SP2T PIN Diode Switch

MSW204x-204
Rev. V5

Features

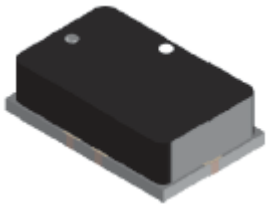
- Wide Frequency Range: 50 MHz to 4 GHz, in 2 bands
- Surface Mount SP2T Switch in Compact Outline: 8 mm L x 5 mm W x 2.5 mm H
- Higher Average Power Handling than Plastic Packaged MMIC Switches: 158 W CW
- High RF Peak Power: 500 W
- Low Insertion Loss: 0.25 dB
- High IIP3: 65 dBm
- Operates From Positive Voltage Only: 5 V & 28 V to 125 V
- Ultra-Thin Termination Plating to Combat Embrittlement
- RoHS* Compliant

Applications

- ISM

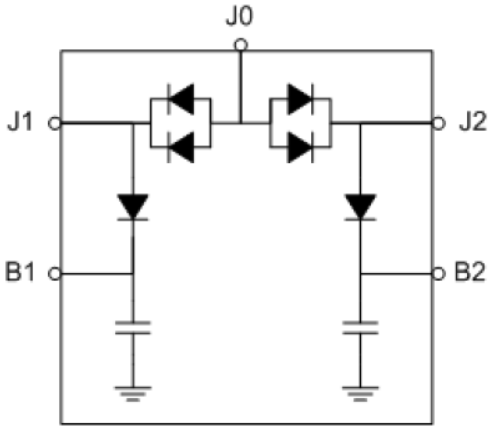
Description

The MSW2040-204 (50 MHz - 1 GHz) and MSW2041-204 (400 MHz - 4 GHz) series of surface mount silicon PIN diode SP2T switches can be used for high power transmit/receive (TR) 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 package has ultra-thin Au termination plating to combat embrittlement. The SP2T switches are designed in a symmetrical topology to enable either 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 (<25 ºC/W) of the PIN diodes in these devices enables them to reliably handle RF incident power levels of 52 dBm CW and RF peak incident power levels of 57 dBm in cold switching applications at T_A = 85ºC. 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 diodes are optimized for use in applications for which high volume, surface mount, solder re-flow manufacturing is employed. These products are durable and capable of reliably operating in military, commercial, and industrial environments.



CS204

Functional Schematic



Ordering Information

Part Number	Package
MSW2040-204-T	tube
MSW2040-204-R	250 or 500 piece reel
MSW2040-204-W	Waffle pack
MSW2041-204-T	tube
MSW2041-204-R	250 or 500 piece reel
MSW2041-204-W	Waffle pack
MSW2040-204-E	RF evaluation board
MSW2041-204-E	RF evaluation board

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

MSW2040-204 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	dB	—	0.2	0.3
Return Loss	Bias State 1: port J0 to J1 Bias State 2: port J0 to J2	dB	18	20	—
Isolation	Bias State 1: port J0 to J1 Bias State 2: port J0 to J2	dB	47	50	—
CW Incident Power[1]	Source & Load VSWR = 1.5:1	dBm	—	—	52
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	—

MSW2041-204 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	dB	—	0.5	0.7
Return Loss	Bias State 1: port J0 to J1 Bias State 2: port J0 to J2	dB	14	15	—
Isolation	Bias State 1: port J0 to J1 Bias State 2: port J0 to J2	dB	30	33	—
CW Incident Power[1]	Source & Load VSWR = 1.5:1	dBm	—	—	52
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 = 2.00 GHz, F2 = 2.01 GHz P1 = P2 = 10 dBm Measure on path biased to low loss state	dBm	60	65	—

Continued

Bias State Conditions:

State 1
(J0 - J1 in low insertion loss state,
J0 - J2 in isolation state):
- a. B1: V_{HIGH}[1], 0 mA
- b. B2: -25 mA, 0 V
- c. J1: -150 mA, 0 V
- d. J2: 25 mA, V_{HIGH}[1]
- e. J0: 150 mA, ≈0.9 V

State 2
(J0 - J2 in low insertion loss state,
J0 - J1 in isolation state):
- a. B1: -25 mA, 0 V
- b. B2: V_{HIGH}[1], 0 mA
- c. J1: 25 mA, V_{HIGH}[1]
- d. J2: -150 mA, 0 V
- e. J0: 150 mA, ≈0.9 V

1. PIN diode minimum reverse DC voltage (VHIGH) to maintain high resistance in the OFF PIN diode is determined by RF frequency, incident power, duty cycle, characteristic impedance and VSWR as well as by the characteristics of the diode. The recommended minimum reverse bias voltage (VHIGH) values are provided in the Minimum Reverse Bias Voltage table of this datasheet.
2. Switching time (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[3,4]

Port J0 - J1	Port J0 - J2	Bias: J1[3,4]	Bias: J2[3,4]	B1[3,4]	B2[3,4]
Low Loss	Isolation	V = 0 V, I = -150 mA	V =V_{HIGH}, I = +25 mA	V = V_{HIGH}, I = 0 mA	V = 0 V, I = -25 mA
Isolation	Low Loss	V =V_{HIGH}, I = +25 mA	V = 0 V, I = -150 mA	V = 0 V, I = -25 mA	V = V_{HIGH}, I = 0 mA

3. 28 V</= V_{HIGH} </= 125 V.
4. PIN diode minimum reverse DC voltage (VHIGH) to maintain high resistance in the OFF PIN diode is determined by RF frequency, incident power, duty cycle, characteristic impedance and VSWR as well as by the characteristics of the diode. The recommended minimum reverse bias voltage (V_{HIGH}) values are provided in the Minimum Reverse Bias Voltage table of this datasheet.

RF Bias Network Component Values

Part #	Frequency (MHz)	Inductors	DC Blocking Capacitors	RF Bypass Capacitors
MSW2040-204	50 - 1000	4.7 µH	0.1 µF	0.1 µF
MSW2041-204	400 - 4000	82 nH	27 pF	270 pF

Minimum Reverse Bias Voltage[5]: 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
MSW2040-204	125 V	25 V	85 V	55 V	28 V	N/A
MSW2041-204	N/A	N/A	125 V	85 V	55 V	28 V

5. 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	J0, J1, J2 port B1, B2 port	250 mA 150 mA
Reverse Voltage	J0, J1, J2, B1, B2 port	200 V
Forward Diode Voltage	I_F = 250 mA	1.2 V
CW Incident Power Handling[6]	J0, J1, J2 port Source & Load VSWR = 1.5:1, T_C = 85°C, cold switching	51 dBm
Peak Incident Power Handling[6]	J0, J1, J2 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[6]	T_C = 85°C, cold switching	6 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

6. 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.

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.

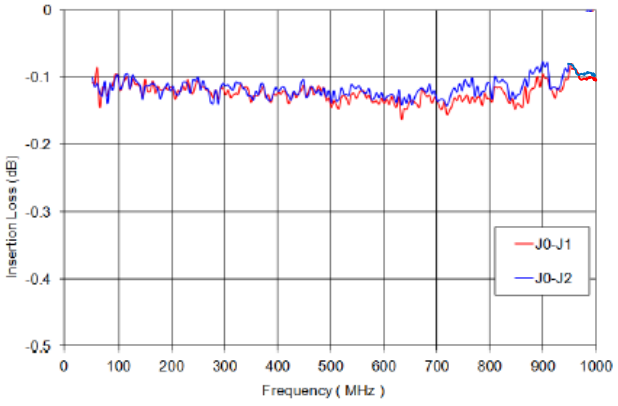
Environmental Capabilities

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

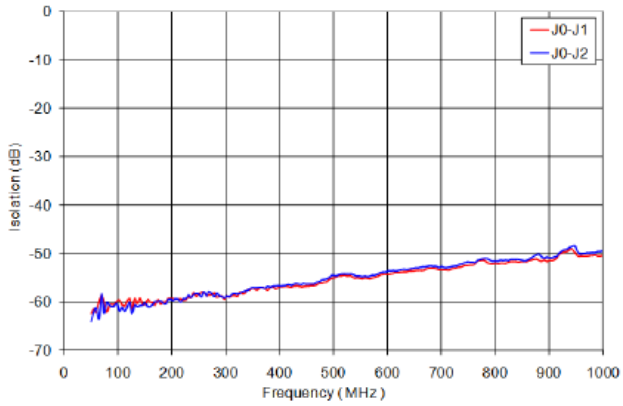
Typical Performance Curves

MSW2040-204

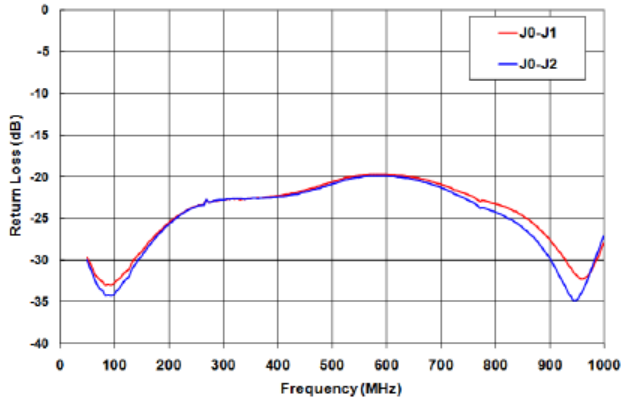
Insertion Loss



Isolation

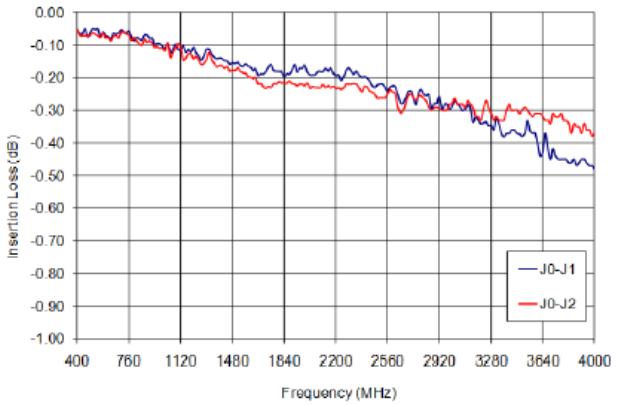


Return Loss

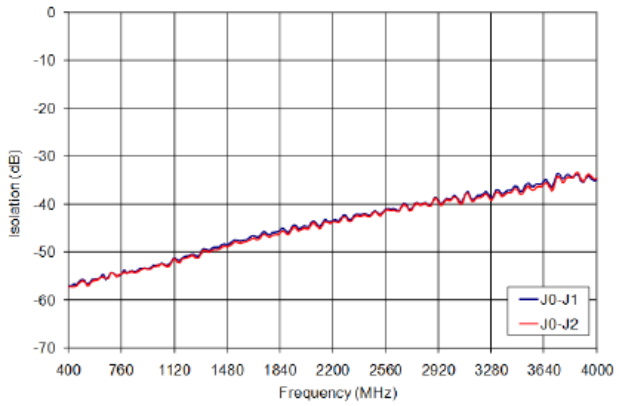


MSW2041-204

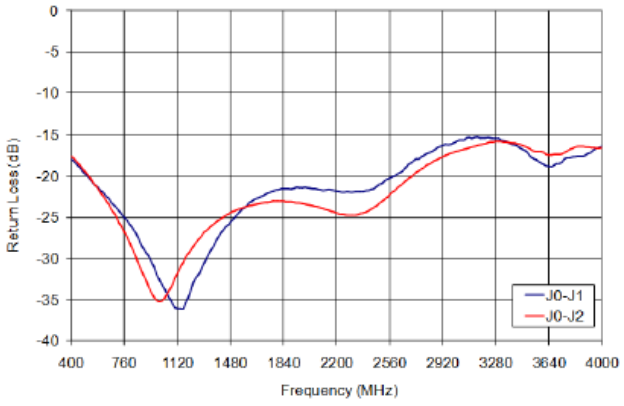
Insertion Loss



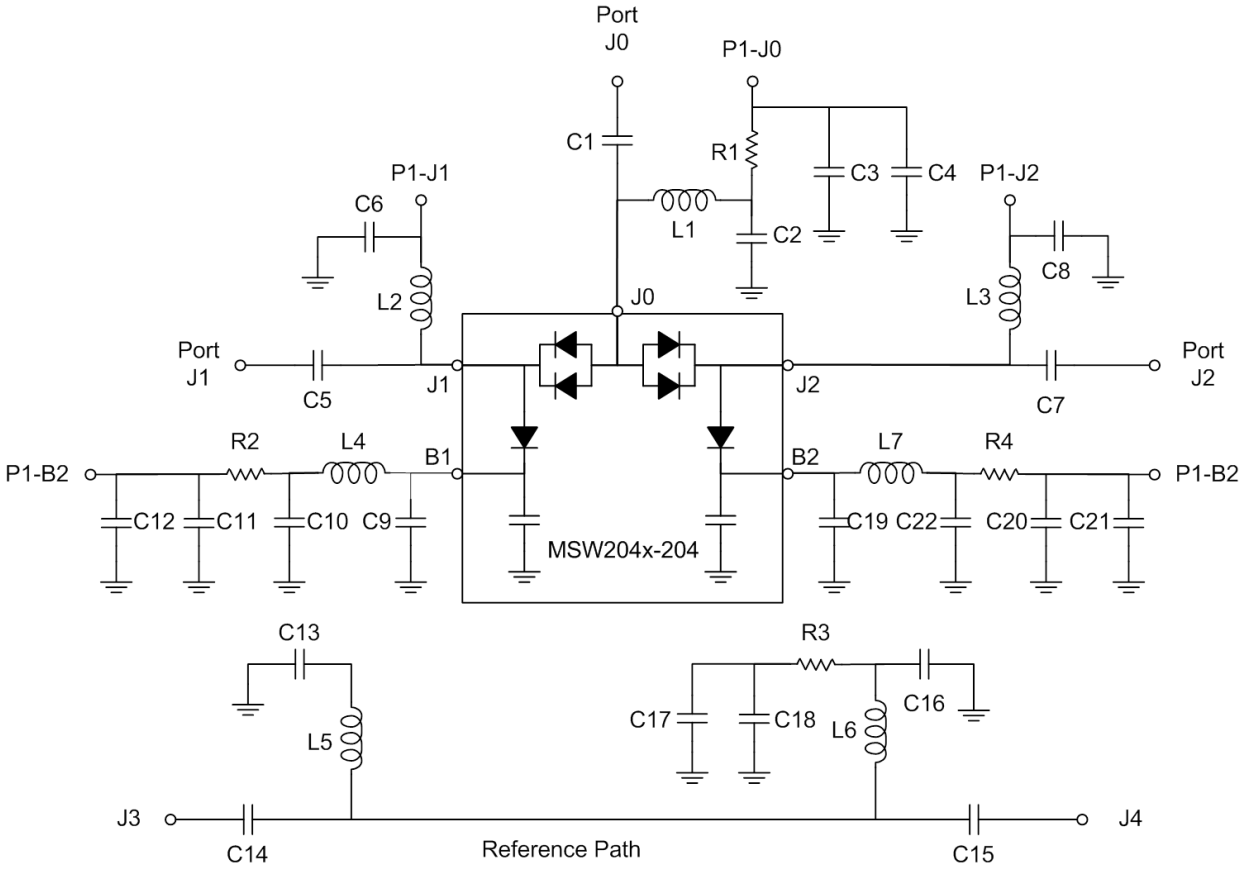
Isolation



Return Loss



SP2T Switch Evaluation Board Schematic



The evaluation boards for the MSW204x family of surface mount silicon PIN diode SP2T T-R switches allow the full exercise of each switch for small signal performance analysis, as well as for large signal operation with maximum input signal power of 45 dBm (CW or peak power). Each evaluation board includes the appropriate MSW204x-204 switch, DC blocking capacitors at each RF port and bias decoupling networks at each RF port which allow DC or low frequency control signals to be applied to the switch. Four complementary control signals are required for proper operation. Bias voltages are applied to the B1 and B2 bias ports, as well as to the J0, J1 and J2 RF ports to control the state of the switch. A fixed bias voltage must be applied to the J0 port (connect 5 V to pin 3 of multipin connector P1) whenever the switch is in operation.

Caution: the 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 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. The evaluation board must be connected to an adequate heat sink for large signal operation. Contact the factory for recommended components. For the purposes of description, State 1 is defined to be the condition in which the evaluation board is biased to produce the low insertion condition between ports J0 and J1 while producing high isolation between ports J0 and J2. State 2 is the converse of State 1.

State 1

In State 1, the series PIN diode between the J0 and J1 ports is forward biased by applying 0 V to the J1 bias input port (pin 1 of multi-pin connector P1). The magnitude of the resultant bias current through the diode is primarily determined by the voltage applied to the J0 bias port (pin 3 of P1), the magnitude of the forward voltage across the PIN diode and the resistance of R1. This current is nominally 150 mA. At the same time, the PIN diode connected between J2 and B2 ports is also forward biased by applying a high bias voltage, nominally 28 V, to the J2 bias port (pin 7 of P1) and 0 V to the B2 bias port (pin 5 of P1). Under this condition, the PIN diode connected between the J0 and J2 ports is reverse biased and the PIN diode connected between the J2 and B2 ports is forward biased. The magnitude of the bias current through this diode is primarily determined by the voltage applied to the J2 bias port, the magnitude of the forward voltage across the PIN diode and the resistance of R4. This current is nominally 25 mA.

The series PIN diode which is connected between the J0 and J2 ports must be reverse biased during State 1. The reverse bias voltage must be sufficiently large to maintain the diode in its non-conducting, high impedance state when large RF signal voltage may be present in the J0-to- J1 path. The reverse voltage across this diode is the arithmetic difference of the bias voltage applied to the J2 bias port and the DC forward voltage of the forward biased J0-to-J1 series PIN diode.

The minimum voltage required to maintain the series diode between J0 and J2 out of conduction is a function of the magnitude of the RF voltage present, the standing wave present at the series diode's anode, the frequency of the RF signal and the characteristics of the series diode, among other factors. Minimum control voltages for several signal frequencies are shown in the table "Minimum Reverse Bias Voltage", assuming the input power to the J0 or J1 port to be 100 W CW and the VSWR on the J0-J1 path to be 1.5:1.

State 2

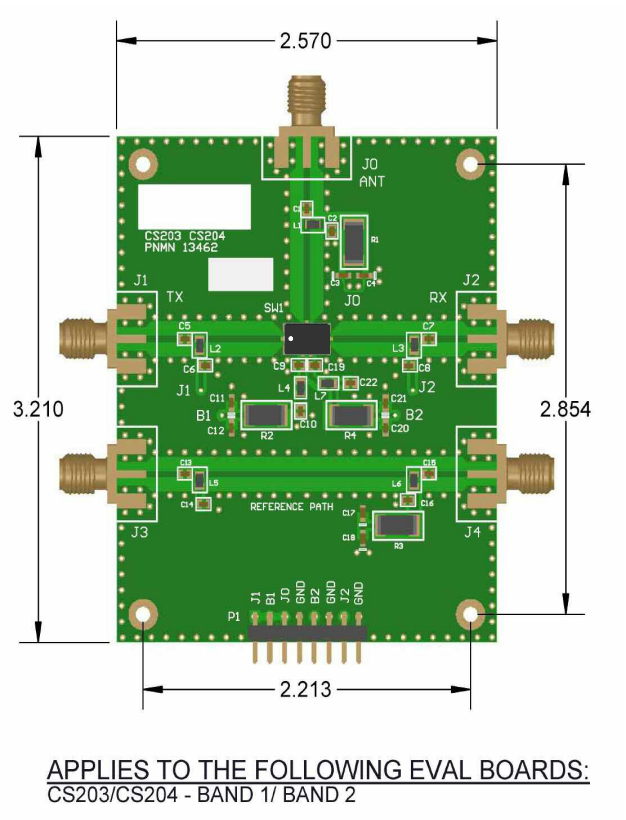
In the State 2, the series PIN diode between the J0 and J2 ports is forward biased by applying 0 V to the J2 bias input port (pin 7 of multi-pin connector P1). The magnitude of the resultant bias current through the diode is primarily determined by the voltage applied to the J0 bias port (pin 3 of P1), the magnitude of the forward voltage across the PIN diode and the resistance of R1. This current is nominally 150 mA. At the same time, the PIN diode connected between J2 and B2 ports is reverse biased by applying a high bias voltage, nominally 28 V, to the B2 bias port (pin 5 of P1). A high voltage, nominally 28 V, is also applied to the J1 bias port (pin 1 of P1). Under this condition, the PIN diode connected between the J0 and J1 ports is reverse biased thus isolating the J1 RF port from the RF signal path between J0 and J2. The reverse voltage across this diode is the arithmetic difference of the bias voltage applied to the J1 bias port and the DC forward voltage of the forward-biased J0-to-J2 series PIN diode. The minimum voltage required to maintain the series diode on the J0-to-J1 side of the switch out of conduction is a function of the magnitude of the RF voltage present, the standing wave present at the diode's anode, the frequency of the RF signal and the characteristics of the series diode, among other factors.

The values of the reactive components which comprise the bias decoupling networks as well as the signal path DC blocking are shown in the table RF Bias Network Recommended Component Values.

Reference Path

A reference path is provided on the evaluation board, complete with bias decoupling networks, so that the magnitude of the insertion loss of the microstrip transmission lines connected to the switch and the associated bias decoupling components can be measured and removed from the measured performance of the switch.

SP2T Switch Evaluation Board Layout



APPLIES TO THE FOLLOWING EVAL BOARDS:
CS203/CS204 - BAND 1/ BAND 2

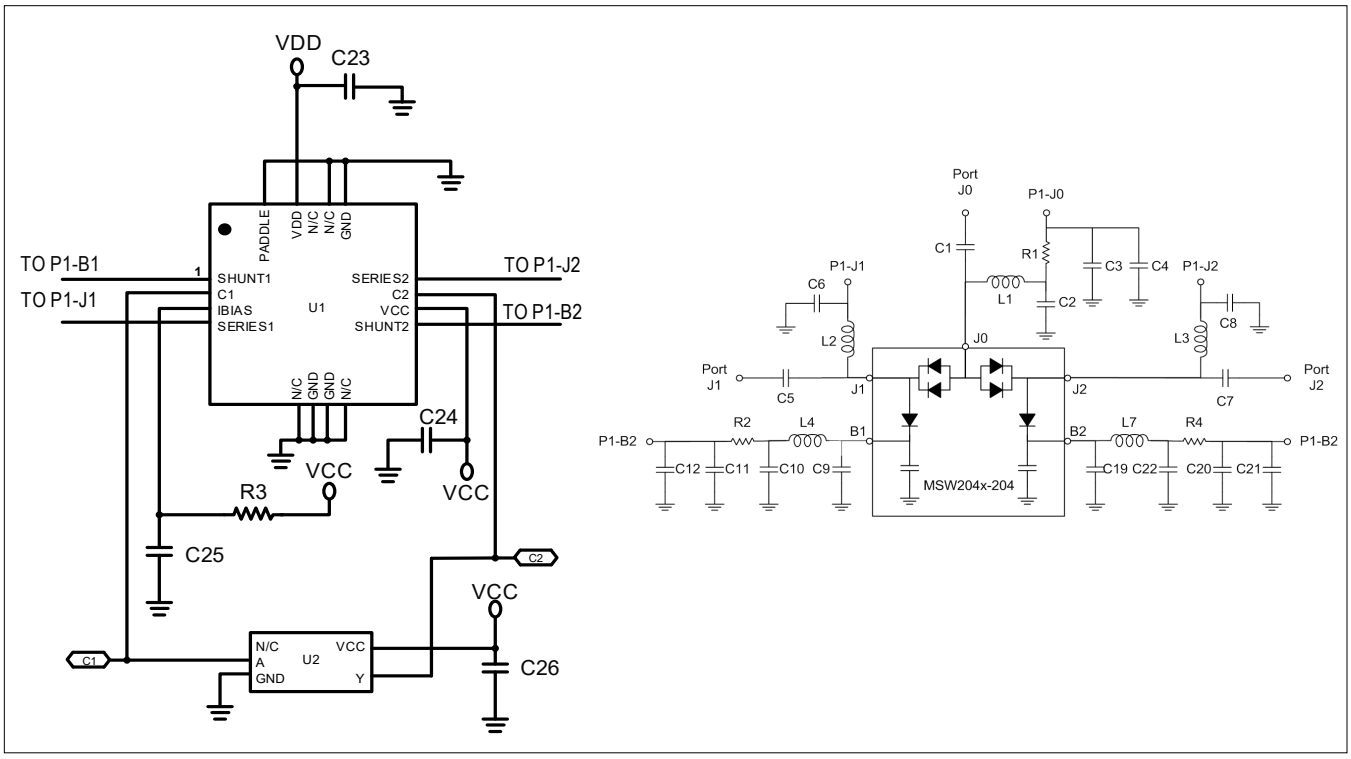
Evaluation Board Parts List

MSW2040-204 Band 1		
Part	**Value**	**Case Style**
C1, C2, C5 - C10, C13 - C16, C19	470 pF	0603
[7]C3, C4, C11, C12, C17, C18, C20, C21	470 pF	0603
L1 - L7	600 Ω	0603
R1, R3	39 Ω	2512
R2, R4	1200 Ω	2512

MSW2041-204 Band 2		
Part	**Value**	**Case Style**
C1, C5, C7, C13, C15	47 pF	0603
C2, C6, C8, C9, C10, C14, C16, C19, C22	220 pF	0603
[7]C3, C4, C11, C12, C17, C18, C20, C21	1000 pF	0603
L1 - L7	43 nH	0603
R1, R3	39 Ω	2512
R2, R4	1200 Ω	2512

7. Second bypass capacitor is optional.

MSW204x-204 with MADR-010574 Driver Application Schematic[8]



8. See page 9 for R1, L1 - L7 and C1 - C22 values. P1-J0 set to V_{CC}.

Parts List

Part	Value
C23	0.01 µF
C24 - C26	0.1 µF
R2, R4[9]	12 KΩ
R3	499 KΩ
U2	SN74AHC1G

9. Resistor value calculated to provide ~10 mA of shunt diode bias current given V_{CC} = 5 V and V_{DD} = 120 V.

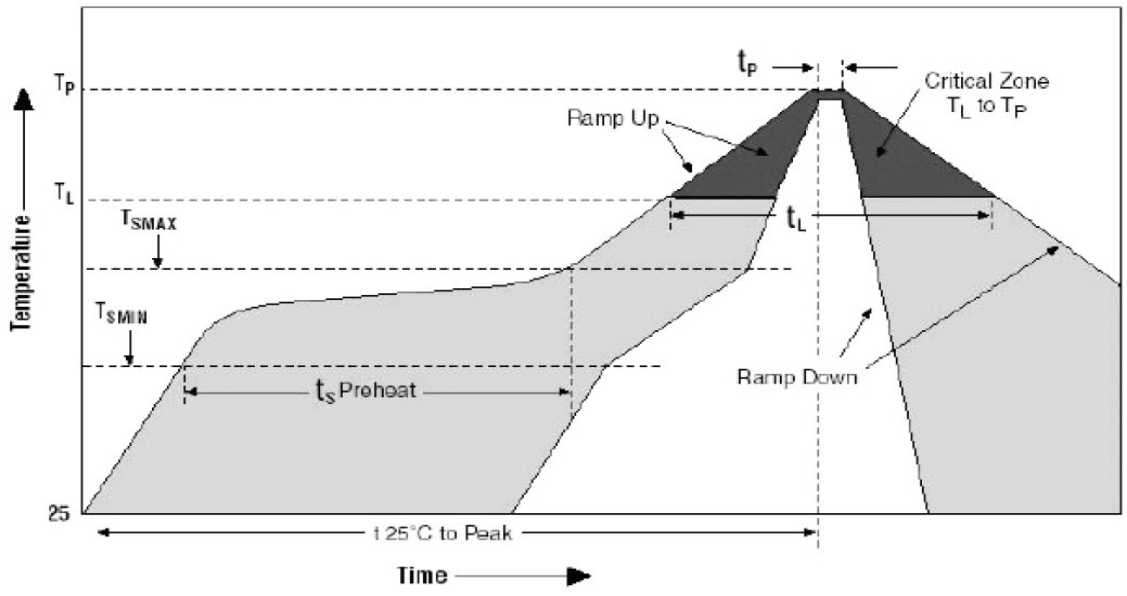
Assembly Instructions

SP2T 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.

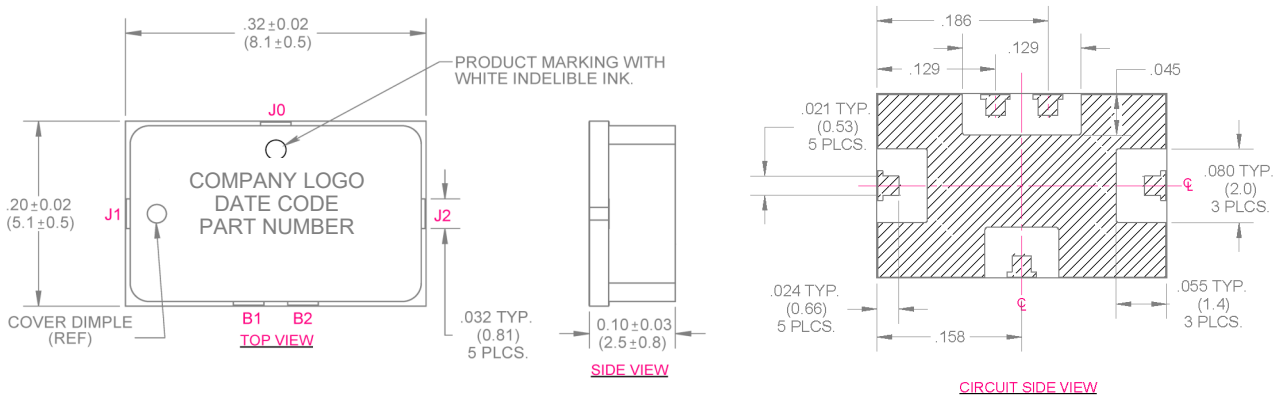
Table 1. Time-Temperature Profile for Sn60/Pb40 or RoHS Type Solders

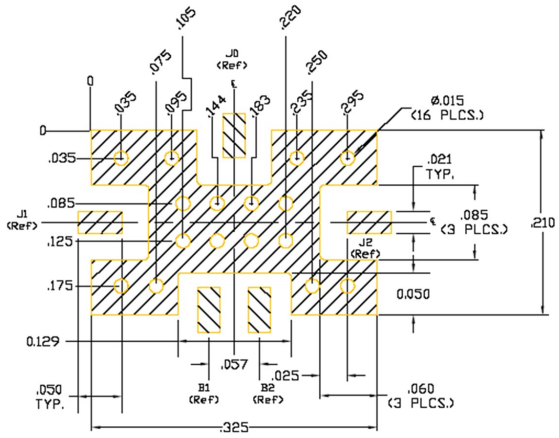
Profile Feature	SnPb Solder Assembly	Pb-Free Solder Assembly
Average Ramp-Up Rate (T_L to T_P)	3°C /second maximum	3°C /second maximum
Preheat: - Temperature Min (T_{SMIN}) - Temperature Max (T_{SMAX}) - Time (min to max)(t_S)	 100°C 150°C 60-120 s	 150°C 200°C 60-180 s
T_{SMAX} to T_L - Ramp-Up Rate		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 (CS204)[10,11]





RF Circuit Solder footprint

10. Hatched metal area on circuit side of device is RF, DC and thermal grounded.
11. 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.

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MACOM:

MSW2040-204 MSW2041-204 MSW2041-204-R MSW2041-204-T