Datasheet
MM5130 – DC to 26 GHz High Power RF Switch

Product Overview

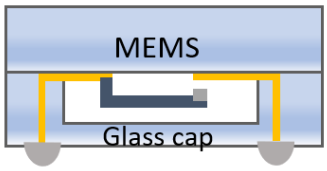
Description

The MM5130 device is a high-power SP4T micro-mechanical switch offered by Menlo Micro. 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 forward power. The MM5130 provides ultra-low insertion loss and superior linearity as an SP4T from DC to 18 GHz, and greater than 3 billion switching cycles.

The MM5130 can also be configured in Super-Port mode that extends the frequency operation to 26 GHz. The MM5130 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: 0.4 dB @ 6.0 GHz
- High Linearity, IIP3 95 dBm Typical
- 25 dB Isolation @ 6.0 GHz / 45 dB Super-Port Mode
- High Reliability > 3.0 x 10^9 Switching Operations
- 2.5 mm x 2.5 mm WLCSP Package

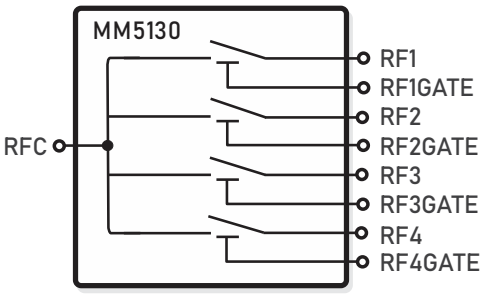


Applications

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

Markets

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



Functional Block Diagram

Electrical Characteristics

Operating Characteristics

Absolute Maximum Ratings

Exceeding the maximum ratings as listed in Table 1 below may reduce the reliability of the device or cause permanent damage. Operation of the MM5130 should be restricted to the limits indicated in
Table 2 recommended operating conditions listed below.

Electrostatic Discharge (ESD) Safeguards

The MM5130 is a Class 0 ESD device. When handling the MM5130, observe precautions as with any other ESD sensitive device. Do not exceed the voltage ratings specified in Table 1 below.

Table 1 Absolute Maximum Ratings[1]

Parameter	Minimum	Maximum	Unit
CW Input Power @ 6 GHz		25	W
Peak Input Power @ 6 GHz		150	W
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		500	mA
Operating Temperature Range	-40	+85	ºC
Storage Temperature Range[5]	-65	+150	ºC
Mechanical Shock[6]		500	G
Vibration[7]	2	500	Hz

[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] See section Storage and Shelf Life more information on shelf and floor life.
[6] See JESD22-B104 for mechanical shock test methodology at 1.0 ms, half-sine, 5 shocks/axis, 6 axis.
[7] See JESD22-B103 for vibration test methodology at 3.1 G and 30min/cycle, 1 cycle/axis, 3 axis.

Table 2 DC and AC Electrical Specifications

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

Parameter	Minimum	Typical	Maximum	Unit
Operating Frequency Range				
Normal SP4T mode	DC		18	GHz
Super-Port mode	DC		26	GHz
CW Power @ 6 GHz[8]			25	W
Peak Power @ 6 GHz[9]			150	W
Insertion Loss				
Normal SP4T mode @ 6 GHz		0.4		
Super- Port mode @ 6 GHz		0.4		
Normal SP4T mode @ 18 GHz		1.3		dB
Super- Port mode @ 18 GHz		0.8		
Normal SP4T mode @ 26 GHz		--		
Super- Port mode @ 26 GHz[10]		1.0		
Input / Output Return Loss				
Normal SP4T mode @ 6 GHz		15		
Super- Port mode @ 6 GHz		15		
Normal SP4T mode @ 18 GHz		10		dB
Super- Port mode @ 18 GHz		18		
Normal SP4T mode @ 26 GHz		--		
Super- Port mode @ 26 GHz[7]		20		
Isolation				
Normal SP4T mode @ 6 GHz		25		
Super- Port mode @ 6 GHz		45		
Normal SP4T mode @ 18 GHz		18		dB
Super- Port mode @ 18 GHz		32		
Normal SP4T mode @ 26 GHz		--		
Super- Port mode @ 26 GHz[7]		22		

[8] Measured at +85ºC.
[9] For 10 % Duty Cycle and 10 µs pulse width, measured at +85ºC.
[10] Measured on non-adjacent paths, see measured data for details.

Channel to Channel Isolation @ 6 GHz		25		dB
Third-Order Intercept Point (IP3)[11]		95		dBm
Second Harmonic (H2) [12]		-130		dBc
Third Harmonic (H3)[13]		-130		dBc
On / Off Switching and Settling Time				
Turn on time[14]		8.5	16	µs
Turn off time		2.5	6	
Full Cycle Frequency			10	kHz
On / Off Switch Operations[15] **(MM5130-03C)**				
at 25 ºC	$3x10^9$	$30 x10^9$		Cycles
at 70 ºC		$1x10^9$		
at 85 ºC		$0.1x10^9$		
DC Steady State Carry Current			500	mA
Off-State RFC to RFOUT Leakage Current		15	150	nA
On-State Resistance (R_{On})		1.2	3	Ω
Off-State Capacitance (C_{Off})		15		fF
Video Feedthrough[16]		16		mV_{Peak}
Gate Bias Voltage (VBB)	88	89	90	V_{DC}
Gate Voltage Slew Rate			20	V/µs
Gate Bias Current		2	10	nA

[11] Measured at +25 ºC.
[12] Measured at 1.0 GHz and 2.0 GHz fundamental frequency and 35 dBm input power.
[13] Measured at 1.0 GHz and 2.0 GHz fundamental frequency and 35 dBm input power.
[14] Includes any actuator bounce, settling time to within 0.05dB of final value, and measured with 20 V/us slew rate GATE pin voltage.
[15] Measured at 5 kHz cycling rate.
[16] Performed with 1 MΩ termination.

Hot Switch Restrictions

The MM5130 is not intended for hot switching applications and care should be taken to insure that switching occurs at less than 0.5 V. Further, the voltage at the switch terminals must be within +/-0.5 V relative to RF ground. These restrictions on hot switching apply to both normal mode (SP4T) and Super-Port modes of operation.

Floating Node Restrictions

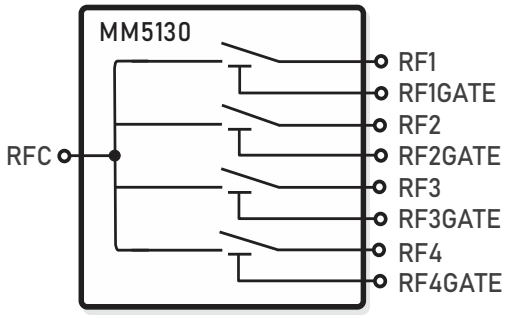
RF pins must not be allowed to electrically float during switch operation and therefore require some form of DC path to ground to prevent charge accumulation. DC paths can be an inductor or high value resistance which serves as a discharge path. Floating node examples are:

- 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 detailed explanation of the hazard conditions to avoid and recommended solutions.

Normal SP4T Mode

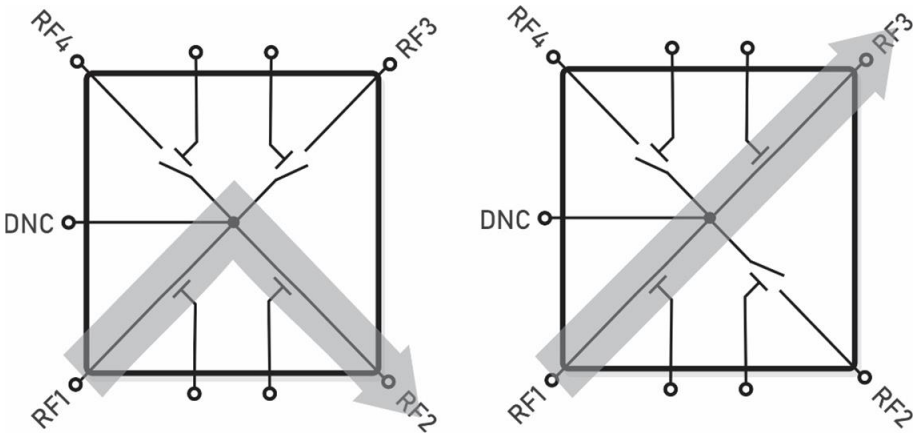
The MM5130 is normally configured as a SP4T, with input on the RFC channel. The RFC is then routed to one of the 4 outputs by biasing the desired RFxGATE pin.



Normal SP4T Mode Block Diagram

Super-Port Mode

The MM5130 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. Please refer to the "Recommended PCB Layout" section with instructions on how to optimize the PCB layout for Super-Port mode.



Super-port adjacent path (left) and non-adjacent path (right)

RF pins must not be allowed to electrically float during switch operation. See section *Floating Node Restrictions* for details of how to avoid floating nodes.

Package / Pinout Information

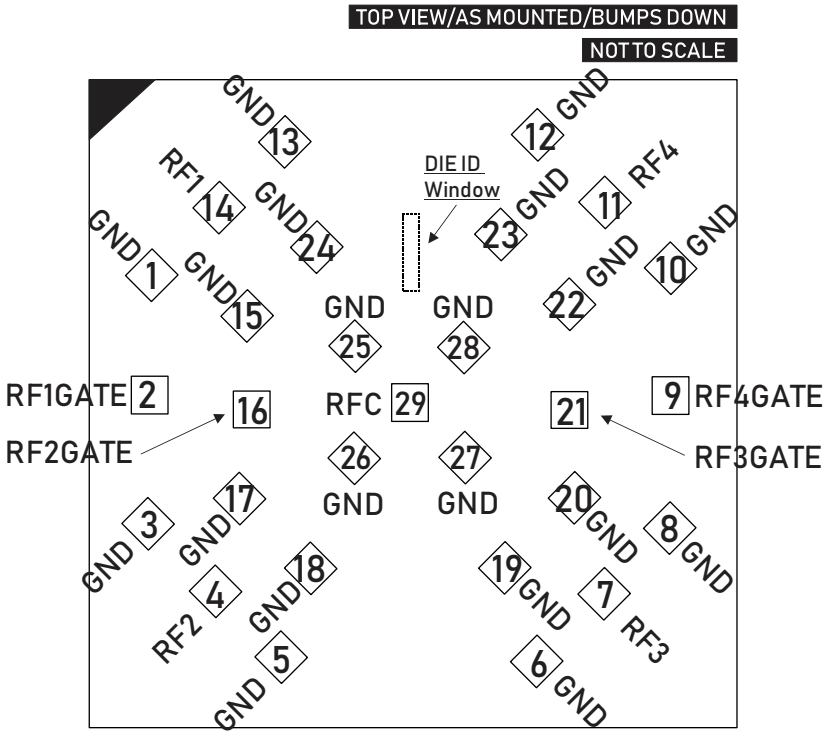


Figure 1:MM5130 2.5 mm x 2.5 mm pinout

Table 3 Detailed Pin Description

Pin #	Pin Name	Description
1,3,5,6,8,10,12,13,15,17, 18,19,20,22,23,24,25,26,27,28	GND	RF Ground
2	RF1GATE	Control for Switch RF1
16	RF2GATE	Control for Switch RF2
4	RF2	RF Switch 2
7	RF3	RF Switch 3
21	RF3GATE	Control for Switch RF3
9	RF4GATE	Control for Switch RF4
11	RF4	RF Switch 4
14	RF1	RF Switch 1
29	RFC	RF Common

Table 4 Applied Gate Voltage vs. RF Switch States (On= Closed, Off = Open)

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.

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*	VBB*	Off	Off	On	On
0	VBB*	0	VBB*	Off	On	Off	On
0	VBB*	VBB*	0	Off	On	On	Off
VBB*	0	0	VBB*	On	Off	Off	On
VBB*	0	VBB*	0	On	Off	On	Off
VBB*	VBB*	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

*Valid states for Super-Port mode

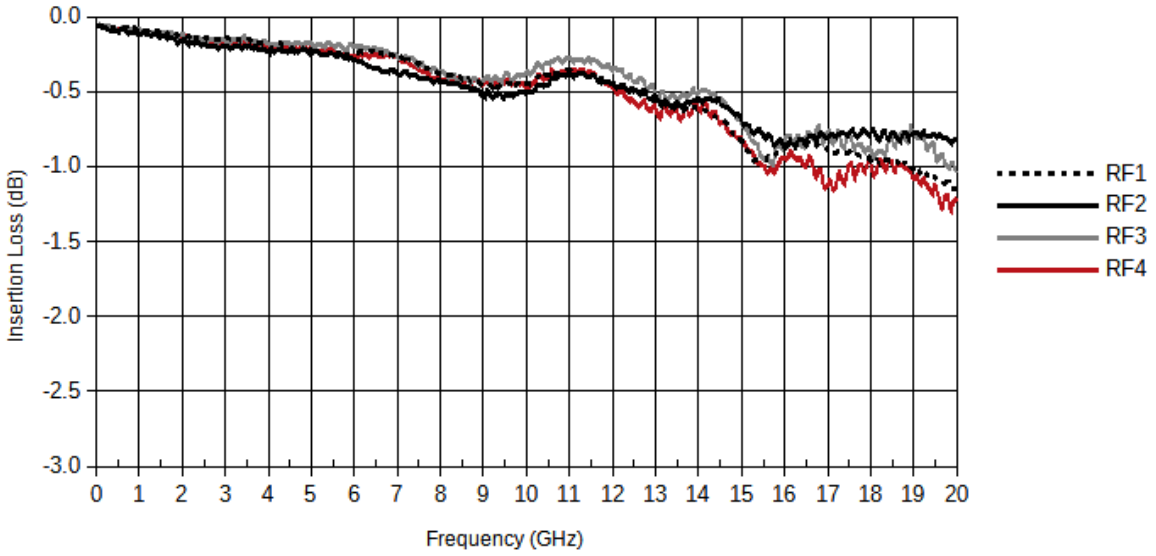
RF Performance

Normal Mode (SP4T)

Typical device performance measured on evaluation board, de-embedded. For band-limited applications, the performance may be further improved with narrowband matching techniques.

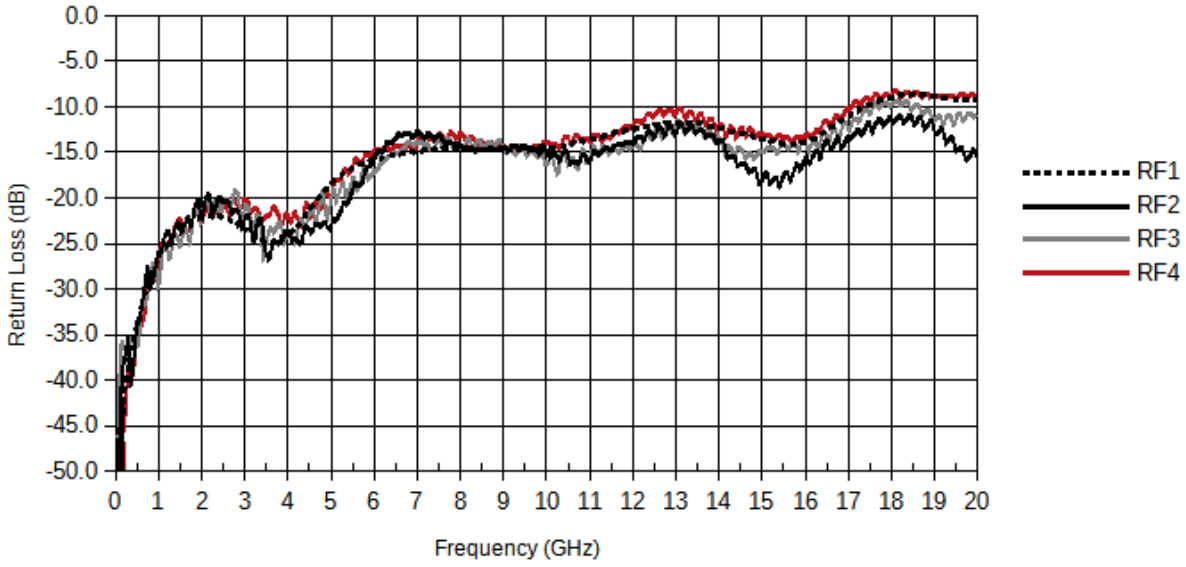
Insertion Loss / S21

RF1, RF2,RF3, RF4, Measured at 25 C, data is de-embedded



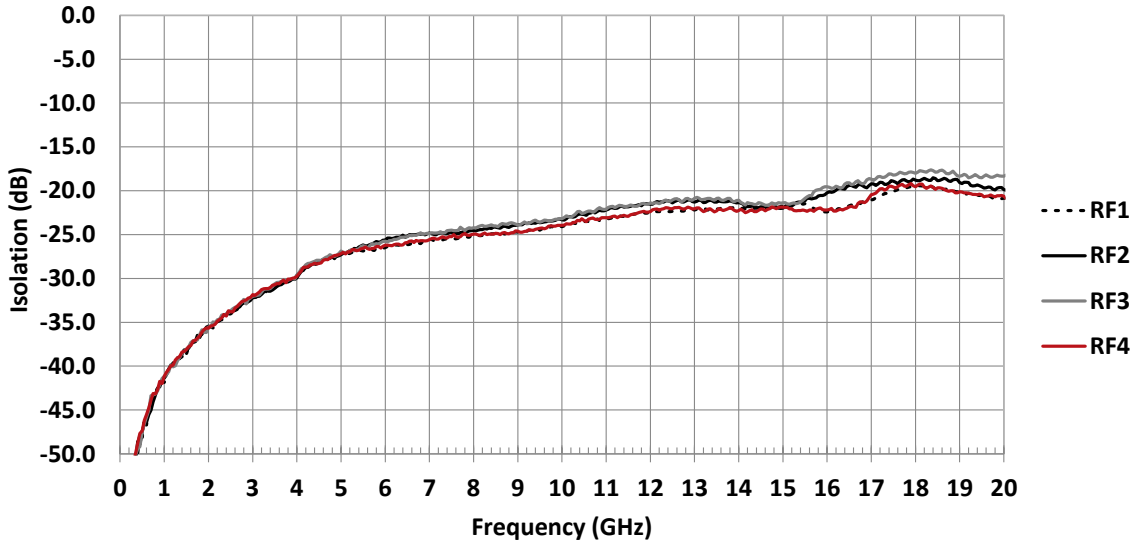
Return Loss / S11

RF1, RF2, RF3, RF4 Measured at 25 C, data is de-embedded



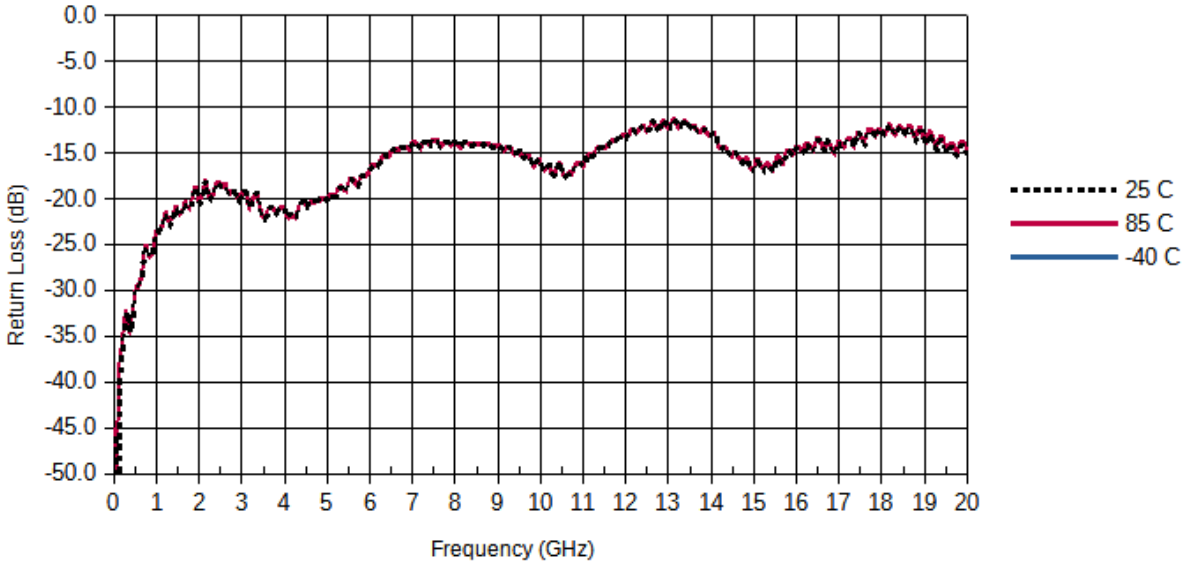
Off-State Isolation / S21

RF1, RF2, RF3, RF4 Measured at 25C, data is de-embedded



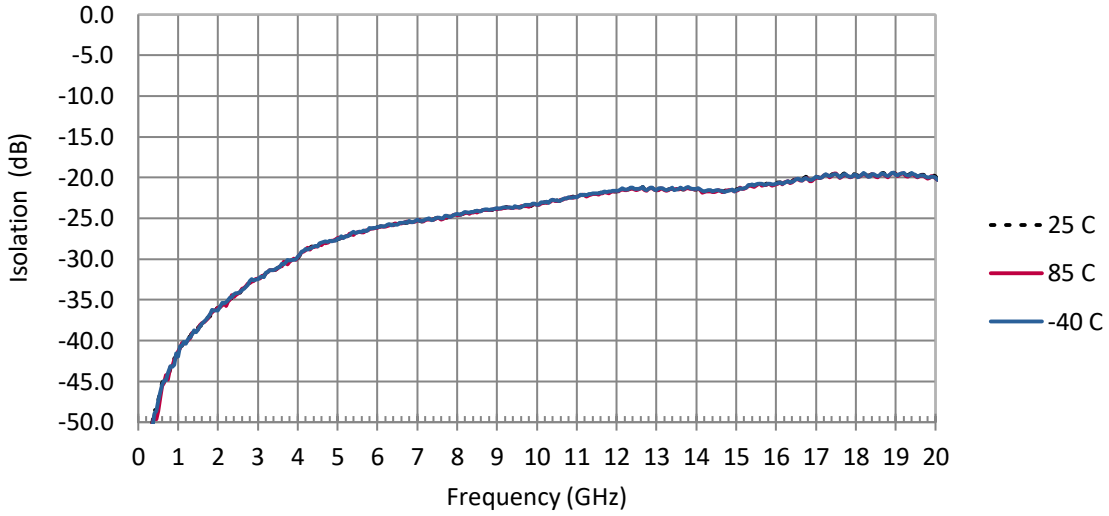
Return Loss / S11 FOR 25 C, 85 C and -40 C

For channel RF2, data is de-embedded



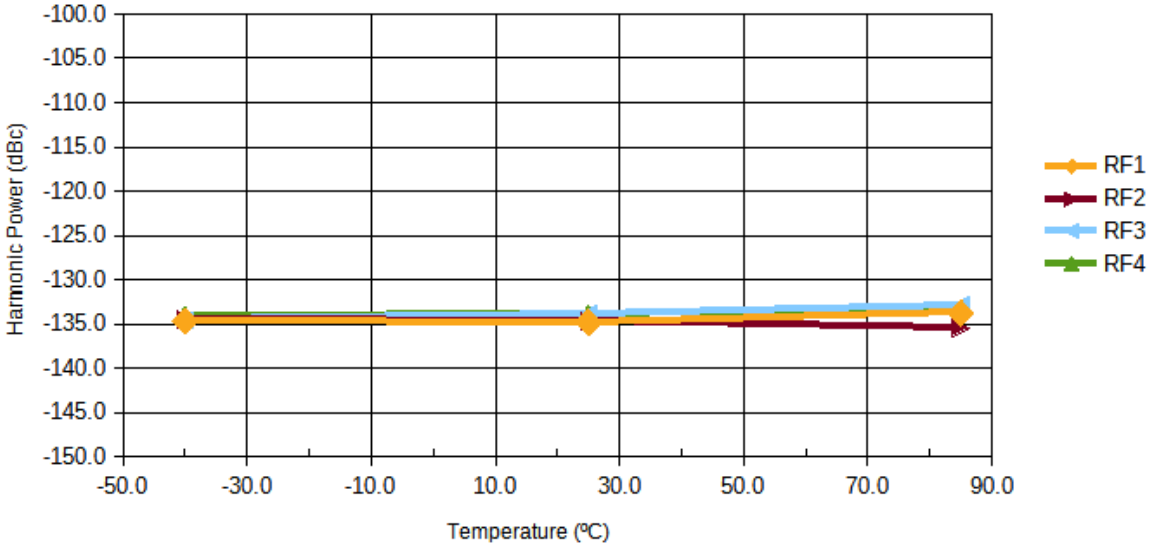
Off-State Isolation / S21 for 25 C, 85 C and -40 C

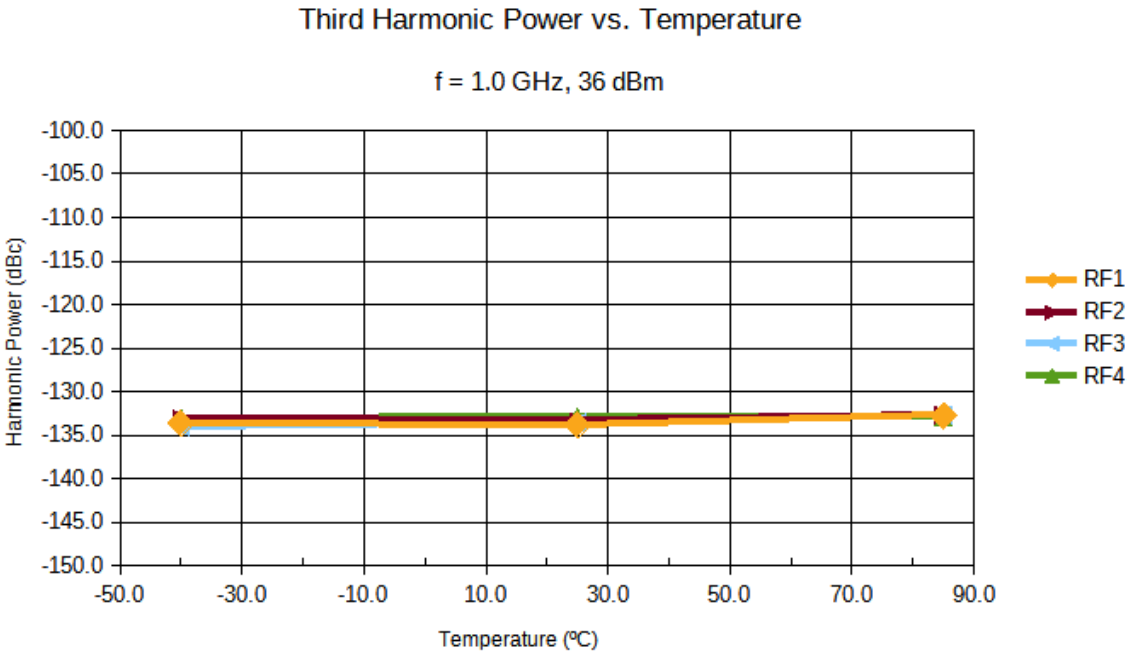
For channel RF2, data is de-embedded



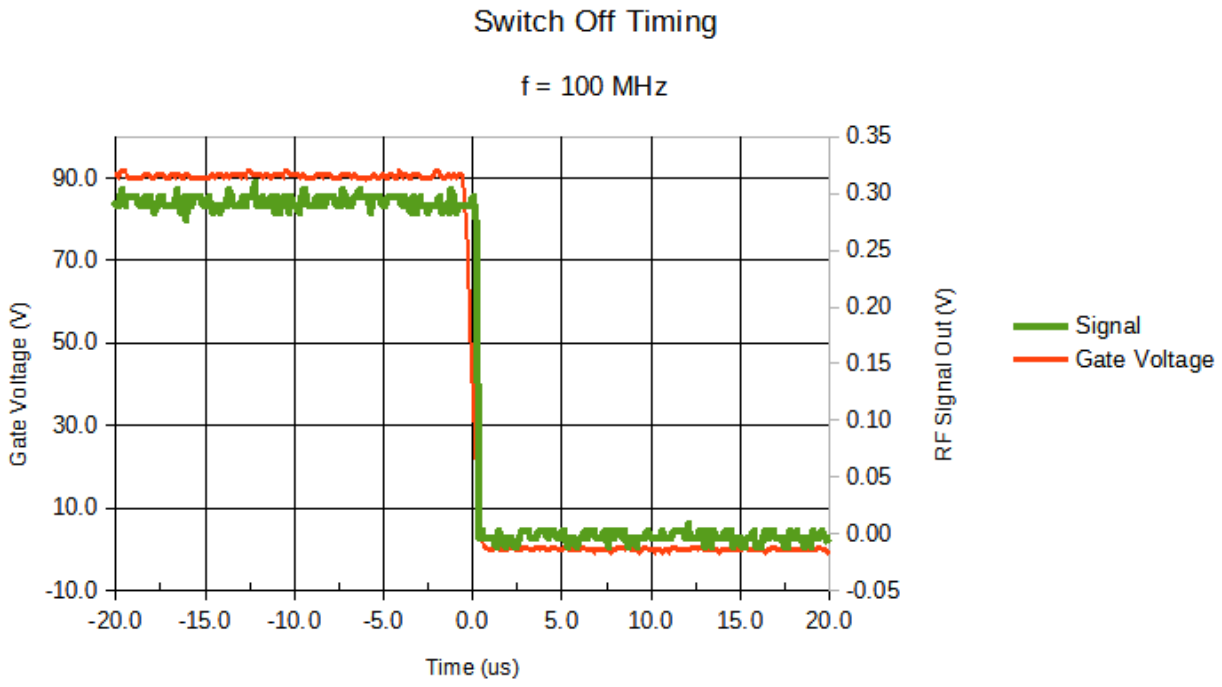
Second Harmonic Power vs. Temperature

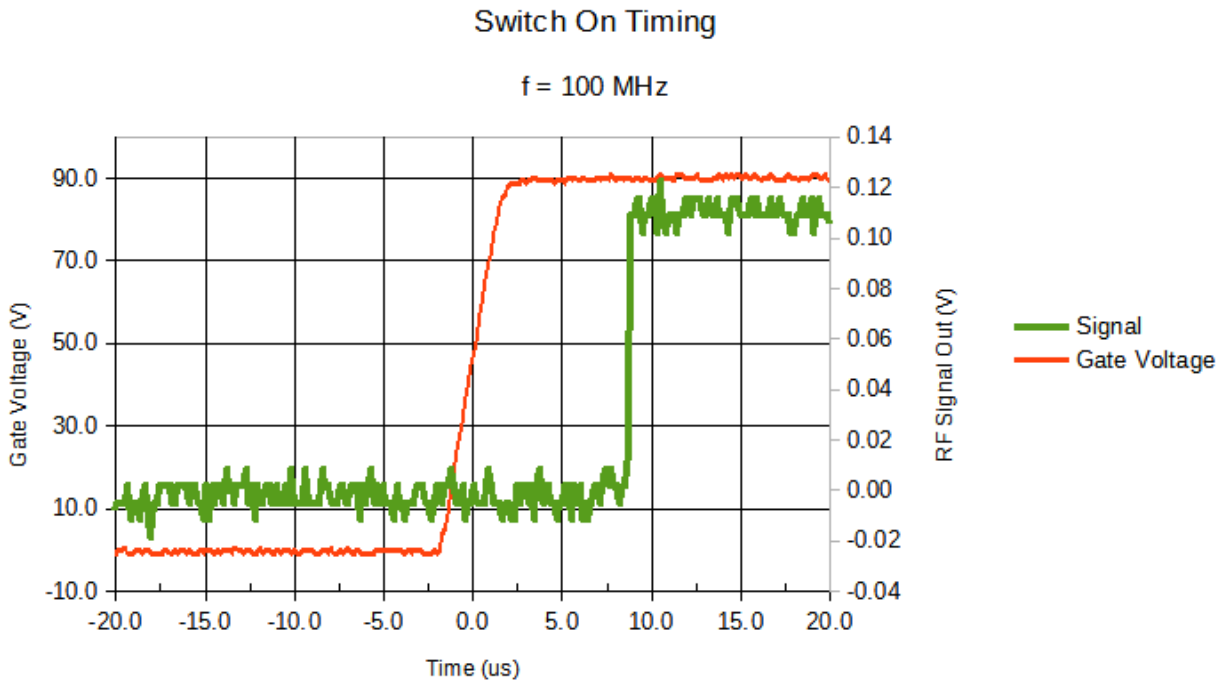
f0 = 1.0 GHz, 36 dBm



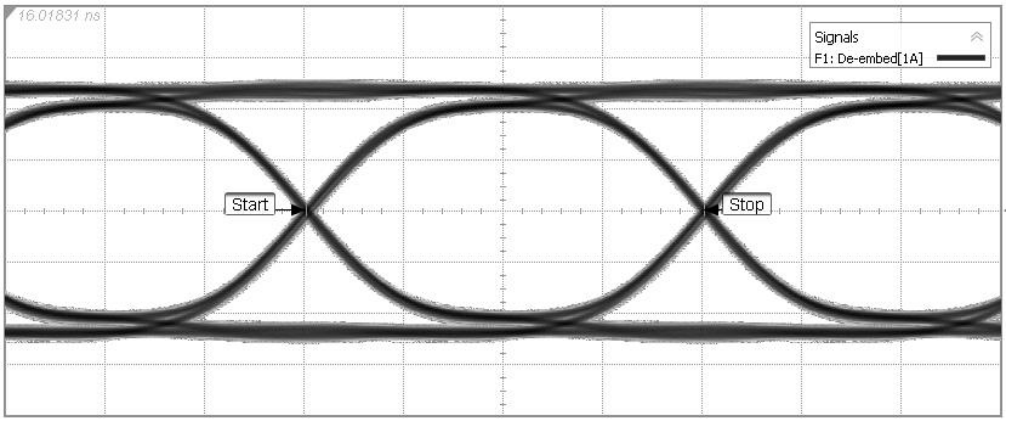


On / Off Switching Time



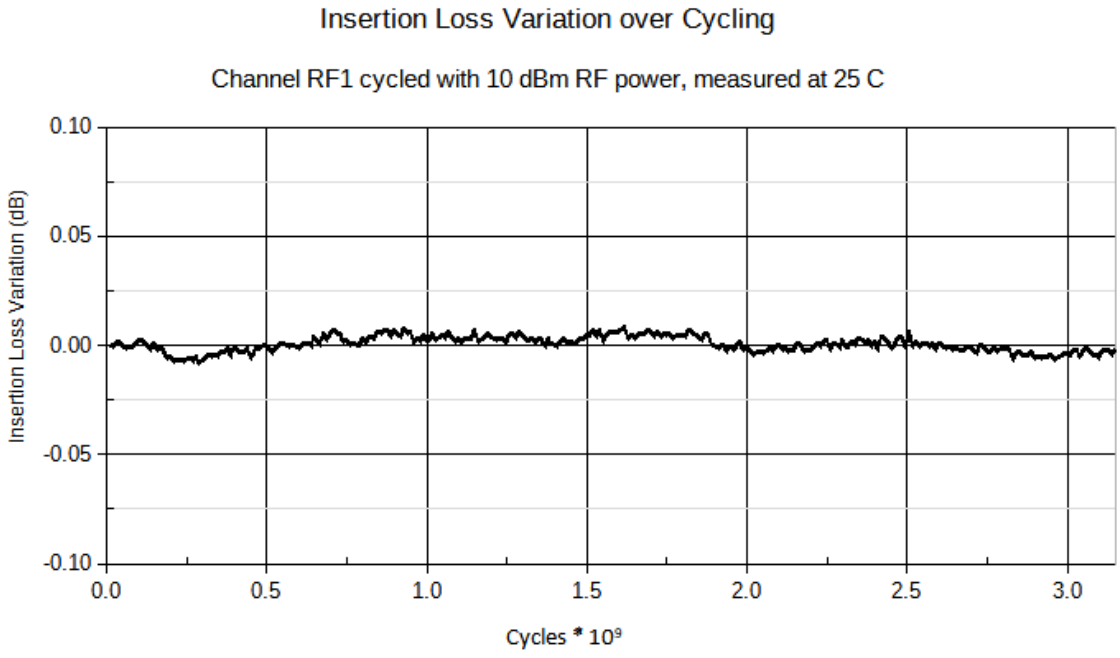


Single-Ended Eye Diagram Measurement



Test Cases	Bit rate	Eye Height	Eye Width	Jitter (Pk to Pk)	Rise Time	Fall Time
Baseline-Test System	20.000 Gbps	440.00 mV	48.16 ps	1.99 ps	14.99 ps	14.33 ps
MM5130 EVK	20.000 Gbps	339.80 mV	48.20 ps	2.16 ps	24.00 ps	24.34 ps

Typical Hot-switching Performance

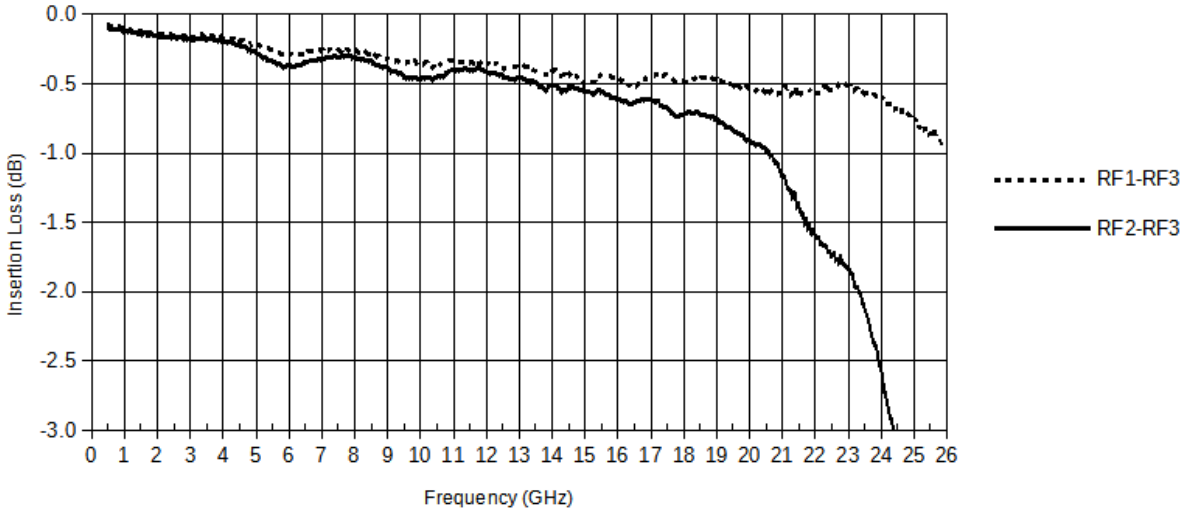


RF Performance

Super-Port Mode

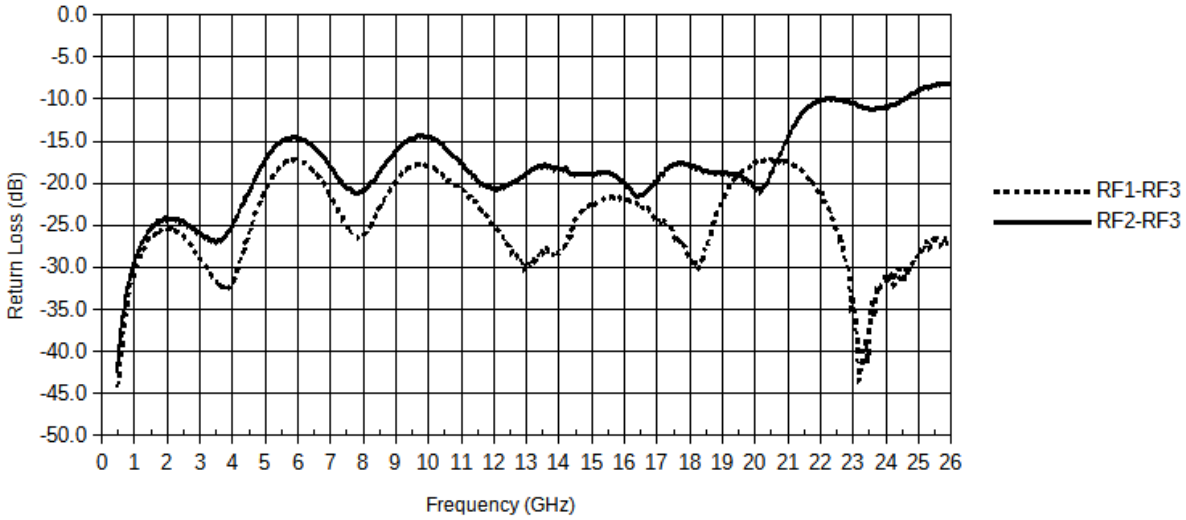
Super-Port Configuration Insertion Loss / S21

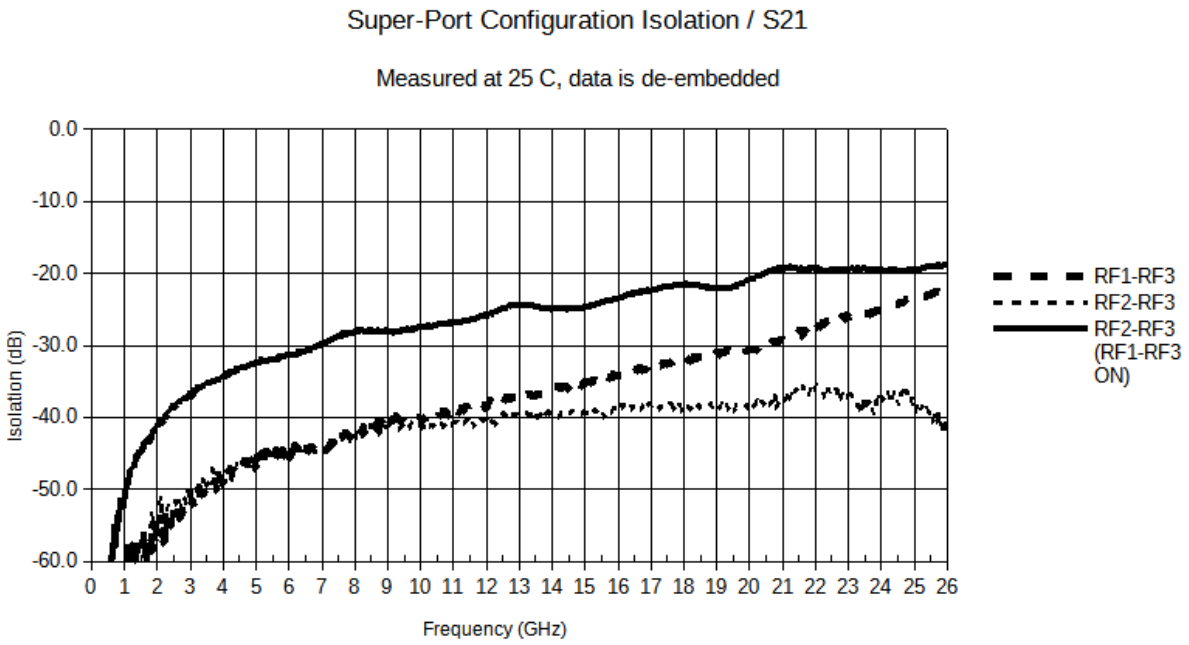
RF1-RF3 & RF2-RF3, Measured at 25 C, data is de-embedded



Super-Port Configuration Return Loss / S11

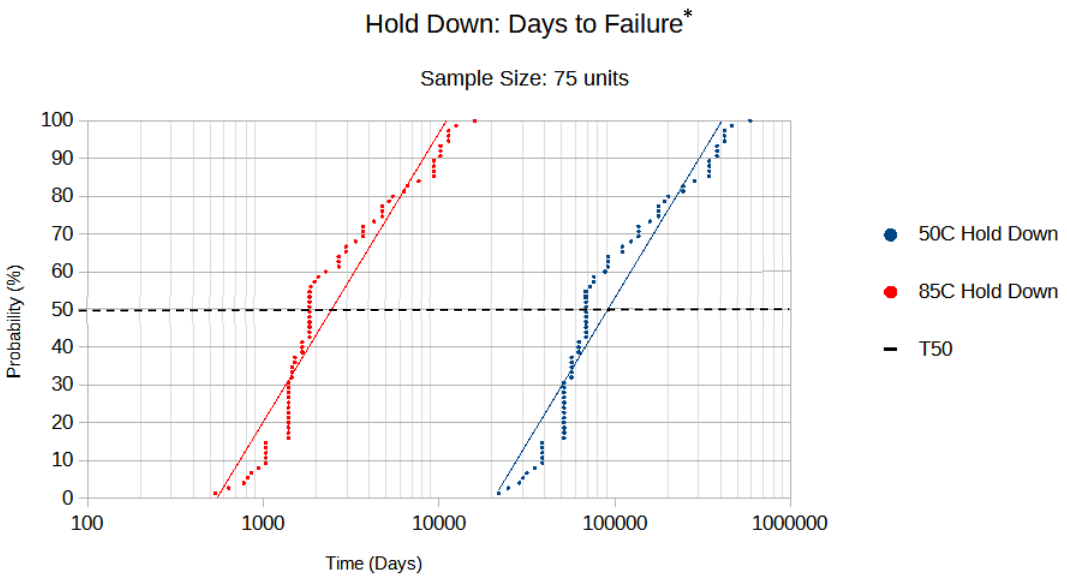
RF1-RF3 & RF2-RF3, Measured at 25 C, data is de-embedded

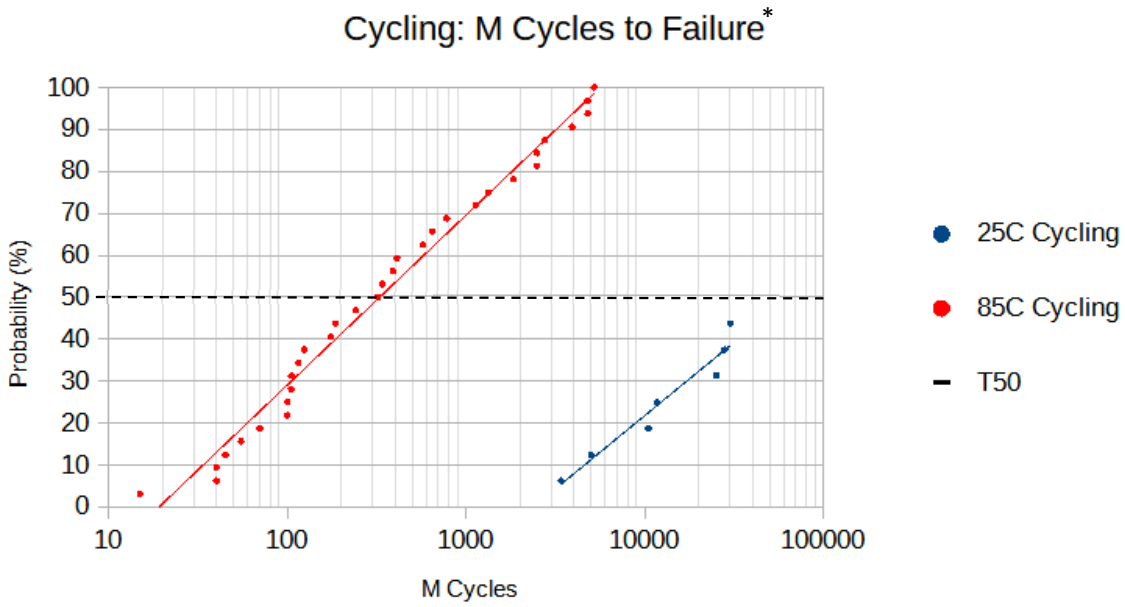




Switch Reliability Test Results

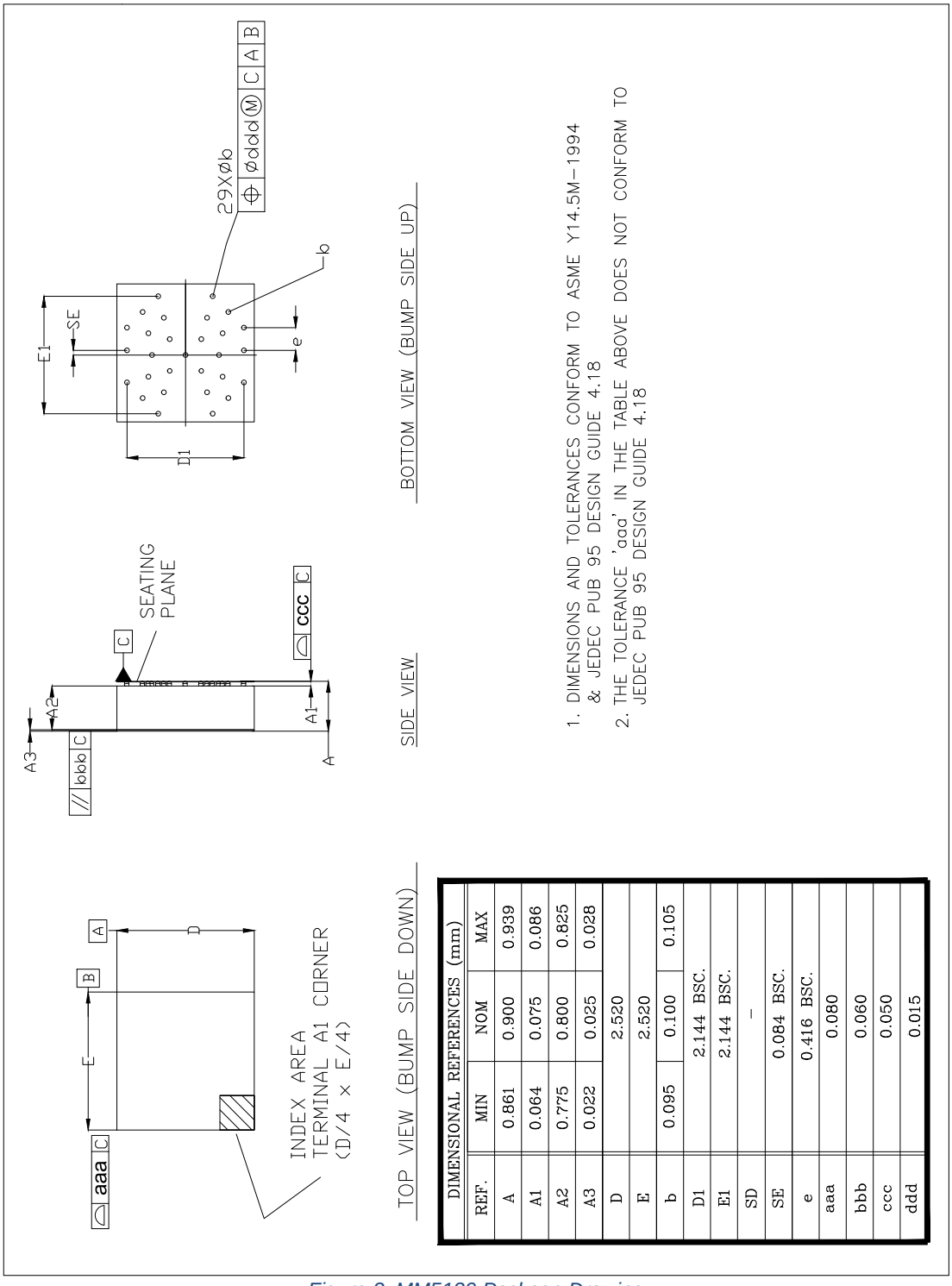
Switch hold-down duration and actuation cycling reliability test results are plotted below. Hold Down median failure is 68675 days (188 years) @ 50C and 1836 days (5.0 years) @ 85C. Cycling median failure is greater than 30 billion cycles @ 25C and 320 million cycles @ 85C.





*Failure definition is 20% shift in pull-in voltage (VPI).

Package Drawing



DIMENSIONAL REFERENCES (mm)			
REF.	MIN	NOM	MAX
A	0.861	0.900	0.939
A1	0.064	0.075	0.086
A2	0.775	0.800	0.825
A3	0.022	0.025	0.028
D		2.520	
E		2.520	
b	0.095	0.100	0.105
D1		2.144 BSC.	
E1		2.144 BSC.	
SD		–	
SE		0.084 BSC.	
e		0.416 BSC.	
aaa		0.080	
bbb		0.060	
ccc		0.050	
ddd		0.015	

Figure 2 MM5130 Package Drawing

Bump Coordinates

0.0, 0.0 at die center

Pin	X(um)	Y(um)
1	1072	500
2	1072	84
3	1072	-500
4	786	-786
5	500	-1072
6	-500	-1072
7	-786	-786
8	-1072	-500
9	-1072	84
10	-1072	500
11	-786	786
12	-500	1072
13	500	1072
14	786	786
15	681	396
16	615	0
17	681	-396
18	396	-681
19	-396	-681
20	-681	-396
21	-615	0
22	-681	396
23	-396	681
24	396	681
25	290	290
26	290	-290
27	-290	-290
28	-290	290
29	0	0

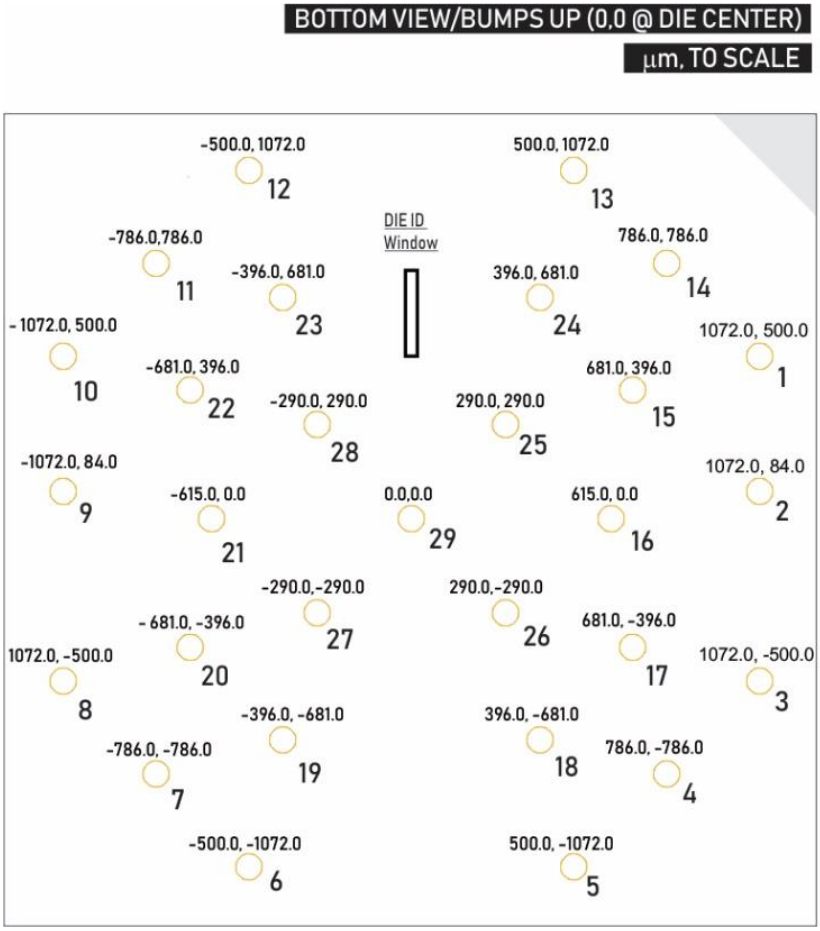


Figure 3: Bump Coordinates

Recommended PCB Layout

Layout recommendation for connecting the MM5130 with coplanar RF line or grounded coplanar line as used for the MM5130 evaluation board.

For the coplanar RF lines, it is recommended to taper the line to fit the 150 um recommended landing pad while keeping the spacing to the ground metal constant and identical to the spacing used for the line.

In those two examples (Normal SP4T Mode and Super-Port Mode) a 4.0 mil/0.10 mm spacing is used. Recommended maximum solder resist thickness 20 um. 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/C or lower.

Normal SP4T Mode

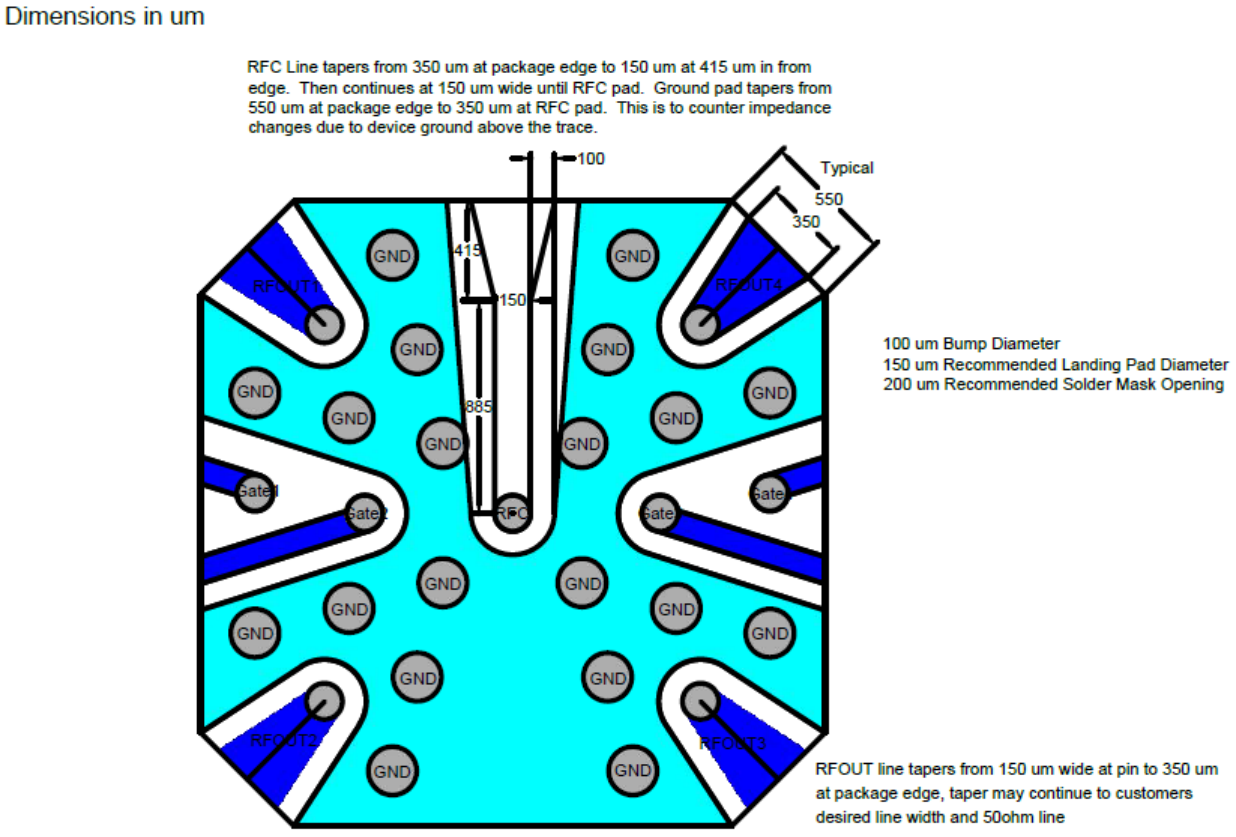


Figure 4: Normal SP4T Mode Layout Recommendation

Super-Port Mode

Dimensions in um

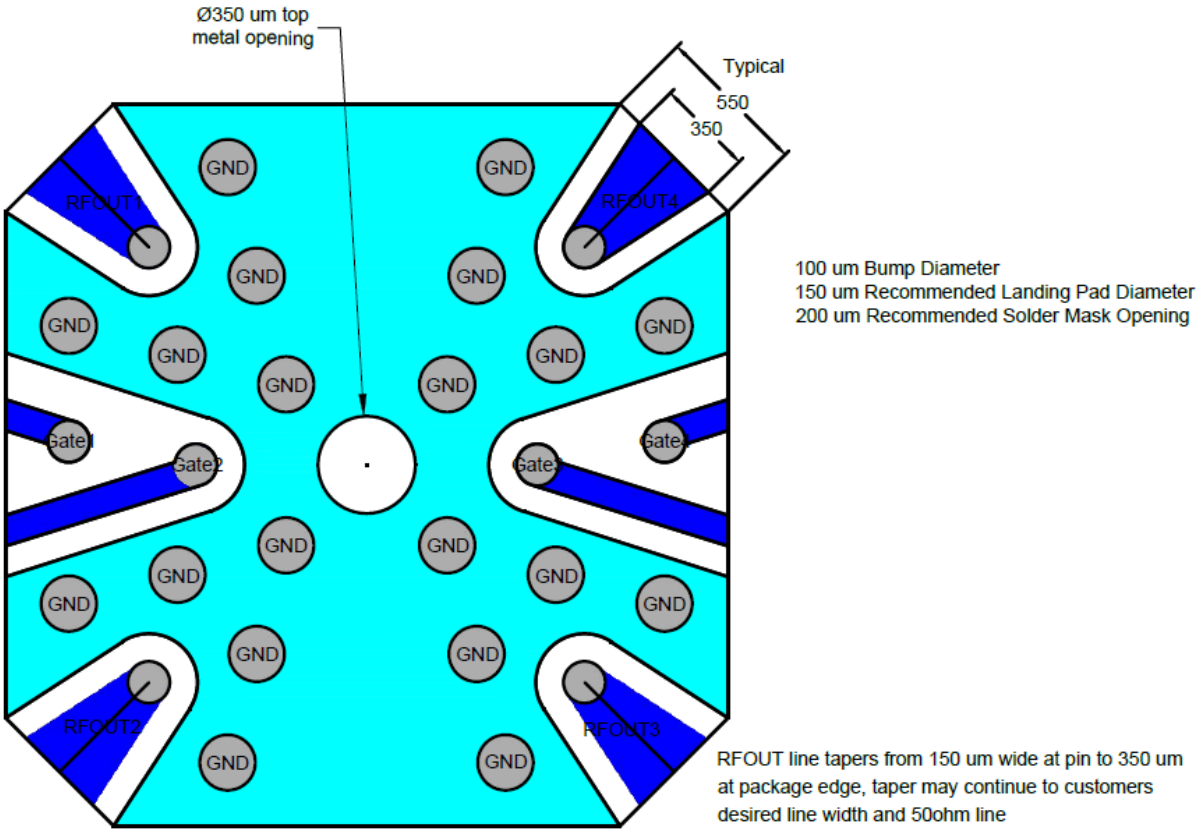


Figure 5: Super-port Mode Layout Recommendation

Recommended Solder Reflow Profile

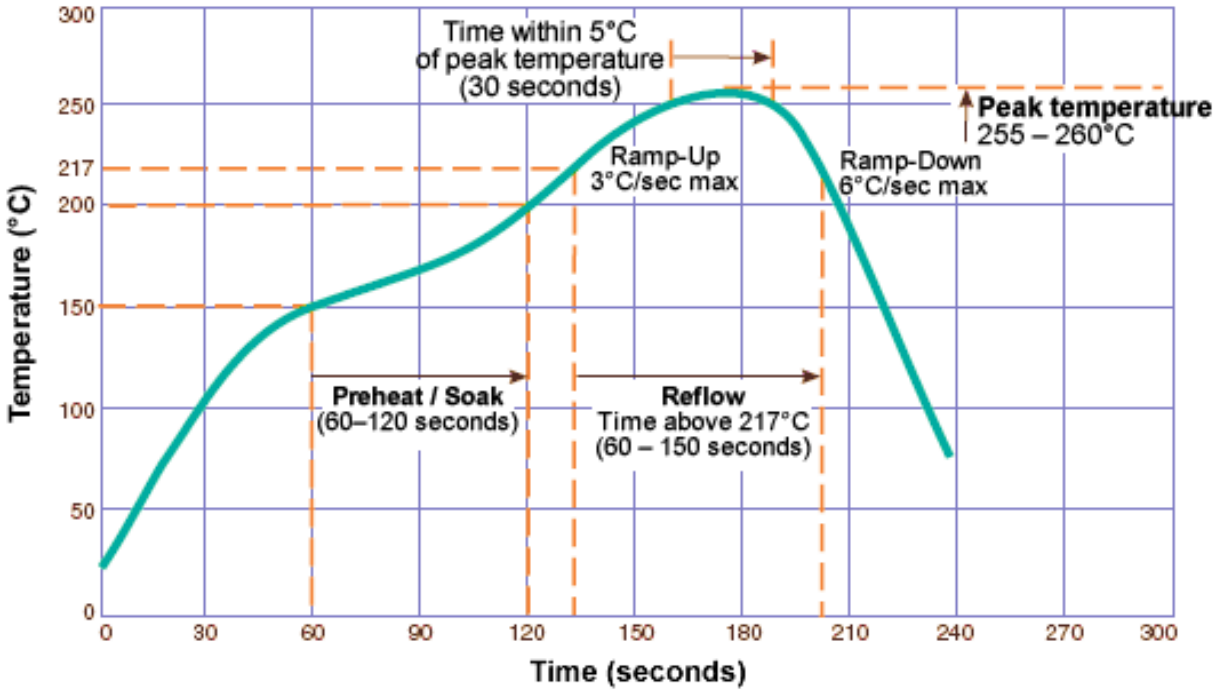


Figure 6: Reflow Profile

For detailed information on soldering the MM5130, please refer to the Menlo Micro application note “WL-FC Assembly Instructions”:

- *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:

- Customer Shelf Life: 24 months from customer receipt date
- Extended Shelf Life: 60 months from customer receipt date if re-bagged every 32 months or less.
- Floor life: Moisture Sensitivity Level (MSL) testing is not required for Hermetic package as per JESD47K.
- Do not re-bake.

Tape & Reel Details

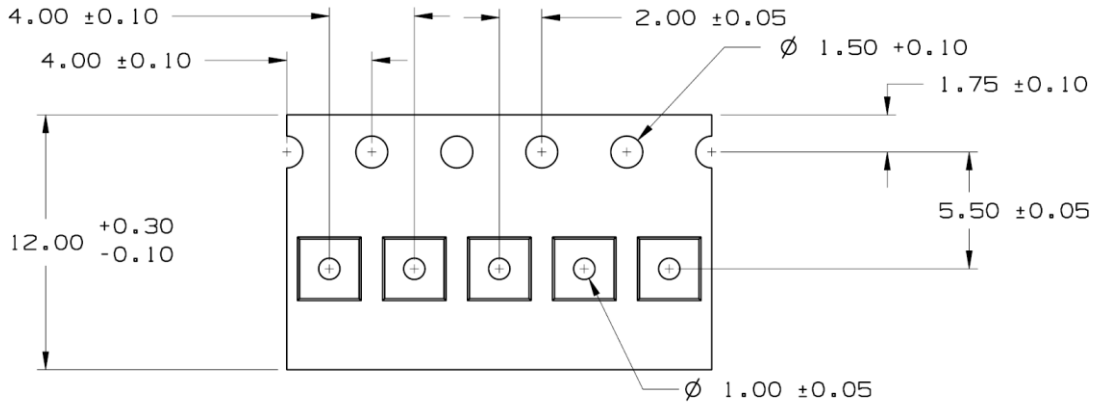


Figure 7: Tape and Reel Drawing

Package Options and Ordering Information

Part Number	ECCN	Package	Temperature Range
MM5130-03	EAR99	DC-26GHz - SP4T - high-temp cycling 2.5 mm x 2.5 mm 29 pin WL-FC	-40°C to +85°C
MM5130-03C	EAR99	DC-26GHz - SP4T 2.5 mm x 2.5 mm 29 pin WL-FC	-40°C to +85°C
MM5130EVK1	EAR99	Evaluation Board MM5130 <12 GHz	
MM5130EVK2	EAR99	Evaluation Board MM5130 18 GHz	
MM5130EVK3	EAR99	Evaluation Board MM5130 Super-Port Mode 26 GHz	

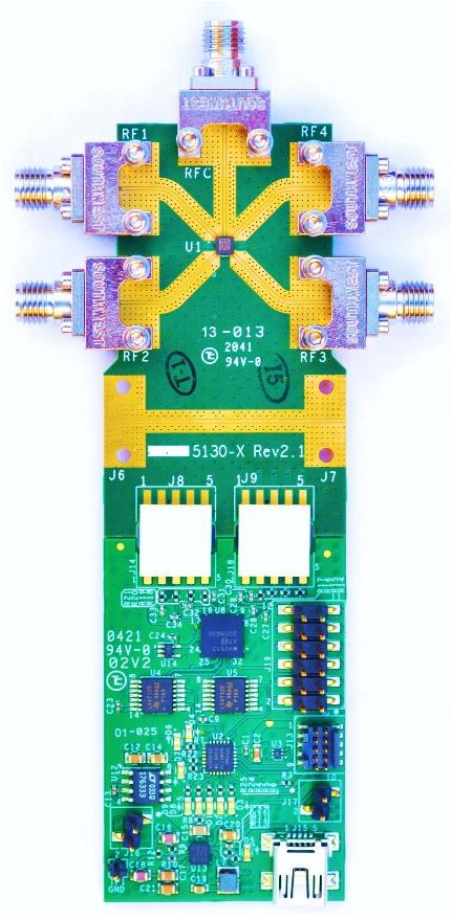


Figure 8: MM5130EVK2 18 GHz Evaluation Board

Important Information

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1) In any life support systems.

2) Applications for implanting into the human body, without the express written approval from Menlo Micro.

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Contact Information

Please contact Menlo Micro for the latest specifications, additional product information, test and evaluation boards, product samples, worldwide sales and distribution locations:

Internet: www.menlomicro.com

E-mail: sales@menlomicro.com

For product technical questions and application information: support@menlomicro.com

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