µs, Duty Cycle = 1%	55 dBm
Junction Temperature	—	+175°C
Operating Temperature	—	-40°C to +85°C
Storage Temperature	—	-65°C to +150°C

Handling Procedures

Please observe the following precautions to avoid damage:

Static Sensitivity

These electronic devices are sensitive to electrostatic discharge (ESD) and can be damaged by static electricity. Proper ESD control techniques should be used when handling these Class 1C (HBM) devices. The moisture sensitivity level (MSL) rating for this part is MSL 1.

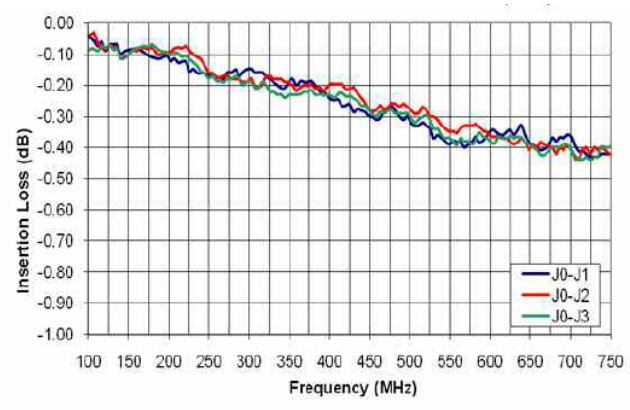
Environmental Capabilities

The MSW204x-204 diode is capable of meeting the environmental requirements of MIL-STD-202 and MIL-STD-750.

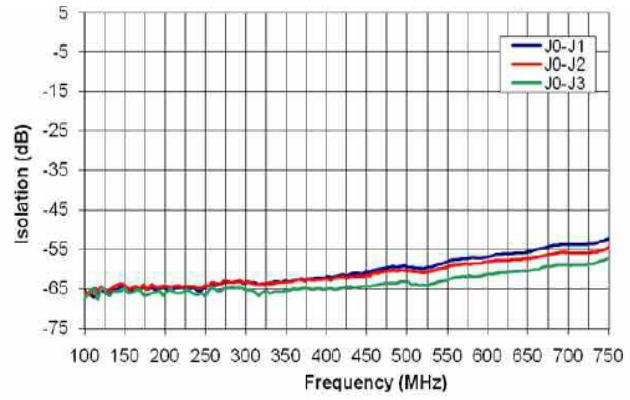
Typical Performance Curves

MSW3100-310

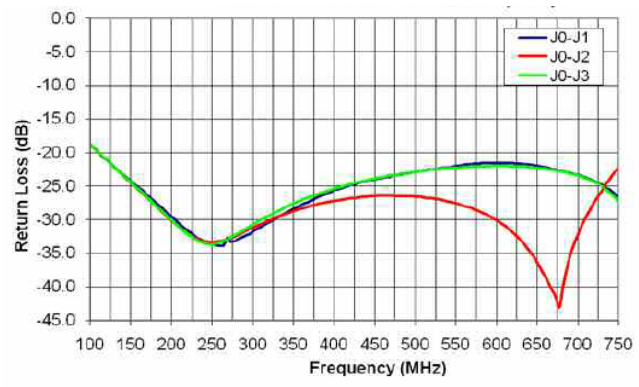
Insertion Loss



Isolation

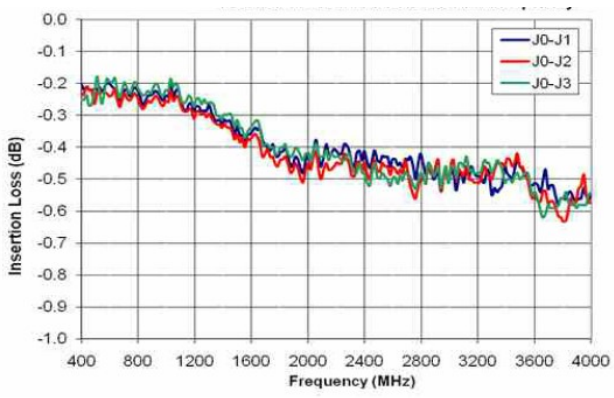


Return Loss

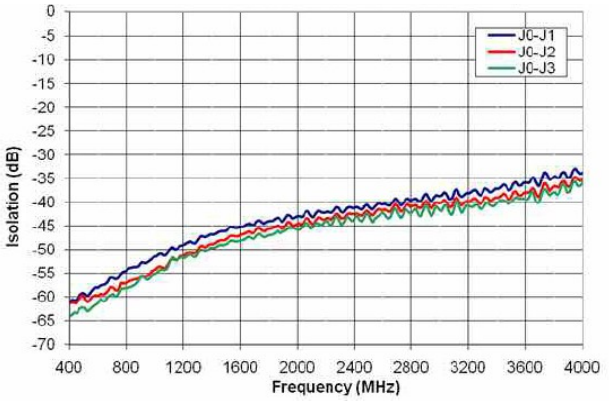


MSW3101-310

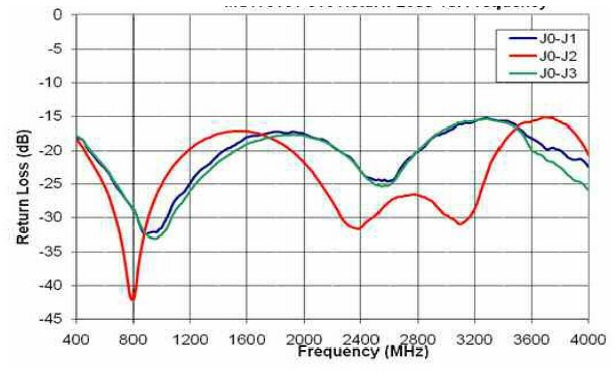
Insertion Loss



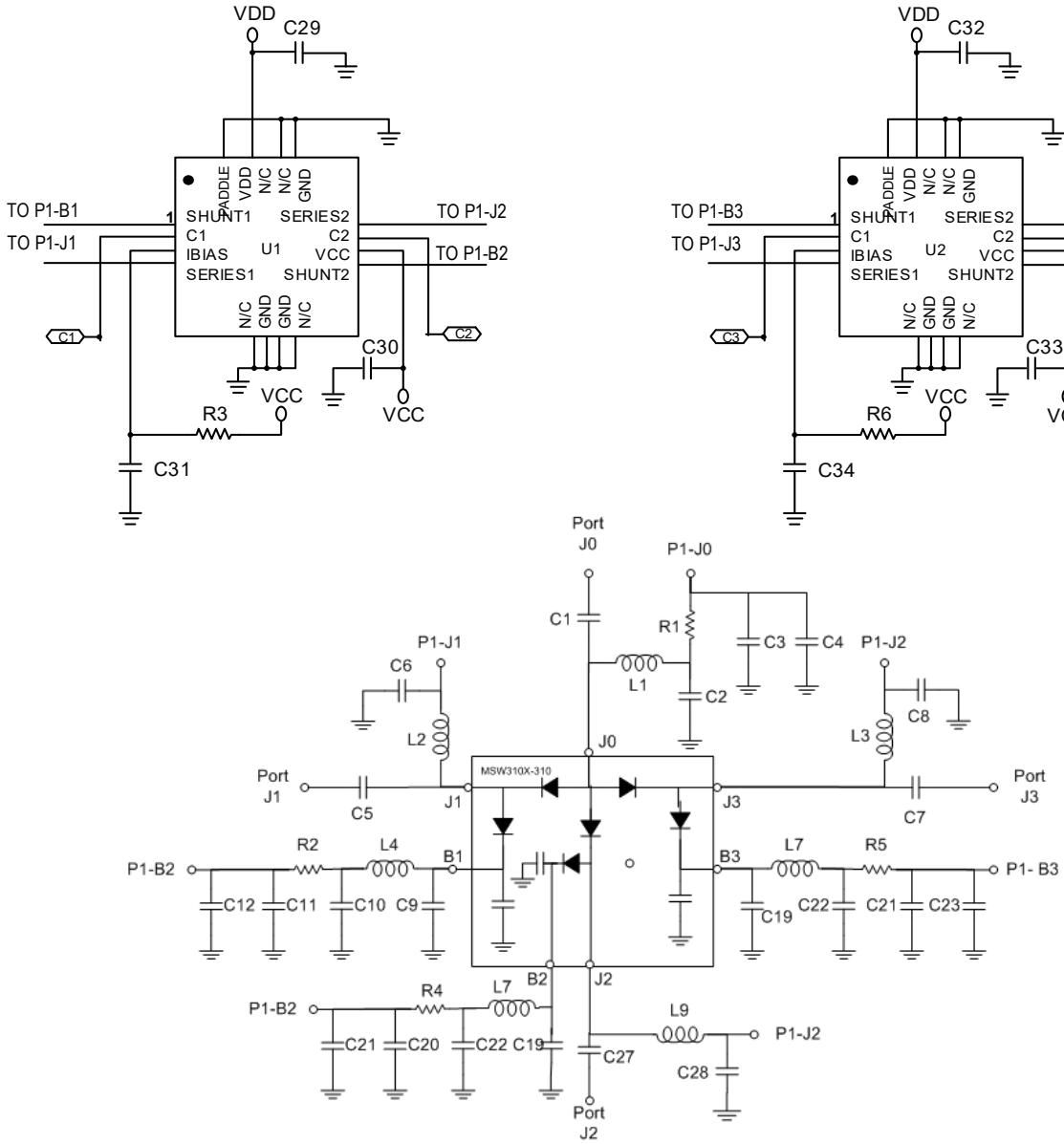
Isolation



Return Loss



SP3T Switch Evaluation Board with MADR-010574 Driver Application Schematic[5]



Parts List

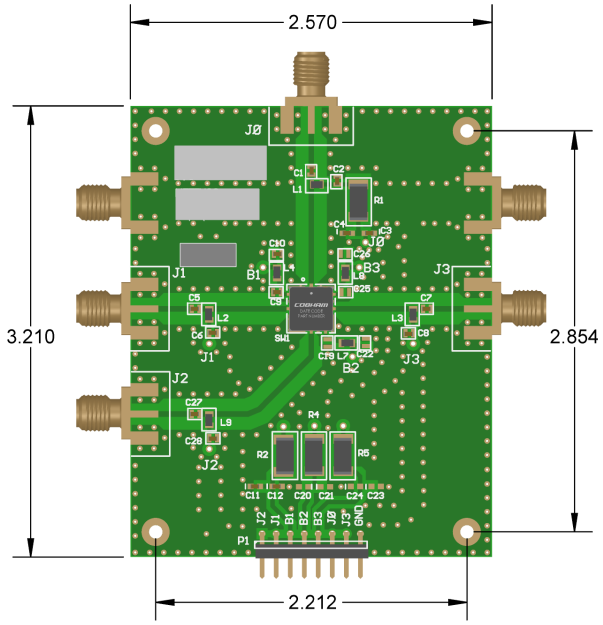
Part	Value	Part	Value
C29, C32	0.01 µF	R2, R4, R5[6]	12 KΩ
C30, C31, C33, C34	0.1 µF	R3, R6	499 KΩ

5. See pg. 8 for R1, L1 - L9 and C1 - C28 values. P1-J0 set to V_{CC}.
6. Resistor value calculated to provide 10 mA of shunt diode bias current given V_{CC} = 5 V and V_{DD} = 120 V.

Truth & Bias Table: SP3T Switch Operation with MADR-010574 PIN Diode Driver

CTRL 1	CTRL 2	CTRL 3	Path J0 - J1	Path J0 - J2	Path J0 - J3	Bias: J1	Bias: J2	Bias: J3	Bias: B1	Bias: B2	Bias: B3	Bias: J0
5 V	5 V	5 V	High Isolation	High Isolation	High Isolation	+120 V, +10 mA	+120 V, +10 mA	+120 V, +10 mA	0 V, -10 mA	0 V, -10 mA	0 V, -10 mA	+5 V, 0 mA
0 V	5 V	5 V	Low Loss	High Isolation	High Isolation	0 V, -100 mA	+120 V, +10 mA	+120 V, +10 mA	+120 V, 0 mA	0 V, -10 mA	0 V, -10 mA	+5 V, +100 mA
5 V	0 V	5 V	High Isolation	Low Loss	High Isolation	+120 V, +10 mA	0 V, -100 mA	+120 V, +10 mA	0 V, -10 mA	+120 V, 0 mA	0 V, -10 mA	+5 V, +100 mA
5 V	5 V	0 V	High Isolation	High Isolation	Low Loss	+120 V, +10 mA	+120 V, +10 mA	0 V, -100 mA	0 V, -10 mA	0 V, -10 mA	+120 V, 0 mA	+5 V, +100 mA

SP3T Switch Evaluation Board Layout



APPLIES TO THE FOLLOWING EVAL BOARDS:
CS310 - BAND 1 / BAND 2 / BAND 3

It is important to note that the switch module evaluation board, as supplied from the factory, is not capable of handling RF input signals larger than 45 dBm. If performance of the switch under larger input signals is to be evaluated, an adequate heat sink must be properly attached to the evaluation board, and several of the passive components on the board must be changed in order to safely handle the dissipated power as well as the high bias voltage necessary for proper performance. Contact the factory for recommended components and heat sink.

Evaluation Board Parts List

MSW3100-310 Band 1		
Part	**Value**	**Case Style**
C1, C2, C5 - C10, C14, C15, C16, C19, C22, C25 - C28	0.1 µF	0603
[7]C3, C4, C11, C12, C17, C18, C20, C21, C23, C24	0.1 µF	0603
L1 - L9	4.7 µH	0603
R1	39 Ω	2512

MSW3101-310 Band 2		
Part	**Value**	**Case Style**
C1, C5, C7, C9, C13, C15, C19, C25, C27	22 pF	0603
C2, C6, C8, C10, C14, C16, C22, C26, C28	270 pF	0603
C3, C4, C11, C12, C17, C18, C20, C21, C23, C24	1000 pF	0603
L1 - L9	82 nH	0603
R1	39 Ω	2512

7. Second bypass capacitor is optional.

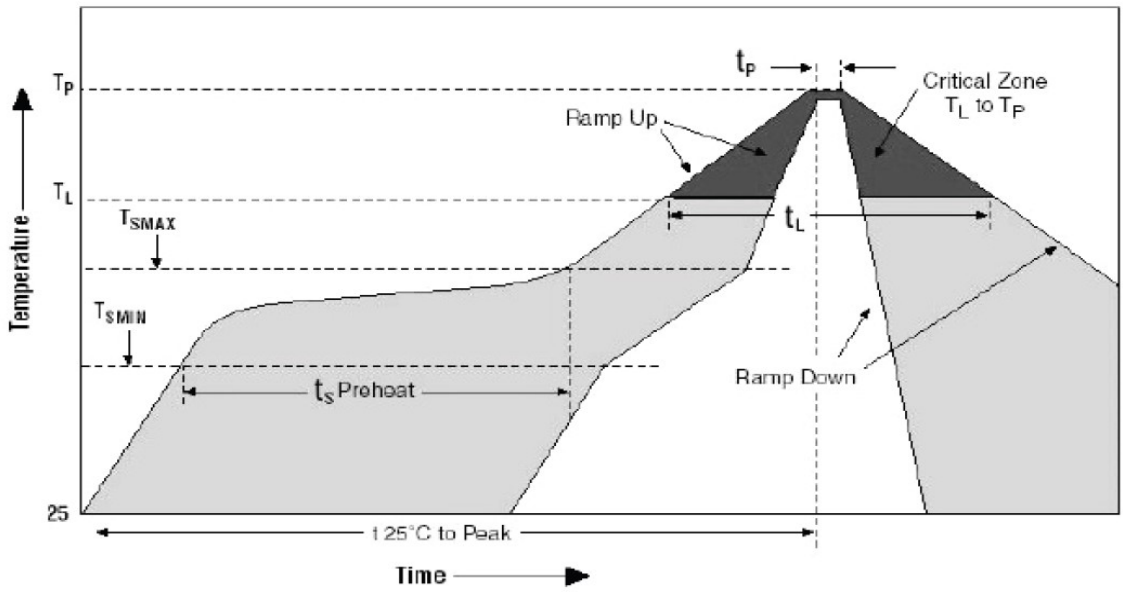
Assembly Instructions

SP3T PIN Diodes may be placed onto circuit boards with pick and place manufacturing equipment from tape and reel. The devices are attached to the circuit using conventional solder re-flow or wave soldering procedures with RoHS type or Sn 60 / Pb 40 type solders.

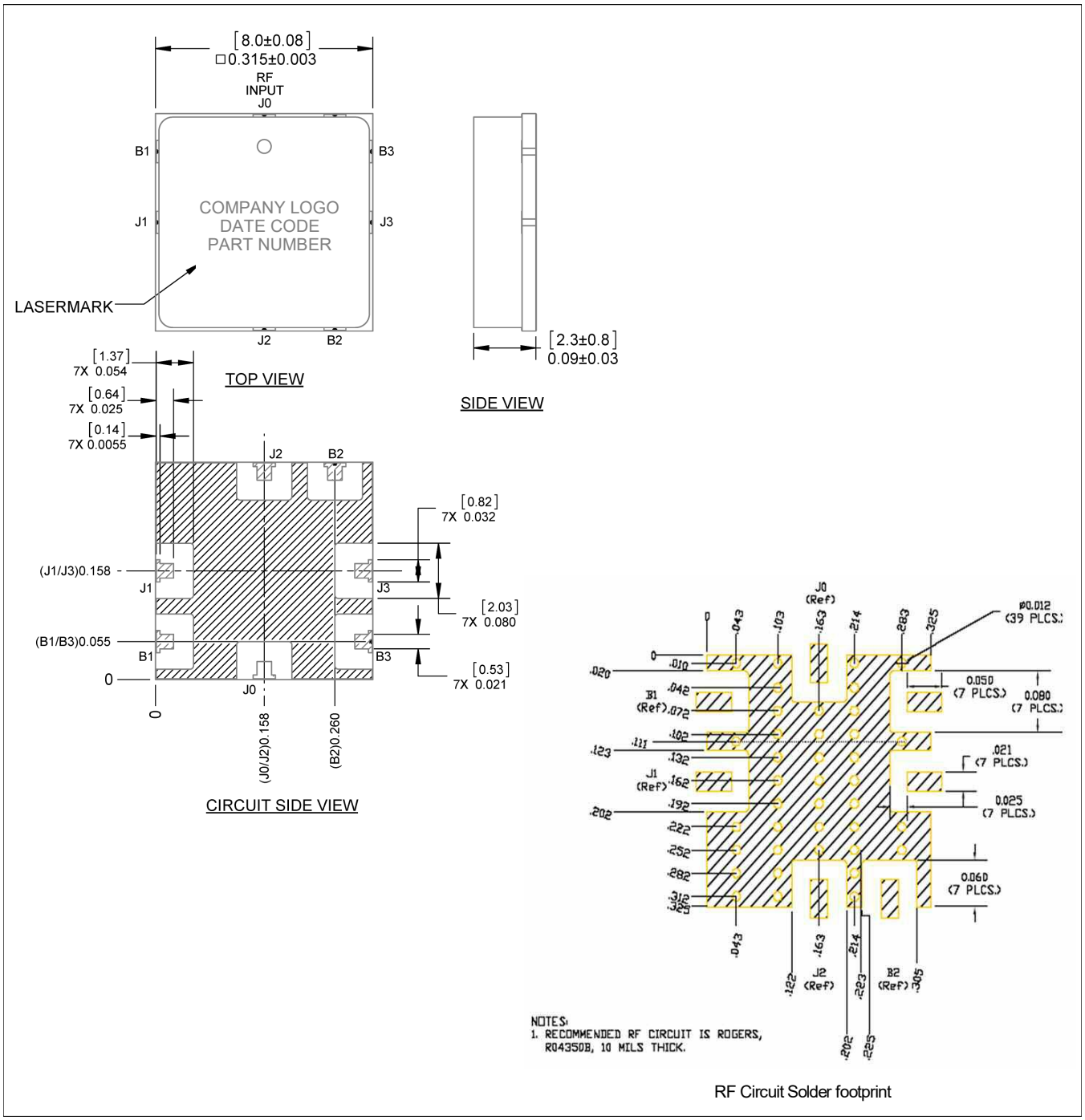
Table 1. Time-Temperature Profile for Sn60/Pb40 or RoHS Type Solders

Profile Feature	SnPb Solder Assembly	Pb-Free Solder Assembly
Average Ramp-Up Rate (T_L to T_P)	3°C /second maximum	3°C /second maximum
Preheat: - Temperature Min (T_{SMIN}) - Temperature Max (T_{SMAX}) - Time (min to max)(t_S)	 100°C 150°C 60-120 s	 150°C 200°C 60-180 s
T_{SMAX} to T_L - Ramp-Up Rate		3°C/s maximum
Time Maintained Above: - Temperature (T_L) - Time (t_L)	 183°C 60-150 s	 217°C 60-150 s
Peak temperature (T_P)	225 +0/-5°C	260 +0/-5°C
Time Within 5°C of Actual Peak Temperature (t_P)	10 – 30 s	20 – 40 s
Ramp-Down Rate	6°C /s maximum	6°C /s maximum
Time 25°C to Peak Temperature	6 minutes maximum	8 minutes maximum

Figure 1. Solder Re-Flow Time-Temperature Profile



Outline (CS310)[8,9]



8. Hatched metal area on circuit side of device is RF, DC and thermal grounded.
9. Vias should be solid copper fill and gold plated for optimum heat transfer from backside of switch module through Circuit Vias to metal thermal ground.