MM5230

DC to 26 GHz High Power RF Switch

POWERED BY ideal switch®

RoHS COMPLIANT

Product Overview

Description

The MM5230 device is a high-power and wide frequency range SP4T micro-mechanical switch. Menlo Micro has developed a new Ideal Switch® fabrication process and applied it to DC and wideband RF/microwave switch applications. This innovative technology enables highly reliable switches capable of 25 W power handling. The MM5230 provides ultra-low insertion loss and superior linearity as an SP4T from DC to 18 GHz, and greater than 3 billion switching cycles.

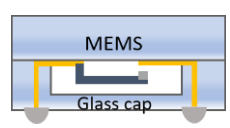
The MM5230 can also be configured in Super-Port mode that extends the frequency operation to 26 GHz. The MM5230 is an ideal solution for replacing large RF electromechanical relays, as well as RF/microwave solid-state switches in applications where linearity and insertion loss are critical parameters. The four switch channels are individually controllable by applying a gate voltage to the corresponding RF GATE pin.

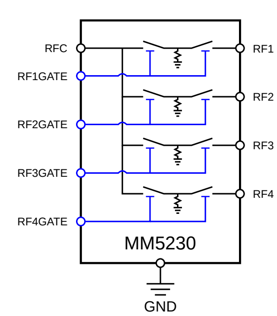
Features

- DC to 26 GHz Frequency Range
- 25 W (CW), 150 W (Pulsed) Max Power Handling
- Low On-State Insertion Loss: 0.3 dB @ 6.0 GHz
- High Linearity, IIP3 95 dBm Typical
- 25 dB Isolation @ 6.0 GHz / 42 dB Super-Port Mode
- High Reliability > 3.0 x 10^9 Switching Operations
- 2.5 mm x 2.5 mm BGA Package (200 µm Solder Ball)

Markets

- Defense and Aerospace
- Medical Equipment
- Test and Measurement
- Wireless Infrastructure





Applications

- Switched Filter Banks and Tunable Filters
- High Power RF Front Ends
- Antenna Tuning
- Low-Loss Switch Matrices & EM Relay Replacement

Electrical Specifications

Operating Characteristics

Exceeding the maximum ratings as listed in Table 1 below may reduce the reliability of the device or cause permanent damage. Operation of the MM5230 should be restricted to the limits indicated in Table 3.

Electrostatic Discharge (ESD) Safeguards

The MM5230 is a Class 0 ESD device. When handling the MM5230, observe precautions as with any other ESD sensitive device. Do not exceed the voltage ratings specified in Table 1.

Table 1. Absolute Maximum Ratings[1]

Parameter	Minimum	Maximum	Unit
Open State Voltage Rating / Switch RF1-4 to RFC[2]	-150	150	V
Open State Voltage RF1-RF4, RFC to GND, GATE pin to GND Potential[2] [3]	-150	150	V
Closed State Voltage RFGATE Pins to RF1-RF4, RFC, GND[2]	-100	100	V
Hot Switching Voltage[4]	-0.5	0.5	V
DC Current Rating/Switch[5]	—	500	mA
CW RF Power[6]	—	25	W
Peak RF Power[7]	—	150	W
Storage Temperature Range[8]	-65	+150	ºC
Mechanical Shock[9]	—	500	G
Vibration[10]	—	3.1	G_{RMS}

Notes:

1. All parameters must be within recommended operating conditions. Maximum DC and RF power can only be applied during the on-state condition (cold-switched condition).
2. This also applies to ESD events. This is a Class 0 device.
3. RF pins must not be allowed to electrically float during switch operation. See section Floating Node Restrictions for details on avoiding floating nodes.
4. See section Hot Switch Restrictions for more information.
5. Total current of all channels combined.
6. For 6 GHz and +85 ºC ambient test condition. See Thermal and Power Handling Considerations for more information.
7. For 6 GHz, 10% Duty Cycle, 100 µs pulse width, and +85 ºC ambient test condition.
8. See section Storage and Shelf Life more information on shelf and floor life.
9. See JESD22-B104 for mechanical shock test methodology at 1.0ms, half-sine, 5 shocks/axis, 6 axis.
10. See JESD22-B103 for vibration test methodology at 3.1G and 30min/cycle, 1 cycle/axis, 3 axis.

Table 2. Recommended Operating Conditions

Parameter	Symbol	Minimum	Typical	Maximum	Unit
Gate Bias Voltage	V_{BB}	87	89	91	V
Gate Voltage Slew Rate		20	—	200	V/µs
CW RF Power[1]					
1 GHz		—	—	50	W
6 GHz		—	—	25	W
18 GHz		—	—	7	W
Ambient Temperature Range	T_A	-40	—	85	ºC
Switch Cycle Frequency[2]		—	—	10	kHz

Notes:

1. For +85 ºC ambient test condition. See Thermal and Power Handling Considerations for more information.
2. Test condition is defined as full enable-disable cycles of one channel.

Electrical Characteristics

All specifications valid over full supply voltage and operating temperature range unless otherwise noted.

Table 3. DC and AC Electrical Specifications

Parameter	Minimum	Typical	Maximum	Unit
Operating Frequency Range				
Normal SP4T mode	DC	—	18	GHz
Super-Port Mode[1]	DC	—	26	GHz
Insertion Loss				
Normal SP4T mode @ 6 GHz	—	0.3	—	dB
Super-Port mode @ 6 GHz	—	0.3	—	dB
Normal SP4T mode @ 18 GHz	—	1.3	—	dB
Super-Port mode @ 18 GHz[1]	—	0.8	—	dB
Normal SP4T mode @ 26 GHz	—	—	—	dB
Super-Port mode @ 26 GHz[1]	—	1.4	—	dB
Input/Output Return Loss				
Normal SP4T mode @ 6 GHz	—	15	—	dB
Super-Port mode @ 6 GHz	—	20	—	dB
Normal SP4T mode @ 18 GHz	—	10	—	dB
Super-Port mode @ 18 GHz[1]	—	14	—	dB
Normal SP4T mode @ 26 GHz	—	—	—	dB
Super-Port mode @ 26 GHz[1]	—	12	—	dB

Parameter	Minimum	Typical	Maximum	Unit
Isolation				
Normal SP4T mode @ 6 GHz	—	25	—	dB
Super-Port mode @ 6 GHz	—	42	—	dB
Normal SP4T mode @ 18 GHz	—	18	—	dB
Super-Port mode @ 18 GHz	—	29	—	dB
Normal SP4T mode @ 26 GHz	—	—	—	dB
Super-Port mode @ 26 GHz	—	19	—	dB
Channel to Channel Isolation @ 6 GHz	—	25	—	dB
Third-Order Intercept Point (IP3)[2]	—	95	—	dBm
Second Harmonic (H2)[3]	—	-130	—	dBc
Third Harmonic (H3)[3]	—	-120	—	dBc
On/Off Switching and Settling Time				
Turn on time4	—	8.5	16	µs
Turn off time	—	2.5	6	µs
On/Off Switch Operations[5] **(MM5230-03NDB)**				
at 25 ºC	3×10^9	30×10^9	—	Cycles
at 70 ºC	—	1×10^9	—	Cycles
at 85 ºC	—	0.1×10^9	—	Cycles
Off-State RFC to RFOUT Leakage Current[6]	—	15	150	nA
On-State Resistance (R_{ON})[7]	—	0.6	1.25	Ω
Off-State Capacitance (C_{OFF})	—	15	—	fF
Video Feedthrough[8]	—	16	—	mV_{Peak}
Gate Bias Current	—	2	10	nA

Notes:

1. Measured on non-adjacent paths, see measured data for details.
2. Measured at 846.5 MHz with two 37dBm tones for +85ºC ambient test condition.
3. Measured at 2.0 GHz fundamental frequency and 35 dBm input power.
4. Includes any actuator bounce, settling time to within 0.05dB of final value, and measured with 20 V/us slew rate GATE pin voltage.
5. Measured at 5 kHz cycling rate.
6. Measured with 150 V RFx to 0 V RFC.
7. Measured with 0.5 A. See On-State Resistance for more information.
8. Performed with 1 MΩ termination.

Hot Switch Restrictions

The MM5230 is not intended for hot switching applications and care should be taken to insure that switching occurs at less than 0.5V. These restrictions on hot switching apply to both normal mode (SP4T) and Super-Port modes of operation. If the MM5230 is used in hot switching applications, the number of cycling operations of the device will be degraded. See section Switch Reliability for more information.

Floating Node Restrictions

RF pins must not be allowed to electrically float during switch operation and therefore require some form of DC path to ground to prevent charge accumulation. DC paths can be an inductor or high value resistance which serves as a discharge path. Floating node examples and recommended solutions are:

- Unconnected RF pins, resistively terminate or tie to ground.
- Series capacitance coupling which floats RF pin, shunt with DC path to ground.
- Series connection of switches together such as in Super-Port mode without DC path to ground, shunt with DC path or sequenced switching.

See Menlo Micro application note ***Avoiding Floating Nodes*** for a detailed explanation of the hazard conditions to avoid and recommended solutions.

Thermal and Power Handling Considerations

Under normal low power operating conditions, the MM5230 case temperature mimics the environment temperature. However, during high power operation, the case will heat up due to power dissipation within the device. It is important to keep the device case temperature below 170 ºC for continued reliable operation. Based on an environmental hot temperature of 85 ºC, then an 85 ºC rise is allowable due to power dissipation. This results in a power dissipation limit of 1.13 W within the device. The operating power limit at a given frequency can then be calculated based on the device insertion loss.

Considering an insertion loss of -0.14 dB at 3000 MHz:

Power Handling = Max. Power Dissipation/(1-10^(Insertion Loss/10))

= 1.13/0.032

= 35.6 W

The MM5230 device insertion loss can also be approximated by a third order polynomial:

$$\text{Insertion Loss (dB)} = -1.1\text{E-}04 \cdot f^{3} + 1.2\text{E-}03 \cdot f^{2} - 0.024 \cdot f - 0.076$$

where f is frequency in GHz.

Alternatively, Figure 1 is provided below for the maximum power handling over frequency.

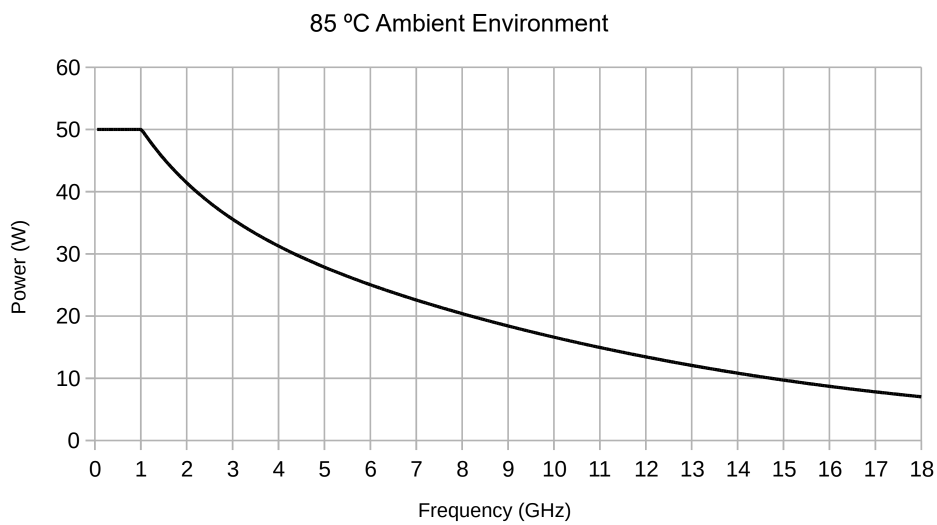


Figure 1. Maximum Power Handling vs. Frequency (1 of 2)

This approach does not hold below 5 MHz, the maximum power handling is shown in Figure 2 for frequencies below 10 MHz.

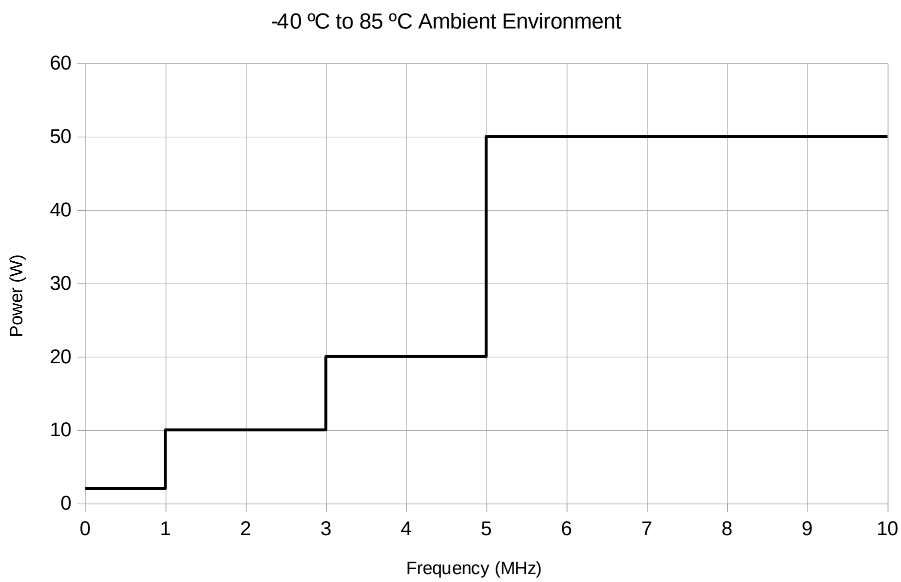


Figure 2. Maximum Power Handling vs. Frequency (2 of 2)

Functional Block Diagram

Normal SP4T Mode

The MM5230 is normally configured as a SP4T, with input on the RFC channel. The RFC is then routed to one of the 4 outputs by biasing the desired RFxGATE pin.

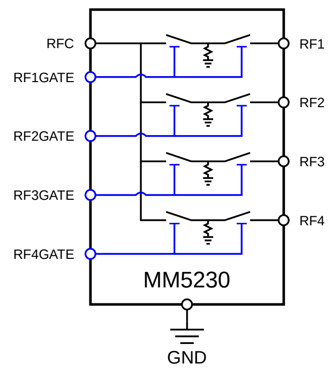


Figure 3. Normal SP4T Mode Block Diagram

Super-Port Mode

The MM5230 provides for an alternate connection method which can provide enhanced performance for certain RF parameters. This configuration is called Super-Port. It consists of bypassing the RFC input port and using the remaining 4 channels as a symmetrically oriented SP3T (or SPST or SPDT if preferred). In this manner, any one of the RF1, RF2, RF3, RF4 channels can be connected to any other channel by biasing both desired channels. When operating in Super-Port mode, slight improvements in RF isolation and return loss can be achieved. Refer to the Recommended PCB Layout section with instructions on how to optimize the PCB layout for Super-Port mode.

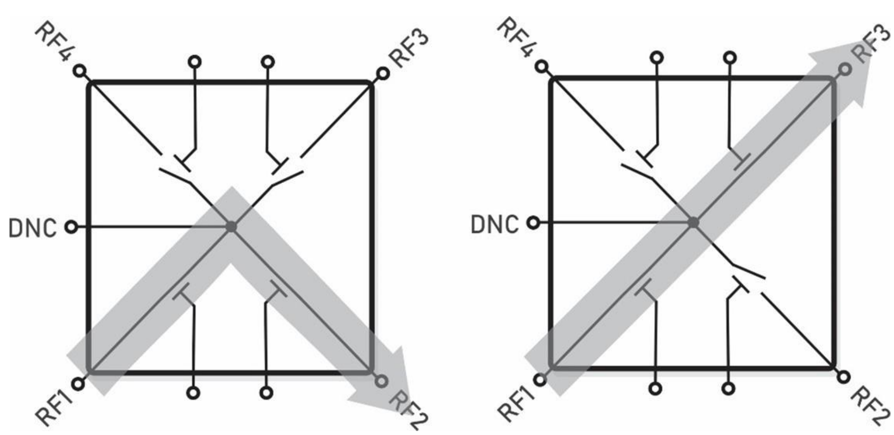


Figure 4. Super-Port Adjacent Path (Left) and Non-adjacent Path (Right)

Package / Pinout Information

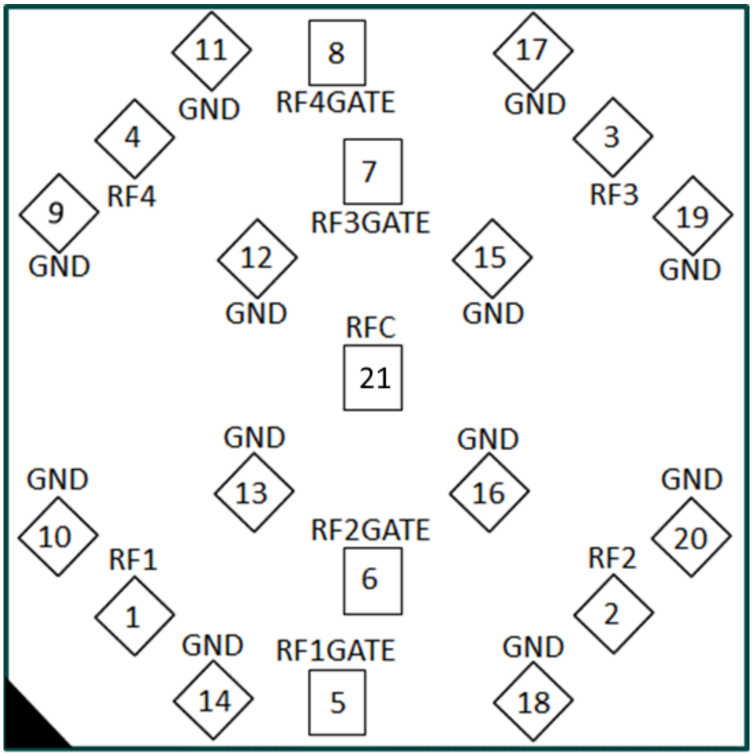


Figure 5. MM5230 2.5 mm x 2.5 mm Pinout

Table 4. Detailed Pin Description

Pin Name	Pin #	Description
RF1	1	RF Switch 1
RF2	2	RF Switch 2
RF3	3	RF Switch 3
RF4	4	RF Switch 4
RF1GATE	5	Control for Switch RF1
RF2GATE	6	Control for Switch RF2
RF3GATE	7	Control for Switch RF3
RF4GATE	8	Control for Switch RF4
GND	9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20	RF Ground
RFC	21	RF Common

Applied Gate Voltage vs. RF Switch States

Each switch is individually controllable. Primary usage states are highlighted in bold. Multiple branches may be closed simultaneously. However, RF performance is not specified for such states.

Table 5. Applied Gate Voltage vs. RF Switch States (On= Closed, Off = Open)

RF4GATE (V)	RF3GATE (V)	RF2GATE (V)	RF1GATE (V)	RFC-RF4	RFC-RF3	RFC-RF2	RFC-RF1
Normal SP4T Mode							
0	**0**	**0**	**VBB**	Off	Off	Off	On
0	**0**	**VBB**	**0**	Off	Off	On	Off
0	**VBB**	**0**	**0**	Off	On	Off	Off
VBB	**0**	**0**	**0**	On	Off	Off	Off
0	0	0	0	Off	Off	Off	Off
Other Valid States							
0	0	VBB[1]	VBB[1]	Off	Off	On	On
0	VBB[1]	0	VBB[1]	Off	On	Off	On
0	VBB[1]	VBB[1]	0	Off	On	On	Off
VBB[1]	0	0	VBB[1]	On	Off	Off	On
VBB[1]	0	VBB[1]	0	On	Off	On	Off
VBB[1]	VBB[1]	0	0	On	On	Off	Off
VBB	VBB	0	VBB	On	On	Off	On
VBB	VBB	VBB	0	On	On	On	Off
VBB	VBB	VBB	VBB	On	On	On	On
0	VBB	VBB	VBB	Off	On	On	On
VBB	0	VBB	VBB	On	Off	On	On

Notes

1. Valid states for Super-Port mode.

Typical Performance Characteristics

RF Performance: Normal Mode (SP4T)

Typical device performance measured on MM5230 evaluation board, de-embedded.

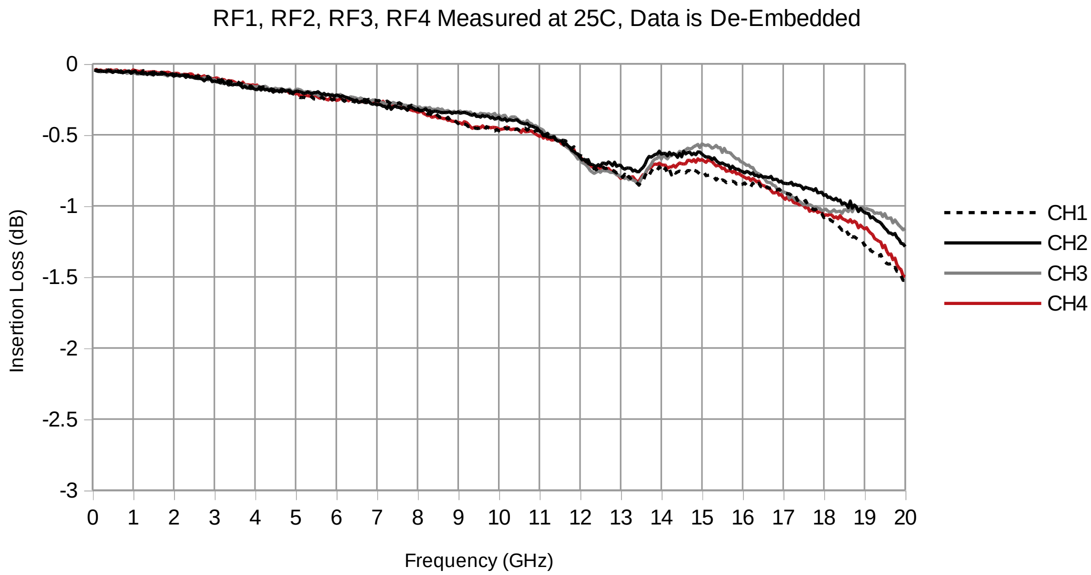


Figure 6. Insertion Loss / S21

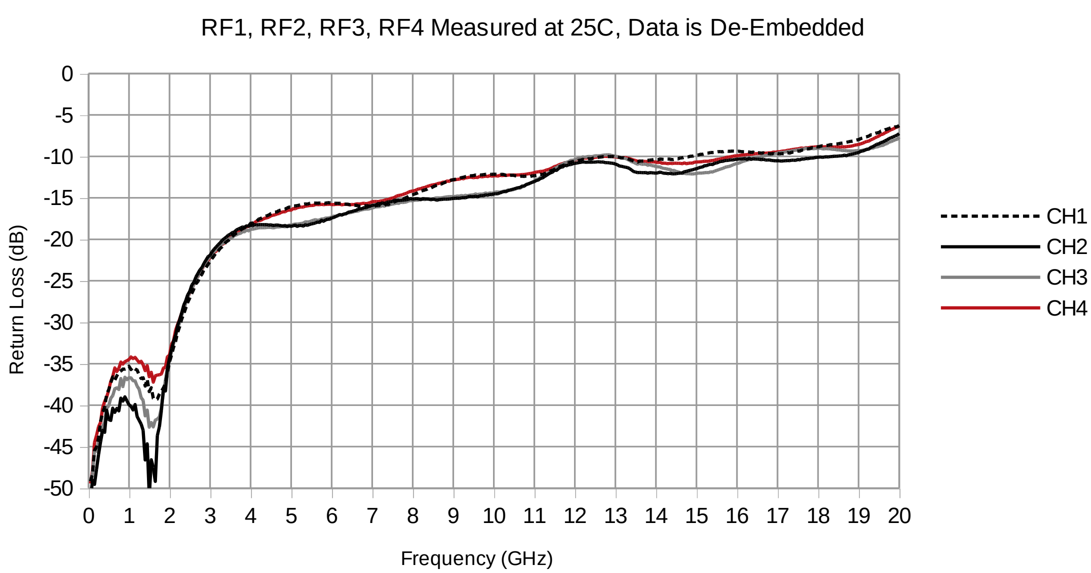


Figure 7. Return Loss / S11

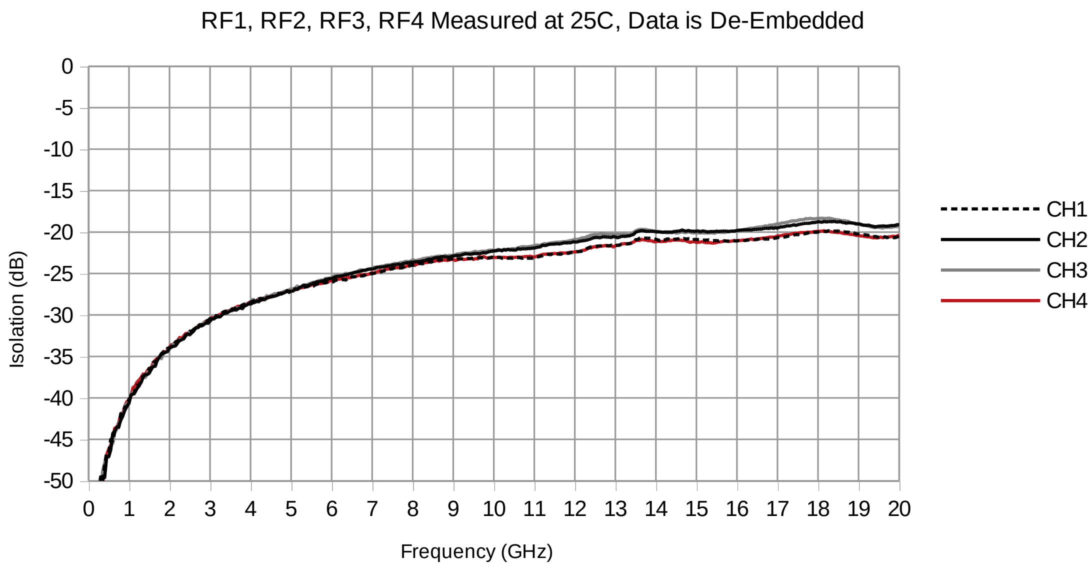


Figure 8. Off-State Isolation / S21

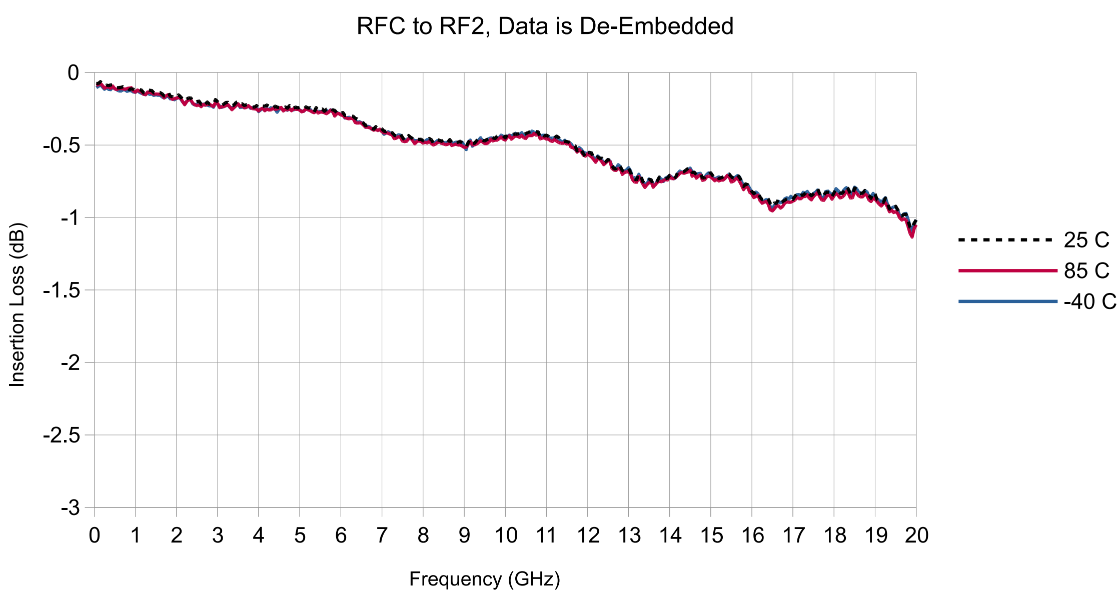


Figure 9. Insertion Loss / S21 vs. Temperature

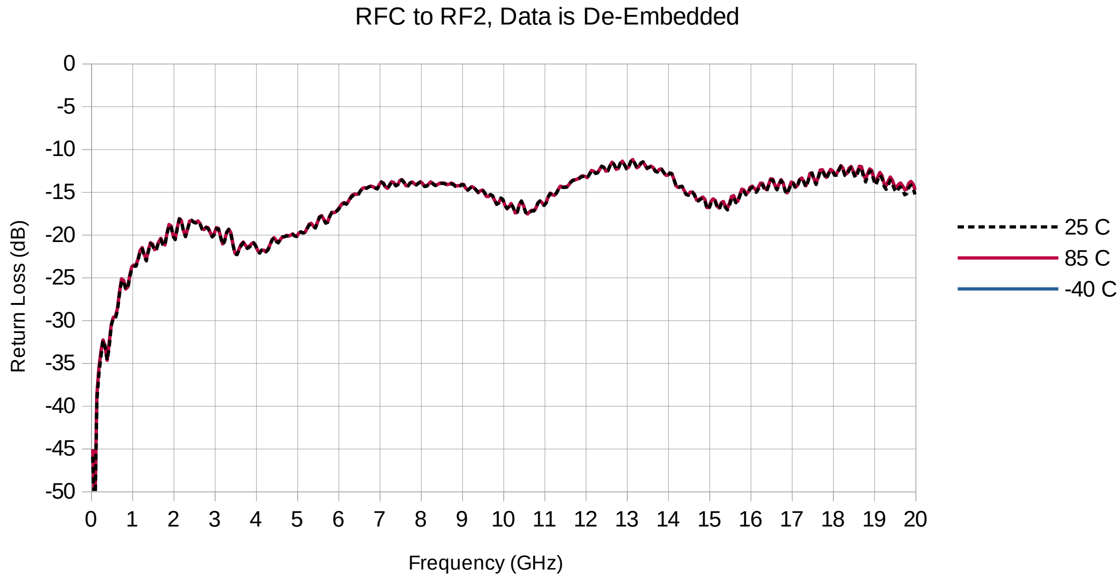


Figure 10. Return Loss / S11 vs. Temperature

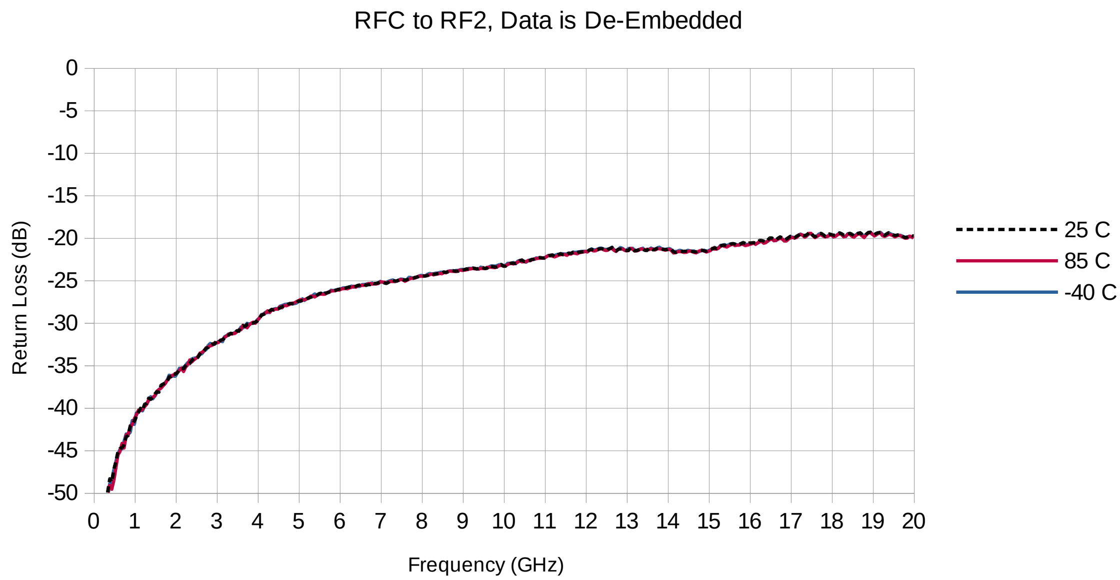


Figure 11. Off-State Isolation / S21 vs. Temperature

On-State Resistance

Typical device performance measured with four-wire Kelvin connection to a soldered-down MM5230. “Dwell Time” is the time that current is applied through the switch before the resistance measurement is made.

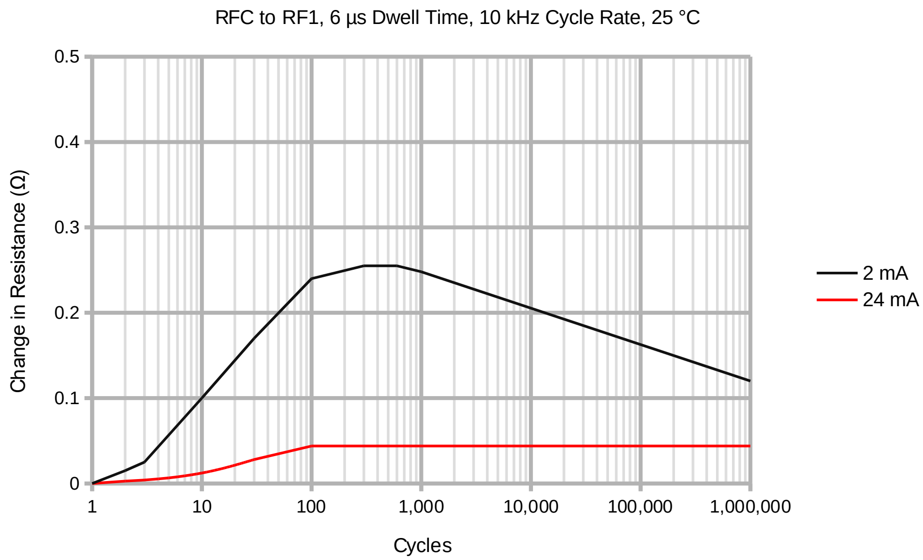


Figure 12. Typical R_{ON} Change Over Cycles and Current (6µs Dwell Time)

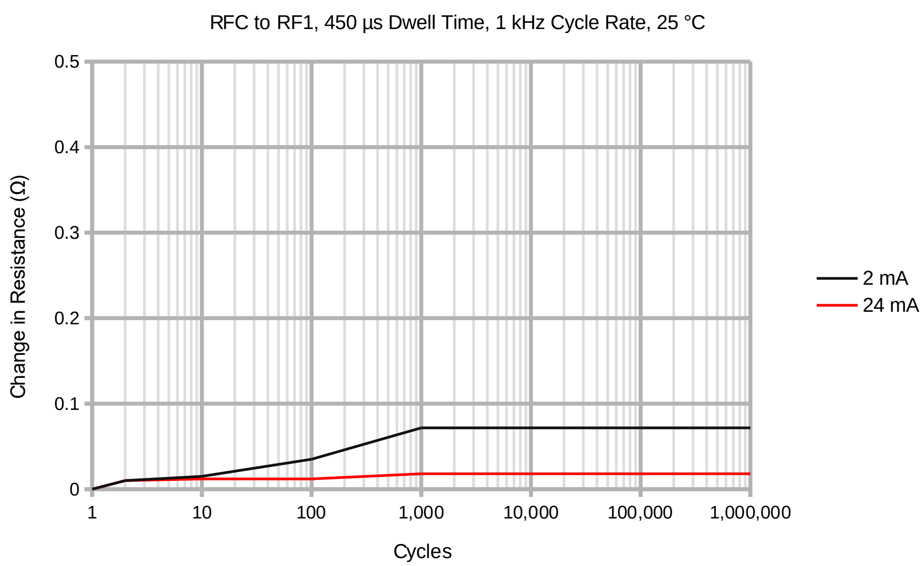


Figure 13. Typical R_{ON} Change Over Cycles and Current (450µs Dwell Time)

On/Off Switching Time

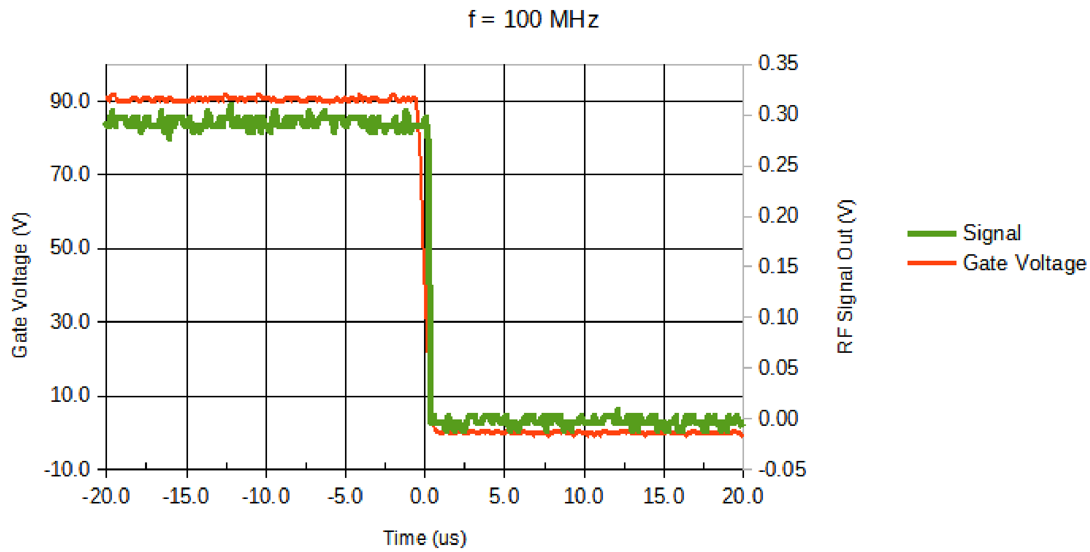


Figure 14. Switch Off Timing

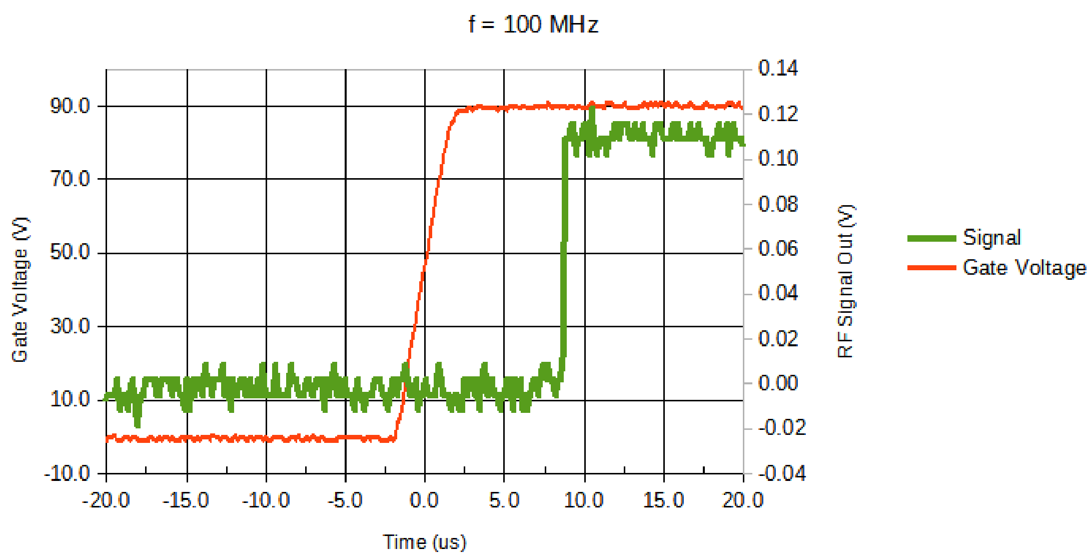


Figure 15. Switch On Timing

Typical Hot Switching Performance

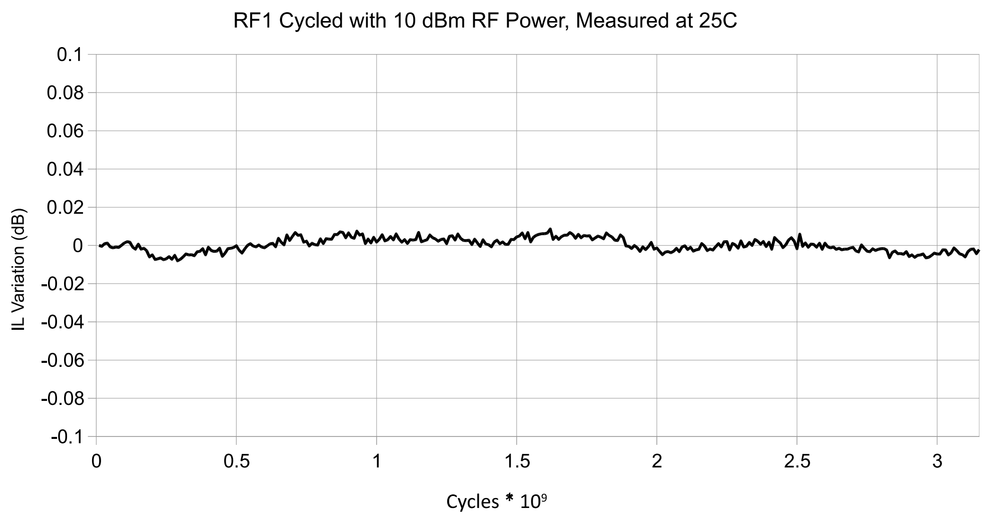


Figure 16. Insertion Loss Variation over Cycling

RF Performance: Super-Port Mode

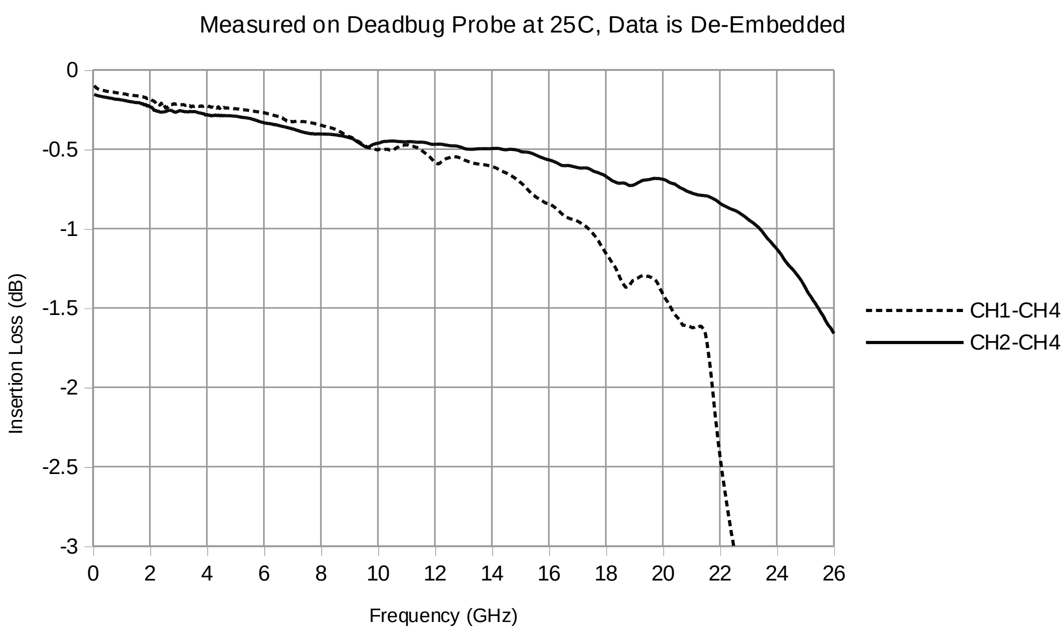


Figure 17. Super-Port Configuration Insertion Loss / S21

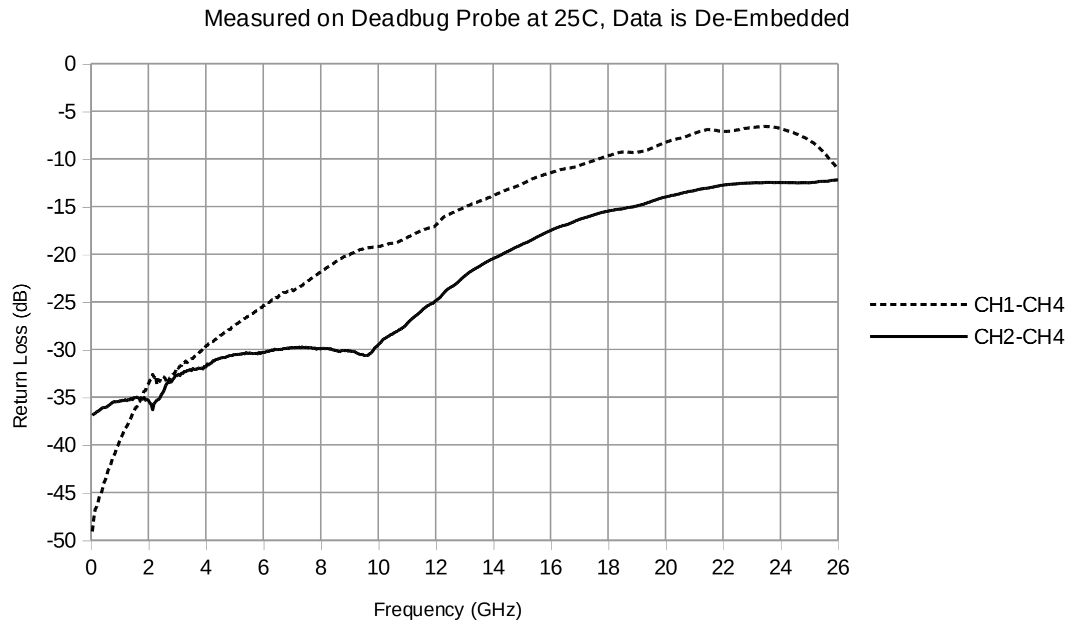


Figure 18. Super-Port Configuration Return Loss / S11

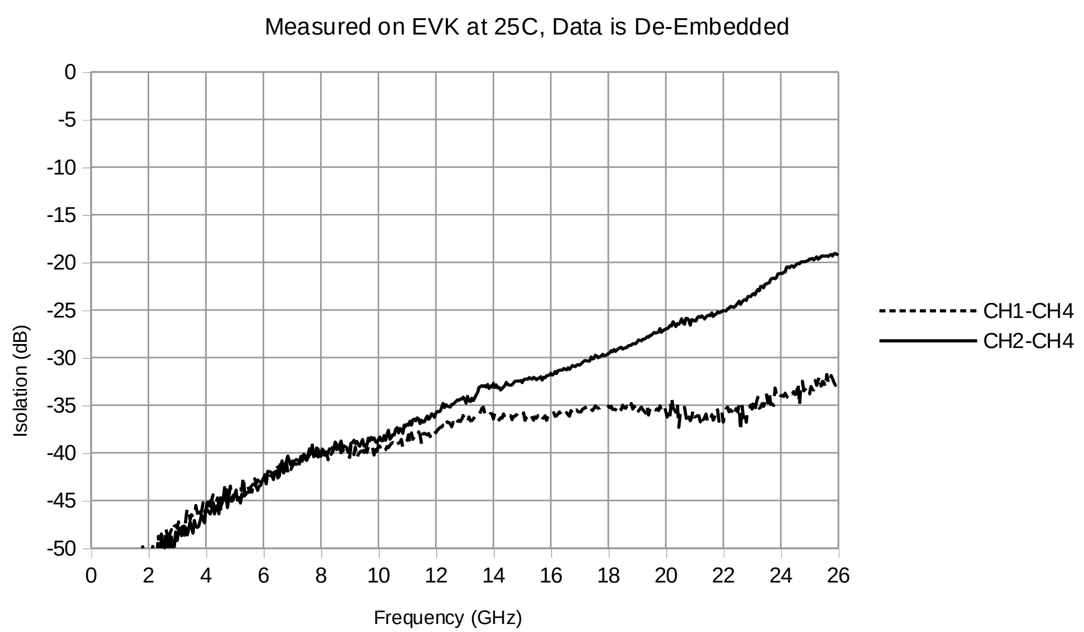
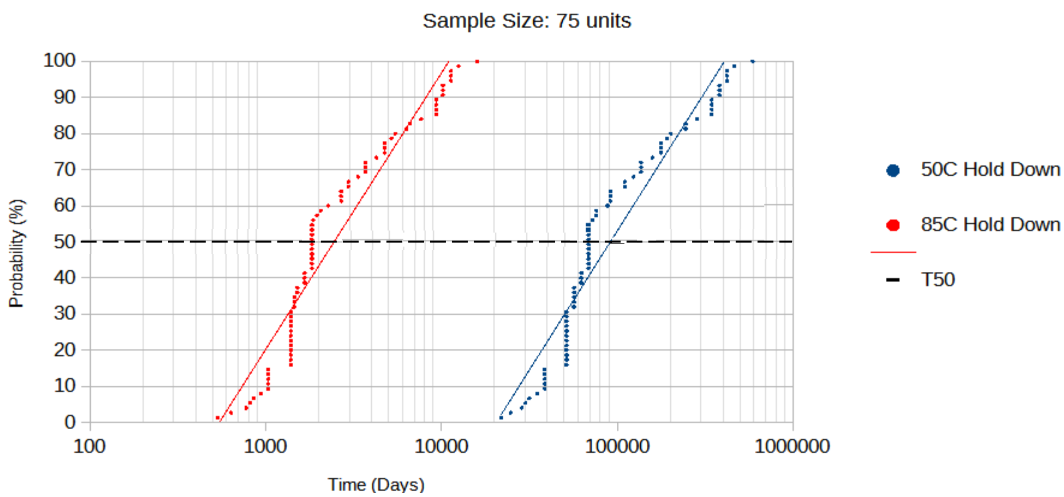


Figure 19. Super-Port Configuration Isolation / S21

Switch Reliability

Switch Hold-Down duration predictions and actuation cycling reliability test results are plotted below. Hold Down median failure is predicted to be >68000 days (>186 years) @ 50ºC and >1800 days (>4.9 years) @ 85ºC. Failure criteria is 20% change in pull in voltage and is based on creep model extrapolation of 1000 hours Hold Down test data.



Cycling median failure is greater than 30 billion cycles @ 25 ºC and 320 million cycles @ 85 ºC.

Figure 20. Hold Down: Days to Failure[1]

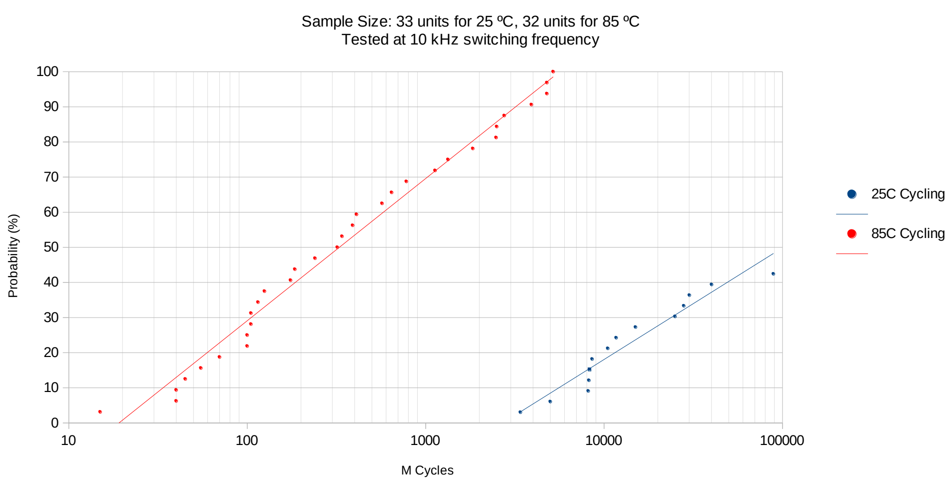


Figure 21. Cycling: M Cycles to Failure[1]

Notes:

1. Failure definition is stuck closed failure.

Hot switched actuation cycling reliability test results are plotted below from 20 dBm to 30 dBm.

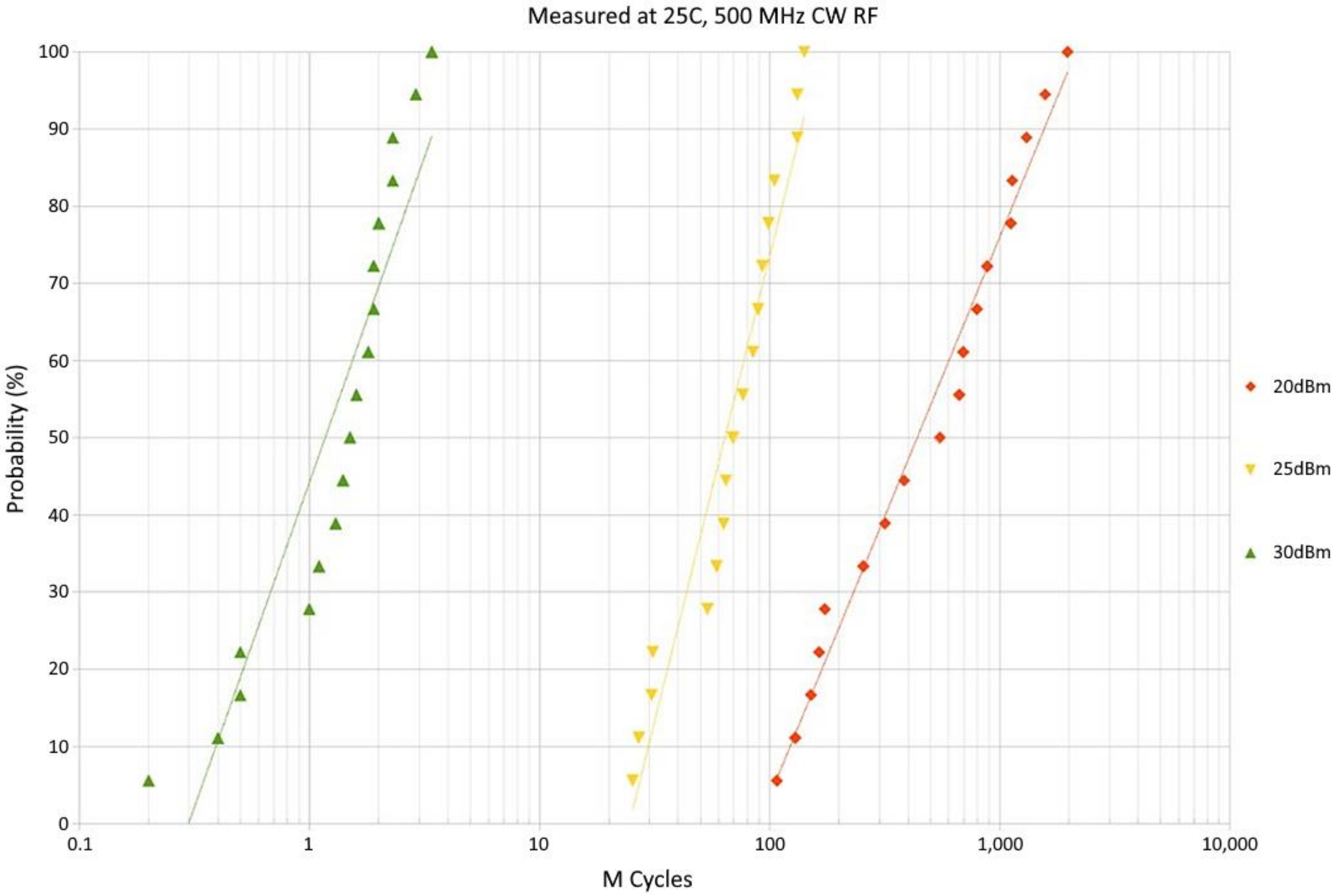
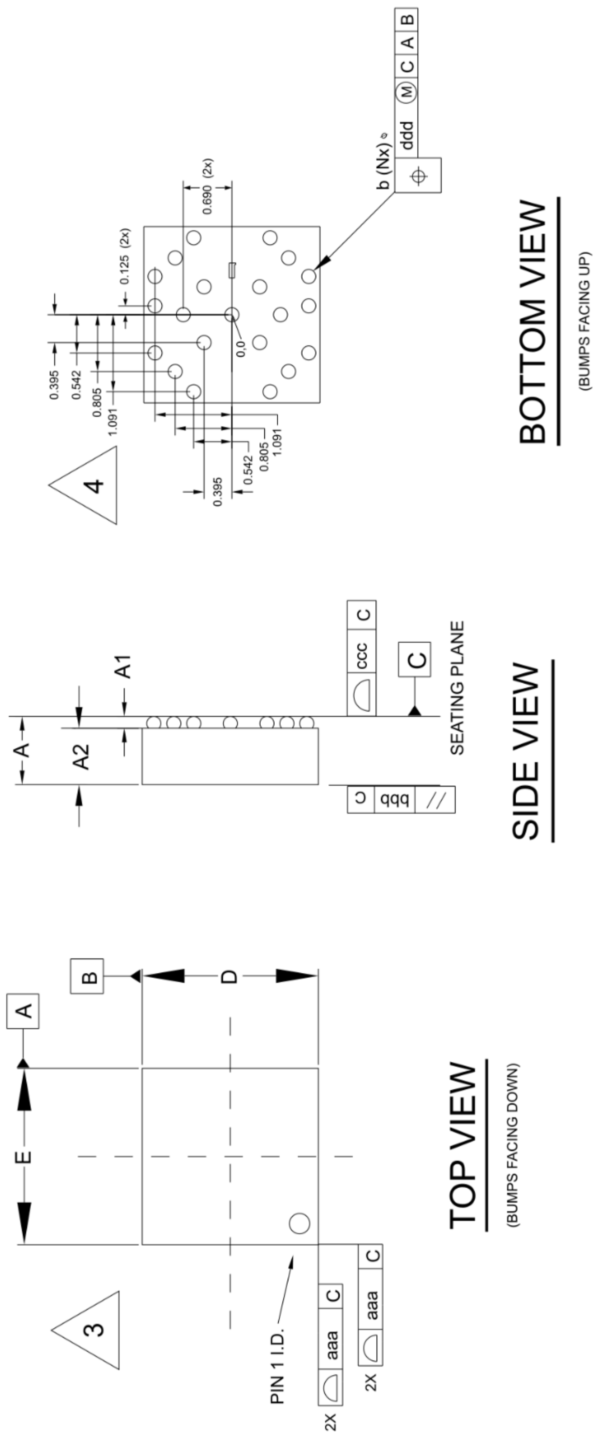


Figure 22. MM5230 Hot Switch

Package Drawing



REF.	Dimensional Ref. Min.	Nom	Max.
A	0.952	0.993	1.034
A1	0.152	0.168	0.184
A2	0.800	0.825	0.850
D		2.50 BSC	
E		2.50 BSC	
N		21	
b	0.174	0.205	0.235

	Dimensional Tol.
aaa	0.030
bbb	0.060
ccc	0.050
ddd	0.015

NOTES:

1. DIMENSIONING AND TOLERANCING PER ASME Y14.5M-2018 AND JEDEC DESIGN GUIDE 4.18
2. N IS THE TOTAL NUMBER OF TERMINALS
3. DATUMS ARE LABELLED WITH A SQUARE AROUND THE DATUM LETTER. ex: C.
4. BOTTOM VIEW DIMENSIONS APPLICABLE TO ALL QUADRANTS EXCEPT THOSE LABELLED (2x)

Figure 23. Package Drawing

Table 6. Bump Coordinates

Pin	X (µm)	Y (µm)	Pin	X (µm)	Y (µm)	Pin	X (µm)	Y (µm)
1	805	-805	9	1091	542	17	-542	1091
2	-805	-805	10	1091	-542	18	-542	-1091
3	-805	805	11	542	1091	19	-1091	542
4	805	805	12	395	395	20	-1091	-542
5	125	-1091	13	395	-395	21	0	0
6	0	-690	14	542	-1091			
7	0	690	15	-395	395			
8	125	1091	16	-395	-395			

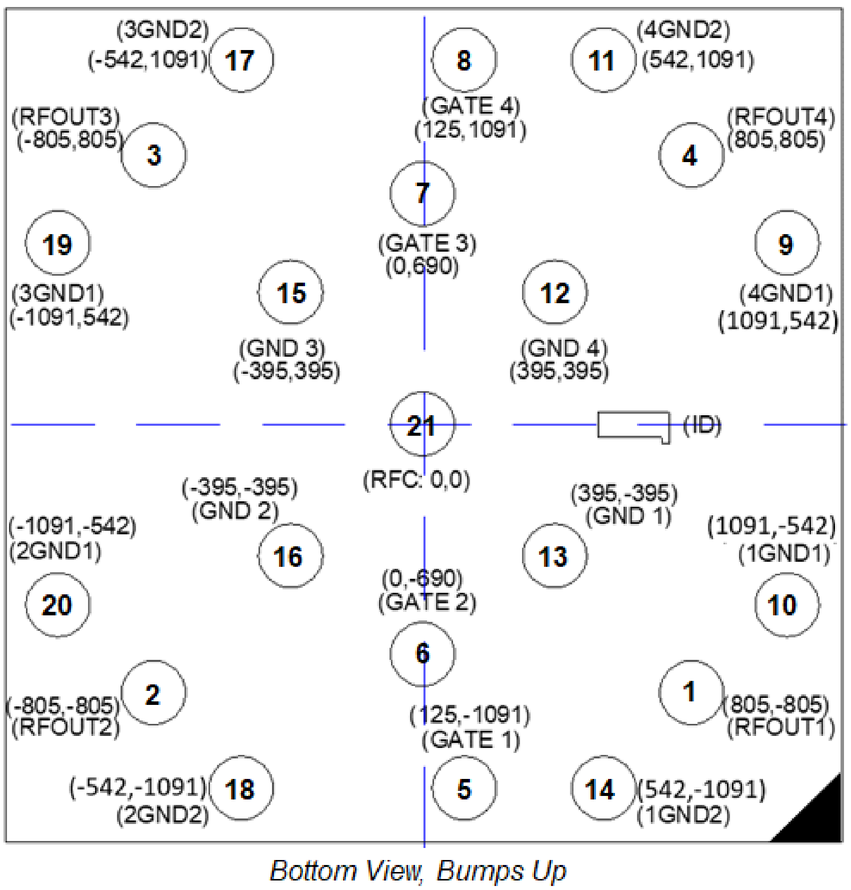


Figure 24. Bottom View/Bumps Up (0.0 at Die Center µm to Scale)

Recommended PCB Layout

The recommended layout for connecting the MM5230 with coplanar RF line or grounded coplanar line is shown below.

For the coplanar RF lines, it is recommended to taper the line to fit the 250 µm recommended landing pad while keeping the spacing to the ground metal constant and identical to the spacing used for the line. In these two examples (Normal SP4T Mode and Super-Port Mode) a 5.0 mil/0.125 mm spacing is used.

Typical solder resist thickness 20 µm. Recommended solder paste stencil thickness is 80 µm. Use a 1-to-1 opening in paste mask (0.2 mm).

Routing of the gate control lines is not critical for RF performance. Ensure the substrate x/y coefficient of thermal expansion (CTE) is 15 ppm/ºC or lower.

Normal SP4T Mode

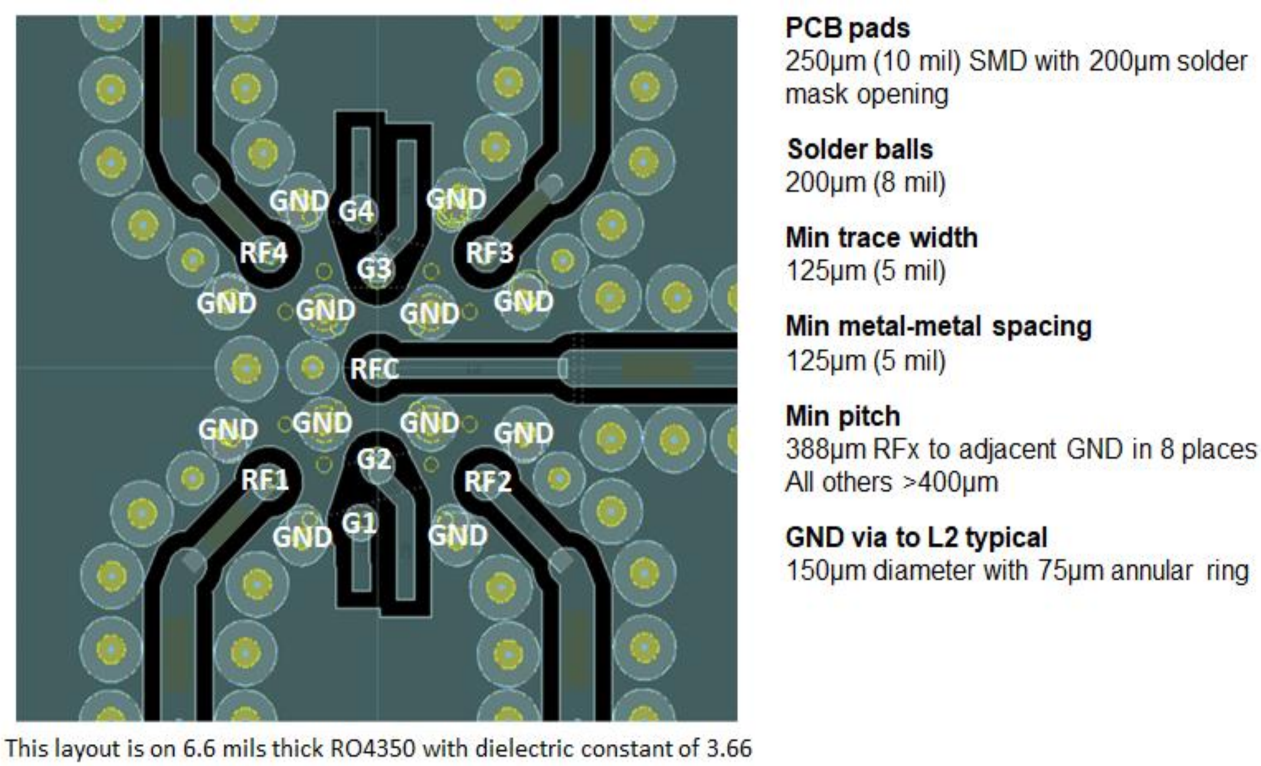


Figure 25. Normal SP4T Mode Layout Recommendation

Super-Port Mode

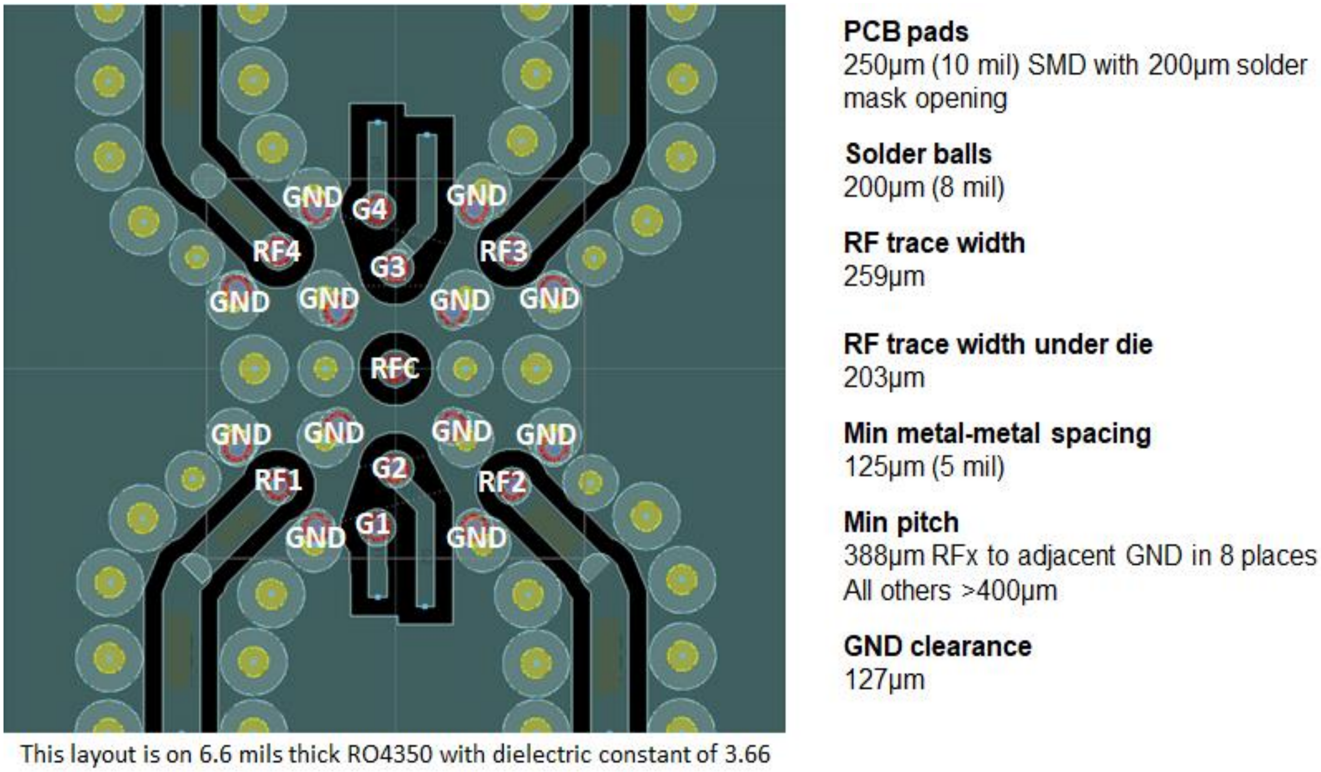


Figure 26. Super-Port Mode Layout Recommendation

Solder Mask Details

Dimensions are given in millimeters. Use 1-to-1 opening in paste mask (0.2 mm).

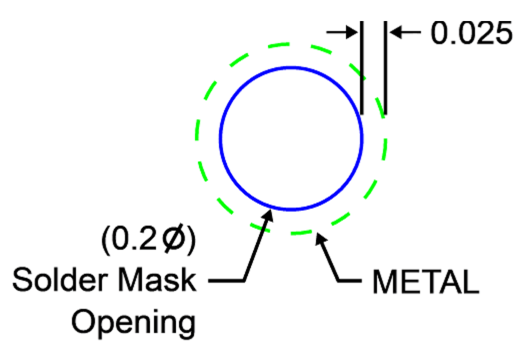


Figure 27. Solder Mask Details

Recommended Solder Reflow Profile

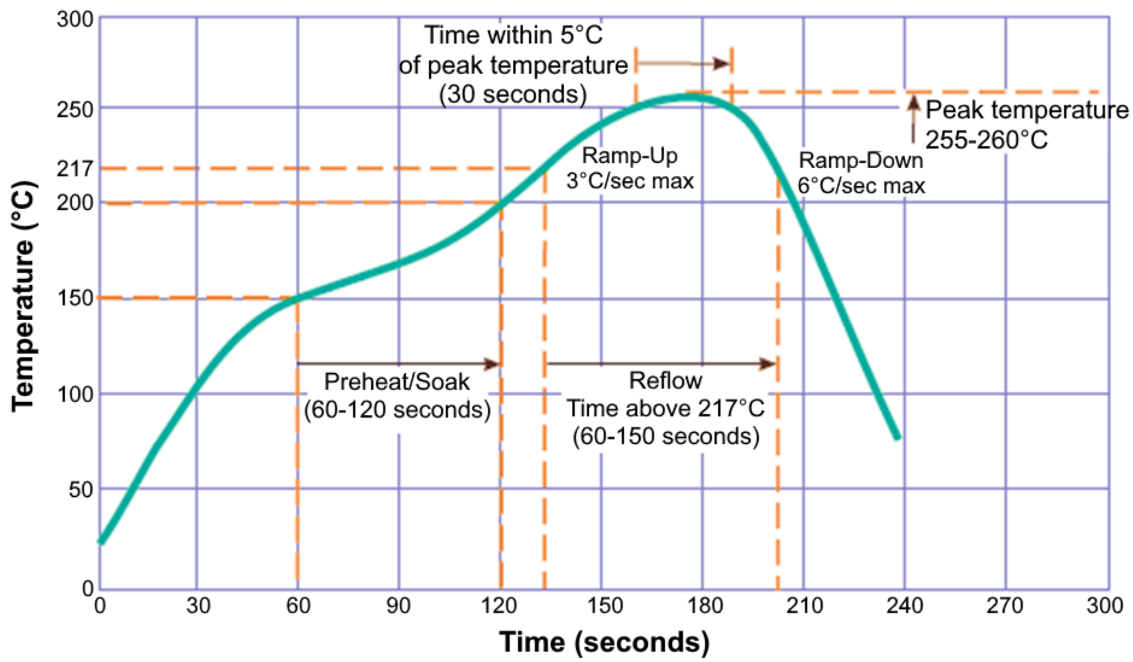


Figure 28. Reflow Profile

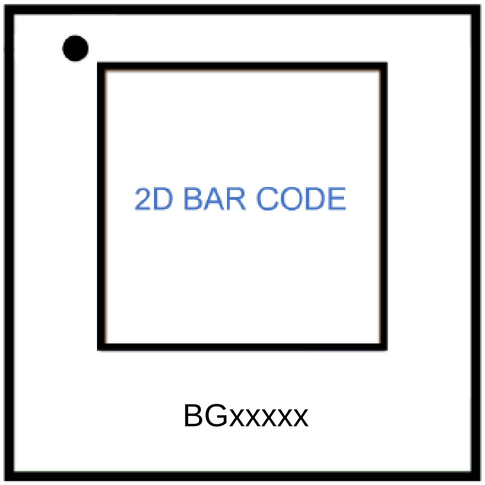
A ROHS-compliant Solder Alloy used is SAC alloy: 96.5% Sn, 3.0%Ag, 0.5%Cu. These are the nominal percentages of the components. This alloy is designed to replace SnPb solders to eliminate Lead (Pb) from the process, requiring a higher reflow temperature. Moisture resistance performance may be impacted if not using the Pb-Free reflow conditions.

Storage and Shelf Life

Under typical industry storage conditions (≤30°C/60% RH) in Moisture Barrier Bags, the following are recommended:

- Customer Shelf Life: 24 months from customer receipt date.
- Extended Shelf Life: 60 months from customer receipt date if re-bagged every 24 months or less.
- Floor life: Moisture Sensitivity Level (MSL) testing is not required for Hermetic package as per JESD47K.
- Do not re-bake.

Package Marking Information



Dot ● = Pin 1 Indicator
Line 1 = 2D Bar Code
Line 2 = Human-readable product code

Figure 29. Package Marking Drawing

Package Materials Information

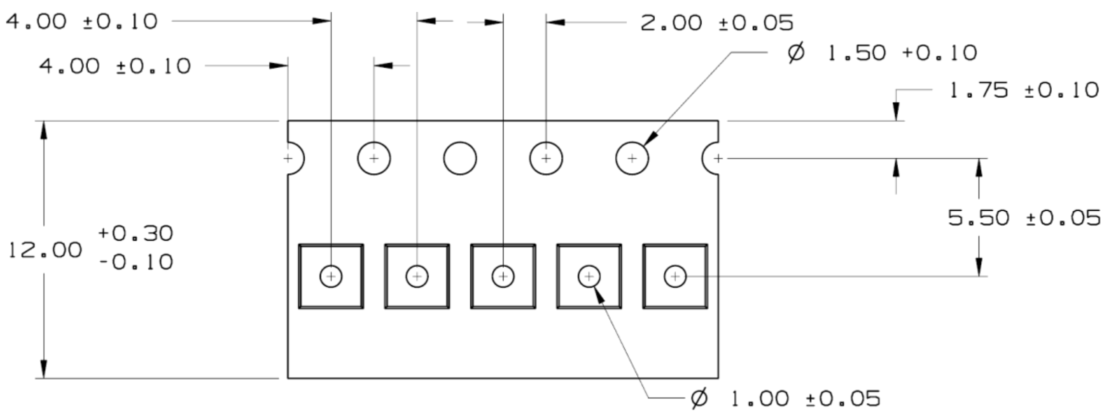


Figure 30. Tape and Reel Drawing

Package Options and Ordering Information

All Menlo Micro solutions are EAR99 compliant.

Part Number	Package Description	Temp Range	Device Marking[1]
MM5230-03NDB	DC-26GHz - SP4T 2.5 mm x 2.5 mm 21 pin WL-FC (200 µm solder ball), Industrial Temp	- 40ºC to +85ºC	BGxxxxx
MM5230-03NDB-TR	DC-26GHz - SP4T 2.5 mm x 2.5 mm 21 pin WL-FC (200 µm solder ball), Industrial Temp Tape and Reel (Qty 250)	- 40ºC to +85ºC	BGxxxxx

Notes:

1. Additional markings may be present, including logo or lot trace code information. This information may be a 2D barcode or other human-readable markings. Note that ‘x’ is a placeholder for a 5-digit numerical code.

Various evaluation boards are available for the MM5230 device. Please see ordering information below.

Table 7. MM5230 Evaluation Boards

Part Number	EVK Description
MM5230EVK1	Standard evaluation board for MM5230 (w/SMA connector-QTY-7, <12GHz)
MM5230EVK2A	High-performance evaluation board for MM5230 (w/Southwest connector- QTY-7, >12GHz improved performance)
MM5230EVK3A	High-performance evaluation board for MM5230 Superport mode (w/Southwest connector-QTY-6, 26GHz improved performance)

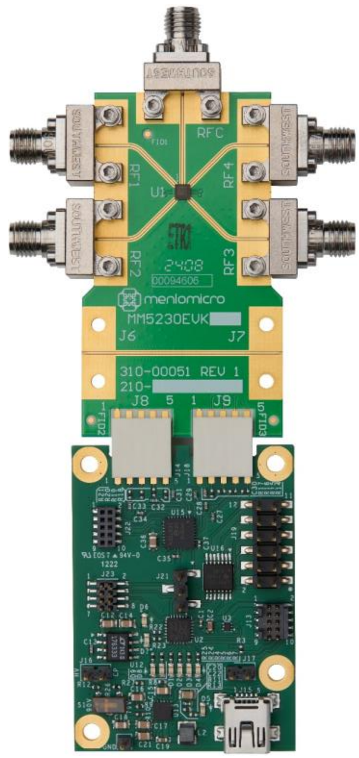


Figure 31. MM5230EVK2A 18GHz Evaluation Board

Important Information

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- In any life support systems.
- Applications for implanting into the human body, without the express written approval from Menlo Micro.

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