

# MM5120



## DC to 18 GHz RF SP4T with Integrated Driver



### Product Overview

#### Description

The MM5120 is a high-power SP4T switch built on Menlo Micro's Ideal Switch® technology. This innovative technology enables highly reliable switches capable of greater than 25 W forward power. The MM5120 provides ultra-low insertion loss and superior linearity as an SP4T from DC to 18 GHz, with greater than 3 billion switching cycles. The MM5120 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 MM5120 features an integrated driver circuit with Serial Peripheral Interface (SPI) and General Purpose Input/Output (GPIO) interface control options and an integrated charge pump to drive the gate.

#### Features

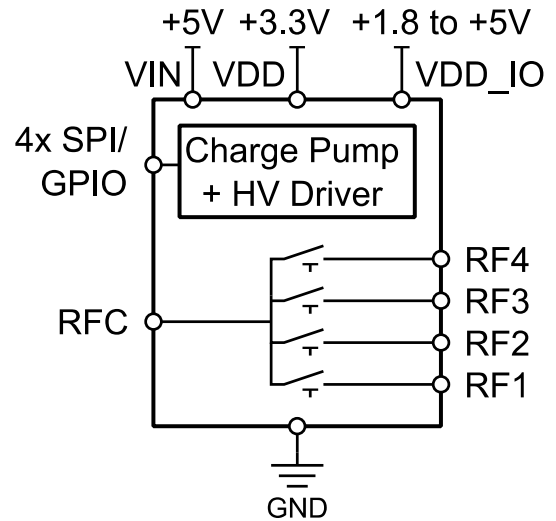
- DC to 18 GHz Frequency Range
- Integrated High-Voltage Driver
- 25 W (CW), 150 W (Pulsed) Max Power Handling
- Low On-State Insertion Loss: 0.4 dB @ 6.0 GHz
- High Linearity, IIP3 > 90 dBm
- > 25 dB Isolation @ 6.0 GHz
- Low Power Consumption <15mW
- High Reliability > 3 billion Switching Operations
- 5.2 mm x 4.2 mm LGA Package

#### Applications

- Switched Filter Banks and Tunable Filters
- High Power RF Front-Ends
- Low-Loss Switch Matrices
- RF EM Relay Replacement
- Antenna Tuning
- Antenna Beam Steering
- Digital Step Attenuators

#### Markets

- Defense and Aerospace
- Test and Measurement
- Wireless Infrastructure



## Electrical Specifications

### 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 MM5120 should be restricted to the limits indicated in the recommended operating conditions listed in [Table 2](#).

#### Electrostatic Discharge (ESD) Safeguards

The MM5120 is a Class 0 ESD device. When handling the MM5120, observe precautions as with any other ESD sensitive device. Do not exceed the voltage ratings specified in [Table 1](#).

**Table 1. Absolute Maximum Ratings<sup>1</sup>**

| Parameter  | Minimum | Maximum                 | Unit |
|--|---------|-------------------------|------|
| Open State Voltage Rating / Switch RF1-4 to RFC <sup>2</sup> | -150    | 150                     | V    |
| Open State Voltage RF1-4, RFC to GND <sup>2,3</sup>          | -150    | 150                     | V    |
| Hot Switching Voltage <sup>4</sup>                           | -0.5    | 0.5                     | V    |
| Charge Pump Input (V <sub>IN</sub> )                         | -0.3    | 5.5                     | V    |
| DC Supply Voltage (V <sub>DD</sub> )                         | -0.3    | 3.6                     | V    |
| I/O Supply Voltage (V <sub>DD_IO</sub> )                     | -0.3    | 5.5                     | V    |
| Logic Input Levels   | -0.5    | V <sub>DD_IO</sub> +0.3 | V    |
| DC Current Rating/Switch <sup>5</sup>                        | —       | 500                     | mA   |
| CW Input Power @ 6 GHz <sup>6</sup>                          | —       | 25                      | W    |
| Peak RF Power <sup>7</sup>                                   | —       | 150                     | W    |
| Storage Temperature Range <sup>8</sup>                       | -65     | 150                     | °C   |
| ESD Rating HBM RF1-4, RFC Pins                               | —       | 150                     | V    |
| ESD Rating HBM Control and Power Pins <sup>9</sup>           | —       | 2000                    | V    |
| ESD Rating HBM VPP Pin                                       | —       | 500                     | V    |
| Mechanical Shock <sup>10</sup>                               | —       | 500                     | G    |
| Vibration <sup>11</sup>                                      | —       | 500                     | Hz   |

**Notes:**

- 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).
- This also applies to ESD events. This is a Class 0 device.
- RF pins must not be allowed to electrically float during switch operation. See section [Floating Node Restrictions](#) for details on avoiding floating nodes.
- See section [Hot Switch Restrictions](#) for more information.
- Total current of all channels combined.
- For +85 °C ambient test condition.
- For a 10% duty cycle, 10 μs pulse width, +25 °C ambient test condition.
- See section [Storage and Shelf Life](#) for more information on shelf and floor life.
- Control and power pins include: VIN, VDD, VDD\_IO, FLT\_MODE, FLT\_B, FLIP\_BIT, CP\_EN, MODE, and CTL1-4.
- See JESD22-B104 for mechanical shock test methodology at 1.0 ms, half-sine, 5 shocks/axis, 6 axis. Data taken from MEMS die (MM5130) test results.
- See JESD22-B103 for vibration test methodology at 3.1 G and 30min/cycle, 1 cycle/axis, 3 axis. Data taken from MEMS die (MM5130) test results.

**Table 2. Recommended Operating Conditions**

| Parameter                                 | Symbol       | Minimum | Maximum | Unit |
|---|--------------|---------|---------|------|
| <b>Charge Pump Power Supply</b>           | $V_{IN}$     | 4.5     | 5.5     | V    |
| <b>Low Voltage Digital Supply</b>         | $V_{DD}$     | 3.0     | 3.6     | V    |
| <b>Logic Reference Level</b>              | $V_{DD\_IO}$ | 1.71    | 5.25    | V    |
| <b>CW RF Power<sup>1</sup></b>            |              |         |         |      |
| 1 GHz                                     |              | —       | 40      | W    |
| 6 GHz                                     |              | —       | 20      | W    |
| 18 GHz                                    |              | —       | 5.7     | W    |
| <b>Ambient Temperature Range</b>          | $T_A$        | -40     | 85      | °C   |
| <b>Switch Cycle Frequency<sup>2</sup></b> |              | —       | 10      | kHz  |

**Notes:**

1. For +85 °C 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. Operating with all GND, AGND, DGND, and CPGND pins connected to system ground (0 V) and with input frequencies of greater than 10 MHz in a 50  $\Omega$  impedance system.

**Table 3. RF Performance Specifications**

| Parameter                                      | Symbol | Minimum | Typical | Maximum | Unit | Conditions   |
|--|--------|---------|---------|---------|------|--|
| <b>Operating Frequency Range</b>               |        | DC      | —       | 18      | GHz  |  |
| <b>Insertion Loss</b>                          |        | —       | 0.4     | —       | dB   | @ 6 GHz  |
|  |        | —       | 0.7     | —       | dB   | @ 12 GHz   |
|  |        | —       | 1.5     | —       | dB   | @18 GHz  |
| <b>Input / Output Return Loss</b>              |        | —       | 14      | —       | dB   | @ 6 GHz  |
|  |        | —       | 12      | —       | dB   | @ 12 GHz   |
|  |        | —       | 8       | —       | dB   | @18 GHz  |
| <b>Isolation (RF1-4 to RFC)</b>                |        | —       | 26      | —       | dB   | @ 6 GHz  |
|  |        | —       | 22      | —       | dB   | @ 12 GHz   |
|  |        | —       | 17      | —       | dB   | @18 GHz  |
| <b>Third-Order Intercept Point</b>             | IP3    | —       | 90      | —       | dBm  | Measured at +25°C.   |
| <b>Second Harmonic</b>                         | H2     | —       | -125    | —       | dBc  | Measured at 2.0 GHz fundamental frequency and 35 dBm input power. Measured at +25°C.   |
| <b>Third Harmonic</b>                          | H3     | —       | -145    | —       | dBc  | Measured at 2.0 GHz fundamental frequency and 35 dBm input power. Measured at +25°C.   |
| <b>Charge Pump Clock Feed Thru<sup>1</sup></b> |        | —       | -132    | —       | dBm  | Measured with 300 Hz resolution BW, 3 Hz video BW, 0dB internal attenuation, internal amplifier ON, single sweep. Measured at +25°C. |

**Notes:**

1. For applications that require low noise figure performance below 2 GHz, MM5130 with external MM101 driver is recommended.

**Table 4. AC and DC Electrical Specifications**

| Parameter                                   | Symbol           | Minimum           | Typical             | Maximum | Unit              | Conditions   |
|---|------------------|-------------------|---------------------|---------|-------------------|--|
| <b>Switching Time</b>                       |                  |                   |                     |         |                   |  |
| Turn on                                     | T <sub>ON</sub>  | —                 | 14                  | —       | μs                | RF switching time measured using a 100 MHz -10dBm signal, from 50% rising edge of SSB to settling to within 0.05 dB of final value.                      |
| Turn off                                    | T <sub>OFF</sub> | —                 | 5                   | —       | μs                |  |
| <b>On/Off Operations (MM5120-01NDB)</b>     |                  |                   |                     |         |                   |  |
| 25 °C                                       |                  | 3x10 <sup>9</sup> | 30x10 <sup>9</sup>  | —       | Cycle             | Data taken from MEMS die (MM5130) reliability test results. Cold switched operations, measured at 10 kHz cycling rate, specified at ambient temperature. |
| 85 °C                                       |                  | —                 | 0.1x10 <sup>9</sup> | —       | Cycle             |  |
| <b>Off-State RFx to RFC Leakage Current</b> |                  | —                 | 40                  | 150     | nA                | Measured with 75 V RFx to 0 V RFC.   |
| <b>On-State Resistance</b>                  | R <sub>ON</sub>  | —                 | 1.0                 | 3       | Ω                 | Measured with 0.5 A.   |
| <b>Off-State Capacitance</b>                | C <sub>OFF</sub> | —                 | 2.5                 | —       | fF                | Measured at 1 MHz, 1 V <sub>RMS</sub> .  |
| <b>Video Feedthrough</b>                    |                  | —                 | 16                  | —       | mV <sub>p-p</sub> | Performed with 50 Ω terminations on all RF channels.   |

**Table 5. Charge Pump and Driver Electrical Specifications**

| Parameter   | Symbol           | Minimum              | Typical | Maximum              | Unit    | Conditions  |
|---|------------------|----------------------|---------|----------------------|---------|---|
| <b>VIN Current (Dynamic)</b>                              | $I_{VIN\,D}$     | —                    | 1.5     | 2.5                  | mA      | SPI mode, Charge pump on, all channels switching at 10 kHz.   |
| <b>VIN Quiescent Current</b>                              | $I_{VIN\,Q}$     | —                    | 1.25    | 2.0                  | mA      | Charge pump on, all I/O and channels static.  |
| <b>VDD UVLO Rising Threshold</b>                          | $UVLO_{RISE}$    | 2.77                 | —       | 2.95                 | V       |   |
| <b>VDD UVLO Falling Threshold</b>                         | $UVLO_{FALL}$    | 2.72                 | —       | 2.90                 | V       |   |
| <b>Low Voltage Digital Current</b>                        | $I_{DD}$         | —                    | 520     | 700                  | $\mu$ A | SPI mode, all channels switching at 10 kHz.   |
| <b>Low Voltage Digital Quiescent Current</b>              | $I_{DD\,Q}$      | —                    | 470     | 550                  | $\mu$ A | Charge pump On, All I/O & channels static.  |
| <b>Low Voltage Digital Sleep Mode Current</b>             | $I_{DD\_SLEEP}$  | —                    | <1      | 10                   | $\mu$ A | Charge pump Off, SPI and inputs in static state.  |
| <b>I/O Logic Supply Current</b>                           | $I_{DD\_IO\_Q}$  | —                    | <10     | 50                   | $\mu$ A |   |
| <b>Fault Indicator Open-Drain Output</b>                  | FLT <sub>B</sub> | 0                    | —       | $V_{DD\_IO}$         | V       |   |
| <b>Logic I/O Level High</b>                               | $I/O_{VH}$       | 0.7*<br>$V_{DD\_IO}$ | —       | $V_{DD\_IO}$         | V       |   |
| <b>Logic I/O Level Low</b>                                | $I/O_{VL}$       | 0                    | —       | 0.3*<br>$V_{DD\_IO}$ | V       |   |
| <b>MISO Load Capacitance</b>                              | $C_{MISO}$       | —                    | —       | 10                   | pF      | Specification is for design guidance only. MISO load capacitance is SDI input capacitance pin and PCB trace capacitance from MISO to SDI. |
| <b>MISO Max Source Current @ <math>V_{DD\_IO}</math>:</b> | $I_{MISOH}$      |                      |         |                      |         | Measured at $V_{OUT} = 0.8 \times V_{DD\_IO}$ .   |
| 5.0 V   |                  | 180                  | 290     | —                    | mA      |   |
| 3.3 V   |                  | 75                   | 140     | —                    | mA      |   |
| 1.8 V   |                  | 20                   | 35      | —                    | mA      |   |

| Parameter   | Symbol       | Minimum | Typical | Maximum | Unit | Conditions   |
|---|--------------|---------|---------|---------|------|--|
| <b>MISO Max Sink Current @ <math>V_{DD\_IO}</math>:</b> | $I_{MISOL}$  |         |         |         |      | Measured at $V_{OUT} = 0.2 \times V_{DD\_IO}$ .  |
| 5.0 V   |              | 140     | 260     | —       | mA   |  |
| 3.3 V   |              | 65      | 140     | —       | mA   |  |
| 1.8 V   |              | 20      | 40      | —       | mA   |  |
| <b>VPP UVLO Rising Threshold</b>                        | $V_{PPEN}$   | 75      | 79      | 81      | V    |  |
| <b>VPP UVLO Falling Threshold</b>                       | $V_{PPDIS}$  | 74      | 78      | 80      | V    |  |
| <b>CP_EN pin toggle low time</b>                        | $T_{TOGGLE}$ | 500     | —       | —       | ns   | Minimum time CP_EN must be held low to restart the IC from fault condition.                      |
| <b>FLTB pin max sink current</b>                        |              | 65      | 140     | —       | mA   | FLTB active low, measured with $V_{DD\_IO} = 3.3V$ .   |
| <b>Logic I/O Hysteresis (SCK only)</b>                  | $I/O_{HYS}$  | —       | 0.25    | —       | V    |  |
| <b>Power-On-Reset</b>                                   | POR          | —       | 1.25    | 2.5     | ms   | Time for logic input signals to be considered valid after application of $V_{IN}$ and $V_{DD}$ . |
| <b>Start-Up Time</b>                                    | $T_{ST}$     | —       | 20      | 33      | ms   | CP_EN=1 (CPEN bit=1) to $V_{PP}$ rises to 90% of set value.                                      |



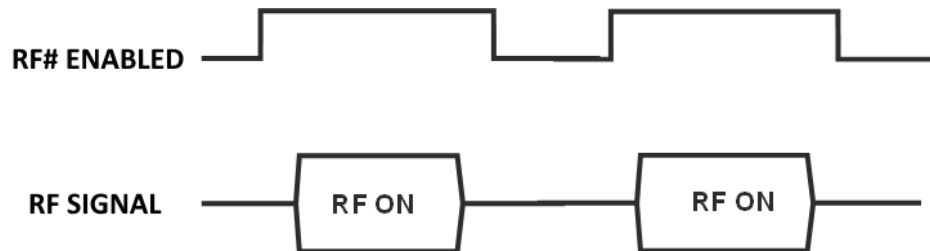
**Table 6. Driver Interface Timing Specifications**

| Parameter   | Symbol      | Minimum | Typical | Maximum | Unit |
|---|-------------|---------|---------|---------|------|
| <b>SPI Clock Frequency SCK</b>                      | $f_{CLK}$   | —       | —       | 33      | MHz  |
| <b>MOSI Valid to SCK Setup Time</b>                 | $t_{SU}$    | 2       | —       | —       | ns   |
| <b>MOSI Valid to SCK Hold Time</b>                  | $t_{HD}$    | 5       | —       | —       | ns   |
| <b>SCK High Time</b>                                | $t_{HI}$    | 15.5    | —       | —       | ns   |
| <b>SCK Low Time</b>                                 | $t_{LO}$    | 15.5    | —       | —       | ns   |
| <b>SSB Pulse Width</b>                              | $t_{CSH}$   | 15      | —       | —       | ns   |
| <b>LSB SCK to SSB High</b>                          | $t_{CSHLD}$ | 15      | —       | —       | ns   |
| <b>SSB Low to SCK High</b>                          | $t_{CSSU}$  | 15      | —       | —       | ns   |
| <b>MISO Propagation Delay from SCK Falling Edge</b> | $t_{MISOH}$ | 10      | —       | —       | ns   |
| <b>MISO Output Valid after SSB Low</b>              | $t_{CMISO}$ | 20      | —       | —       | ns   |
| <b>SSB Inactive to MISO High Impedance</b>          | $t_{MISOZ}$ | —       | —       | 10      | ns   |

See the [Programming](#) section on page 22 for driver interface timing diagrams and details.

## Hot Switch Restrictions

The MM5120 is not intended for hot switching applications and care should be taken to ensure that switching occurs at less than 0.5 V as illustrated below. Further, the voltage at the switch terminals must be within  $\pm 0.5$  V relative to RF ground.



## Floating Node Restrictions

RF pins must not be allowed to electrically float during switching 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 pins, shunt with DC path to ground.

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

## Functional Block Diagram

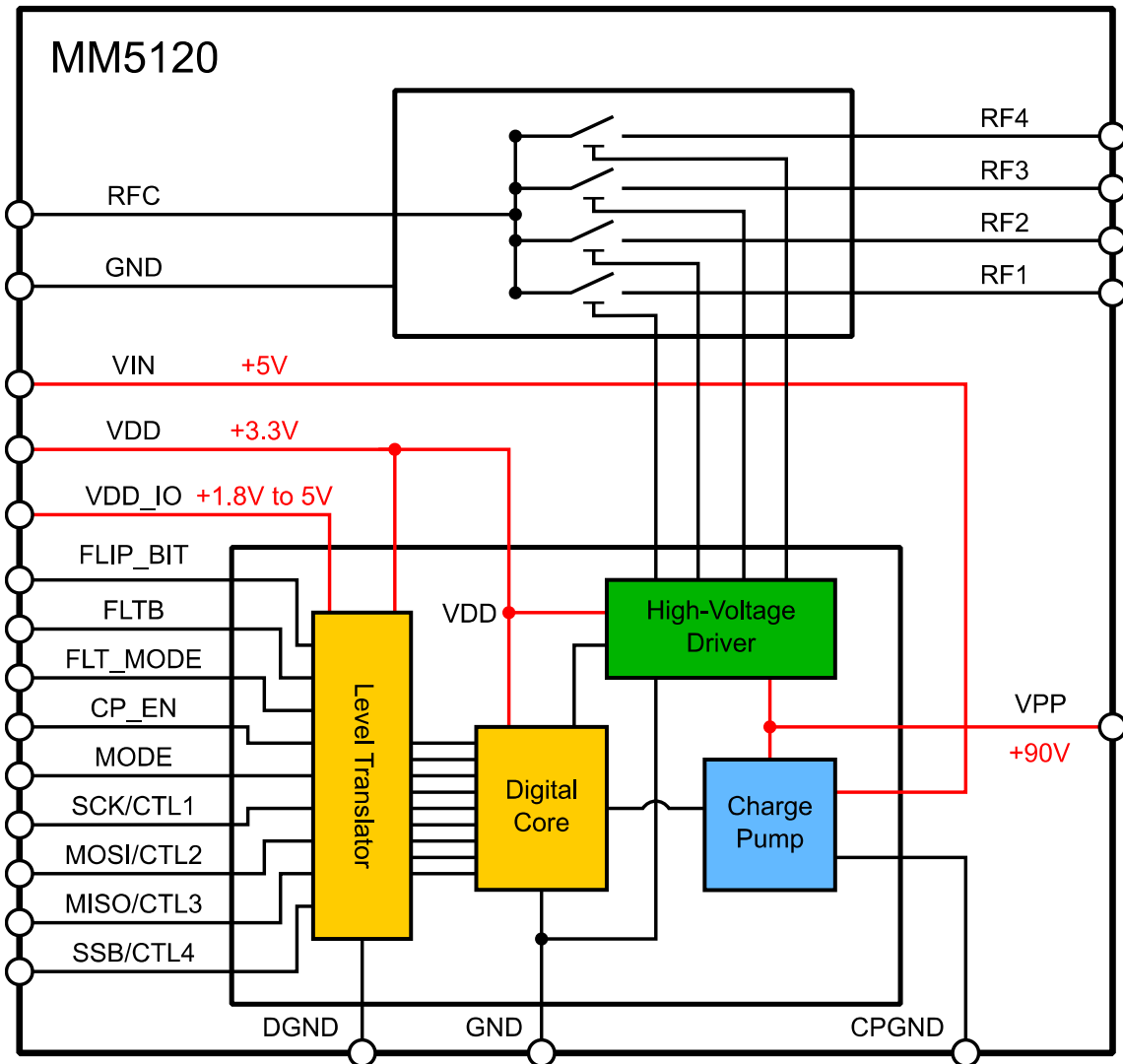


Figure 1. Functional Block Diagram

## Package/Pinout Information

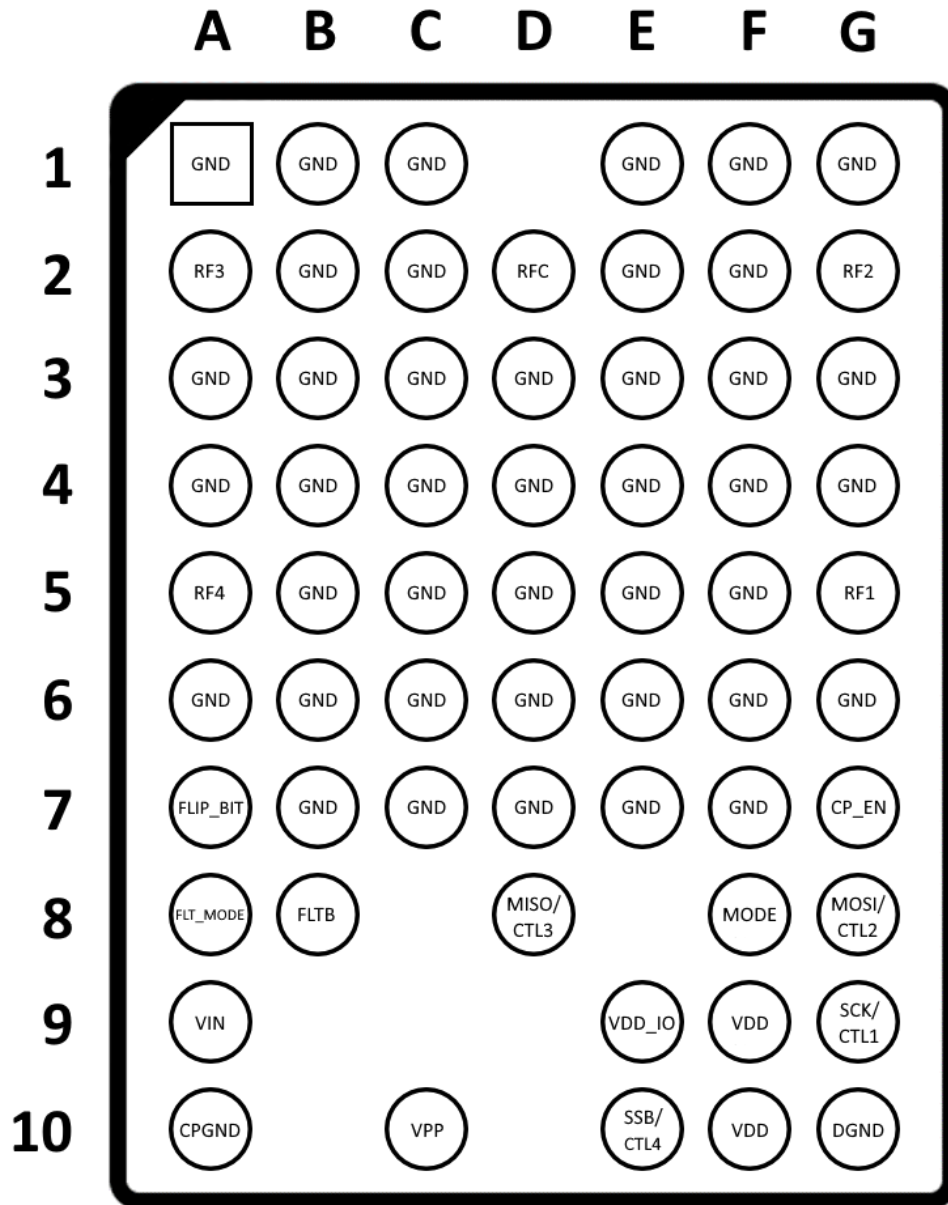


Figure 2. MM5120 5.2 mm x 4.2 mm LGA Package Pinout (Top View/As Mounted)

**Table 7. Detailed Pin Description**

| Pin #   | Pin Name  | Description  |
|---|-----------|--|
| A1, A3, A4, A6, B1-B7, C1-C7, D3-D7, E1-E7, F1-F7, G1, G3, G4, G6 | GND       | Connect to common ground. These pins are internally connected to the RF ground reference.  |
| A2  | RF3       | RF channel 3 input/output.   |
| A5  | RF4       | RF channel 4 input/output.   |
| A7  | FLIP_BIT  | This pin has an internal pull-down resistor. Set high in SPI mode.<br><br>In GPIO mode FLIP_BIT controls the logic mapping between CTL1-4 and RF1-4. When FLIP_BIT is low, CTL1 enables RF1 when high, and so on for CTL2-4. When FLIP_BIT is high, refer to <a href="#">Table 8</a> . |
| A8  | FLT_MODE  | Fault Mode select in GPIO mode. Fault Mode is disabled if high. Has a built-in pull-down resistor. Pin is ignored in SPI mode.   |
| A9  | VIN       | 5 V nominal input to internal charge pump. Bypass with a low ESR 1 $\mu$ F ceramic capacitor.  |
| A10   | CPGND     | Charge pump ground, should be connected to common ground.  |
| B8  | FLT_B     | Fault indicator in GPIO and SPI modes. Open drain output to allow “Wire-OR” of multiple ICs. Goes low when fault is detected. Can be left open if not used.<br><br>Pull-up voltage must be $\leq V_{DD\_IO}$ .   |
| C10   | VPP       | High-voltage output pin, 90 V nominal. Must connect with a 4.7 nF, 200 V, 10 % COG ceramic capacitor to AGND.  |
| D2  | RFC       | RF common input/output.  |
| D8  | MISO/CTL3 | SPI data output in SPI mode; RF channel control in GPIO mode. Has an internal pull-down resistor.  |
| E9  | VDD_IO    | For 3.3 V nominal logic I/O levels, connect to VDD. For alternate I/O levels, connect to a separate supply (+1.8 V to +5.0 V). Bypass with a low ESR 1 $\mu$ F ceramic capacitor if separate from VDD.   |
| E10   | SSB/CTL4  | Chip select in SPI mode; RF channel control in GPIO mode. Has an internal pull-up resistor in SPI mode, and an internal pull-down resistor in GPIO mode.   |

| Pin #   | Pin Name          | Description   |
|---------|-------------------|---|
| F8      | MODE <sup>1</sup> | Logic level input to switch inputs between SPI and GPIO modes. MODE = 0 is SPI mode. MODE = 1 is GPIO mode.                       |
| F9, F10 | VDD               | 3.3 V nominal input to digital logic and internal level translators. Bypass with a low ESR 1 $\mu$ F ceramic capacitor.           |
| G2      | RF2               | RF channel 2 input/output.  |
| G5      | RF1               | RF channel 1 input/output.  |
| G7      | CP_EN             | Charge pump enable pin in GPIO mode. High enables the charge pump. Has a built-in pull-down resistor. Pin is ignored in SPI mode. |
| G8      | MOSI/CTL2         | SPI data input in SPI mode; RF channel control in GPIO mode. Has an internal pull-down resistor.                                  |
| G9      | SCK/CTL1          | Clock input in SPI mode; RF channel control in GPIO mode. Has an internal pull-down resistor.                                     |
| G10     | DGND              | Digital ground, should be connected to common ground.   |

**Notes:**

1. MODE should be tied to GND or VDD\_IO if the use case is SPI or GPIO control, respectively.

## Thermal and Power Handling Considerations

Under low-power operating conditions, the MM5120 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 150 °C for continued reliable operation of the internal controller. Based on an environmental hot temperature of 85 °C, then a 65 °C rise is allowable due to power dissipation. This results in a power dissipation limit of 0.92 W within the device. The operating power limit at a given frequency can then be calculated based on the insertion loss of the internal MEMS switch (MM5130).

Considering an insertion loss of -0.14 dB at 3 GHz:

$$\text{Power Handling} = \text{Max. Power Dissipation} / (1 - 10^{(\text{Insertion Loss}/10)})$$

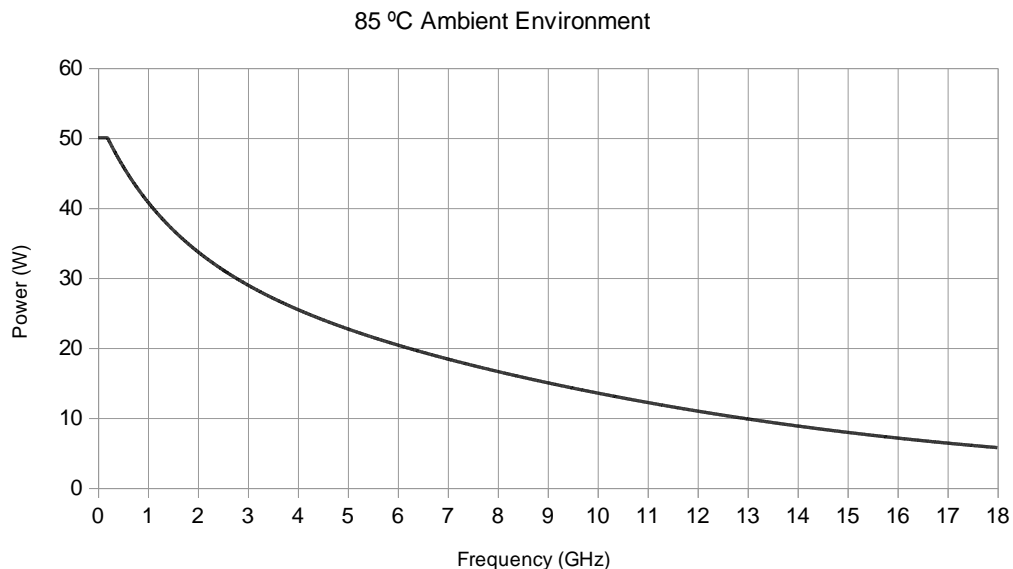
$$= 0.92 / 0.032$$

$$= 28.75 \text{ W}$$

As most self-heating within the package comes from the MM5130 insertion loss, we use this to set a limit on the power handling. The MM5130 insertion loss can also be approximated by a third order polynomial:

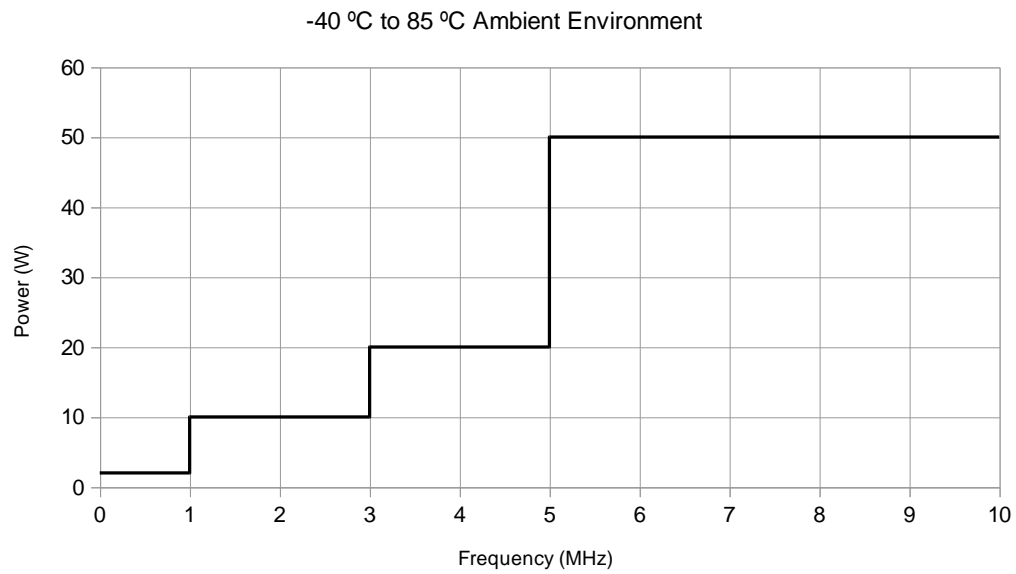
$$\text{Insertion Loss (dB)} = -1.1\text{E-}04 * f^3 + 1.2\text{E-}03 * f^2 - 0.024 * f - 0.076$$

where f is frequency in GHz. See Figure 3 for the power derating curve in an 85 °C environment.



**Figure 3. Maximum Power Handling vs. Frequency (1 of 2)**

Below 10 MHz; the maximum power handling is shown in Figure 4.

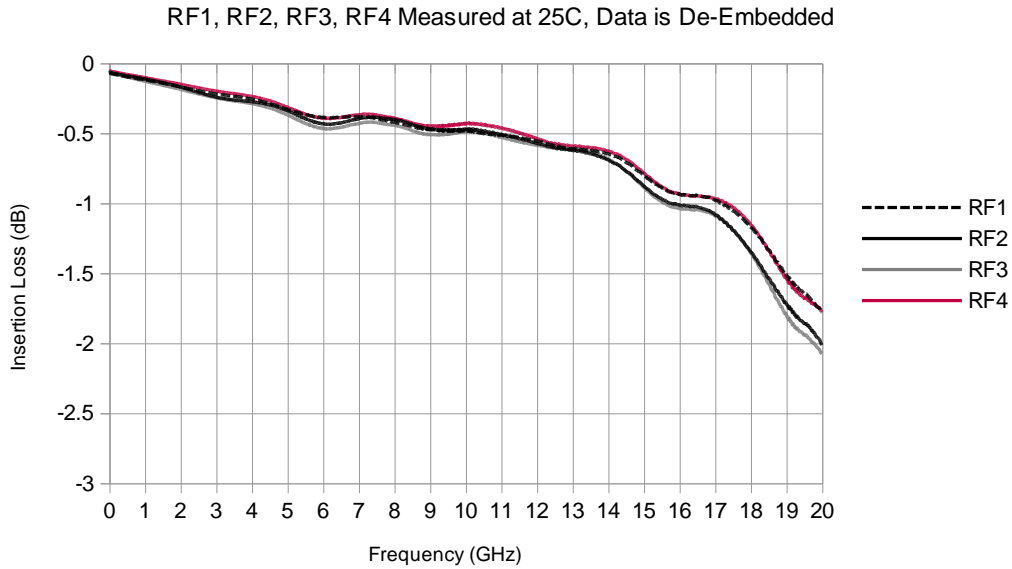


**Figure 4. Maximum Power Handling vs. Frequency (2 of 2)**

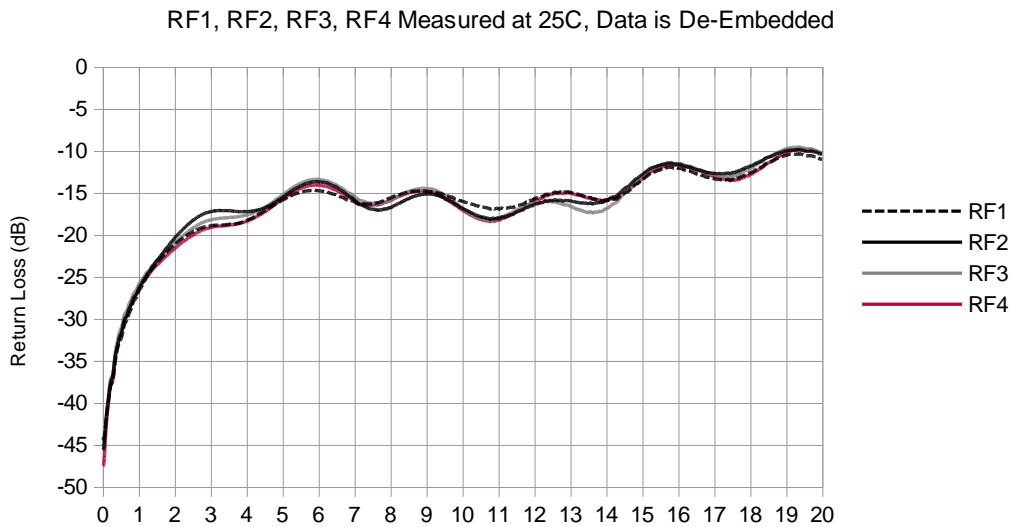


## RF Performance

Typical device performance measured on MM5120 evaluation board, de-embedded.



**Figure 5. Insertion Loss / S21**



**Figure 6. Return Loss / S11**

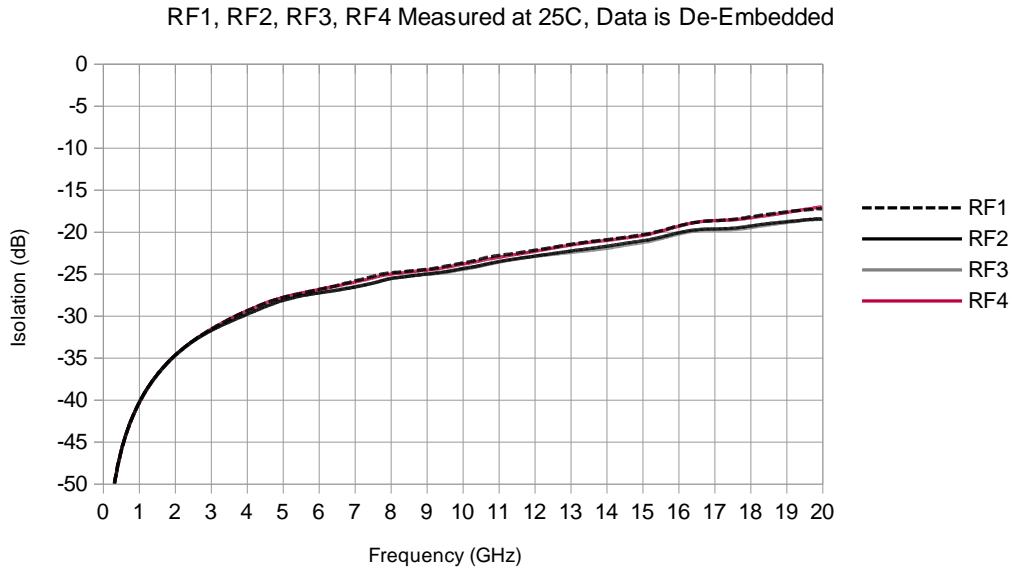


Figure 7. Off-State Isolation / S21

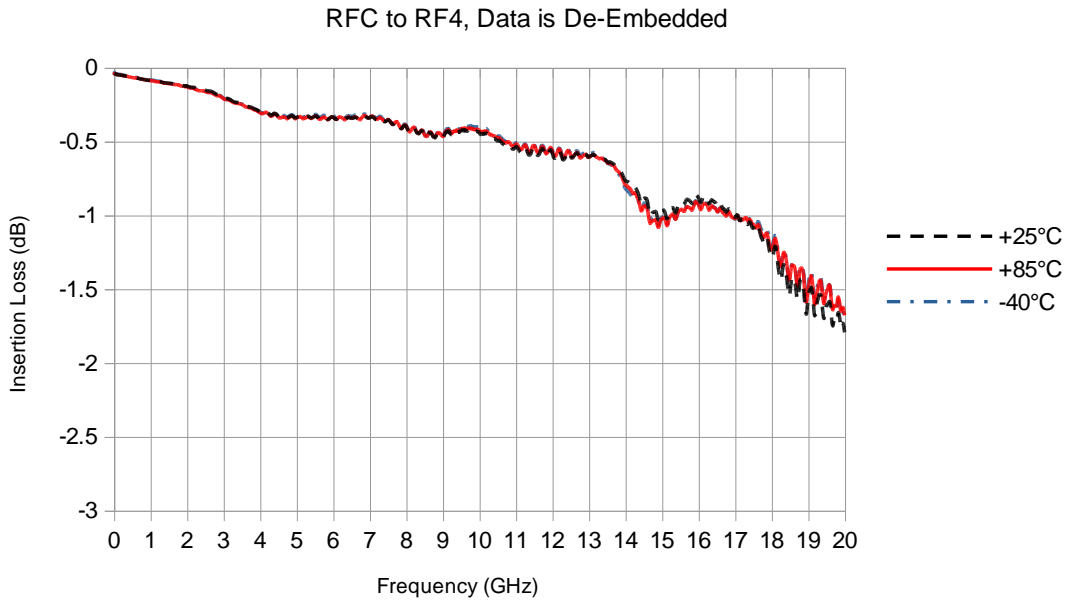
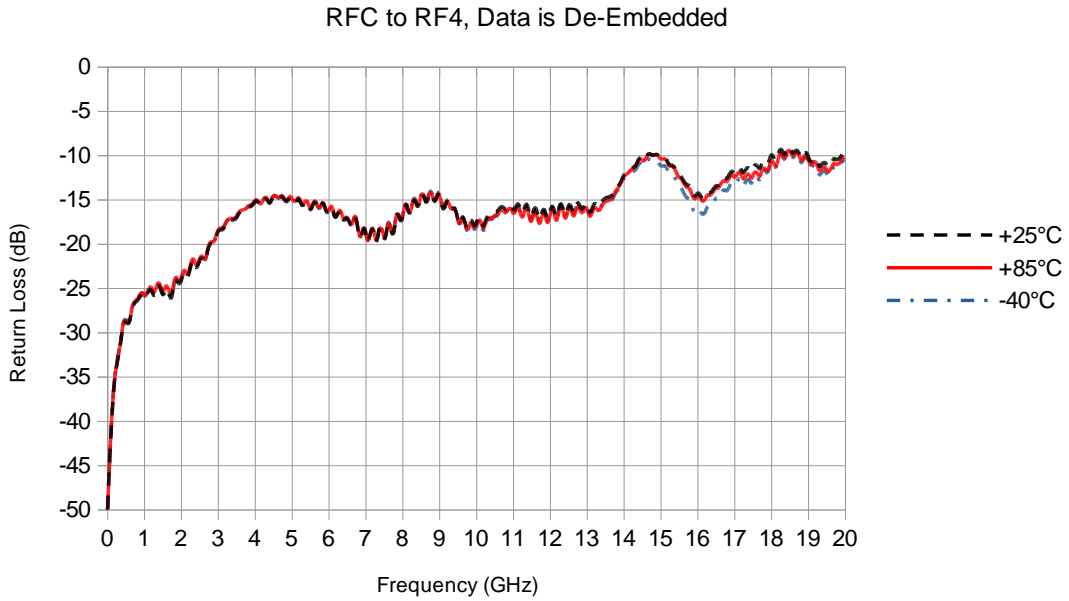
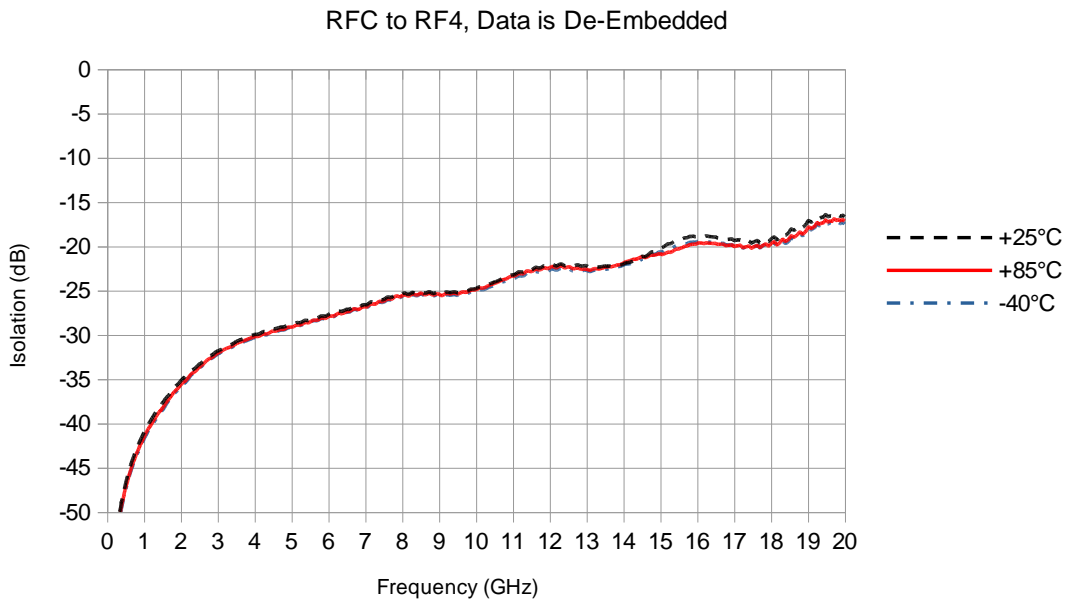


Figure 8. Insertion Loss / S21 vs. Temperature

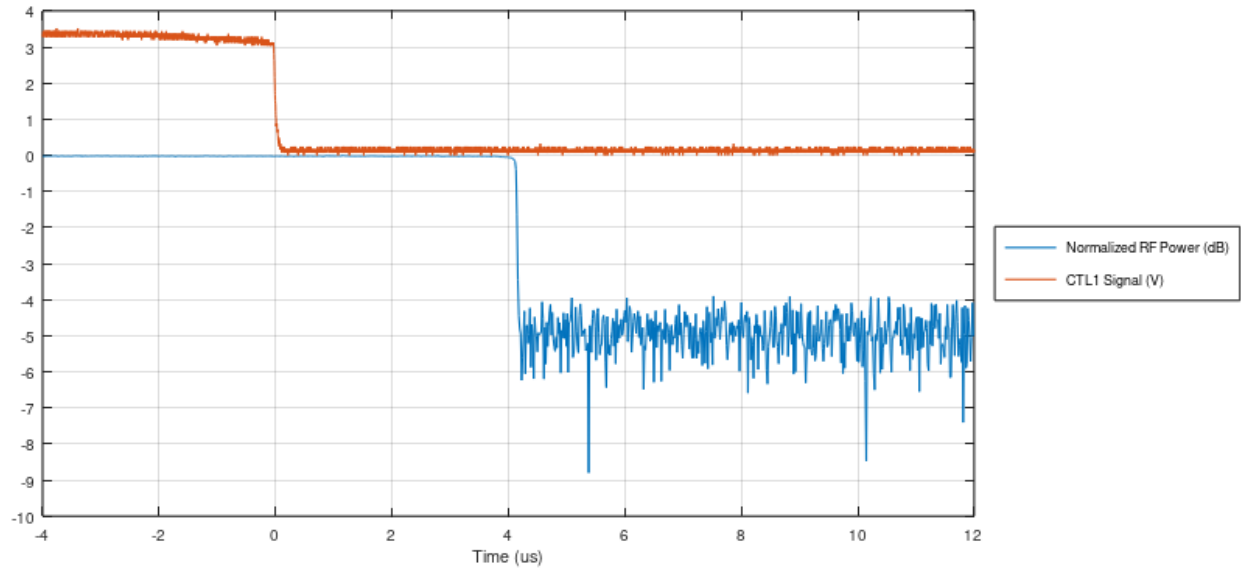


**Figure 9. Return Loss / S11 vs. Temperature**

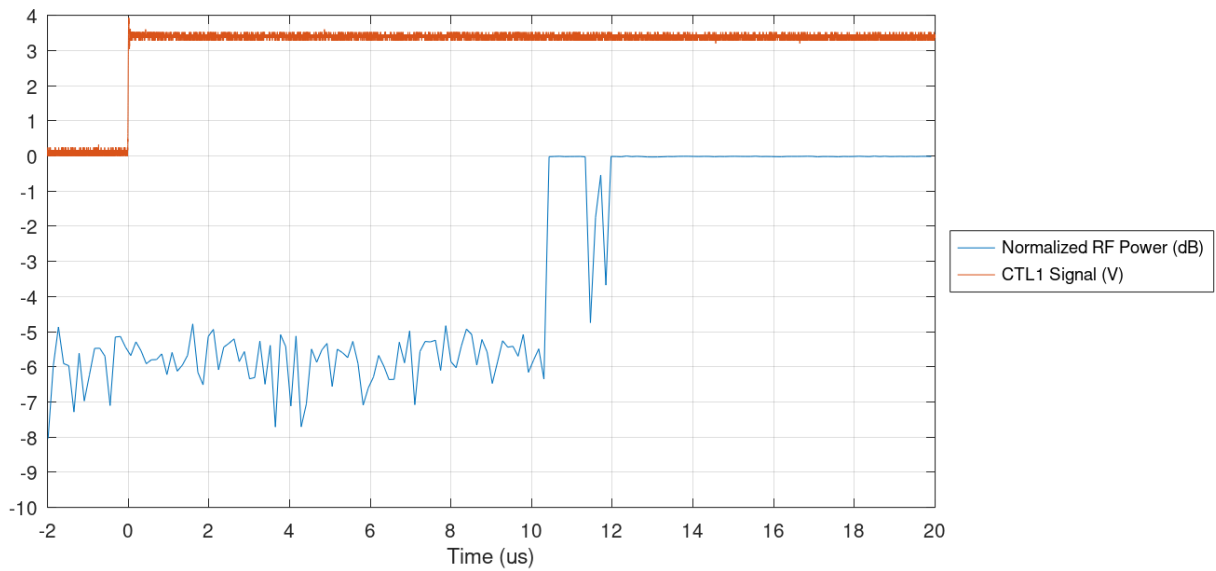


**Figure 10. Off-State Isolation vs. S21 vs. Temperature**

## On / Off Switching Time



**Figure 11. RF Off Switching Time (GPIO Mode)**

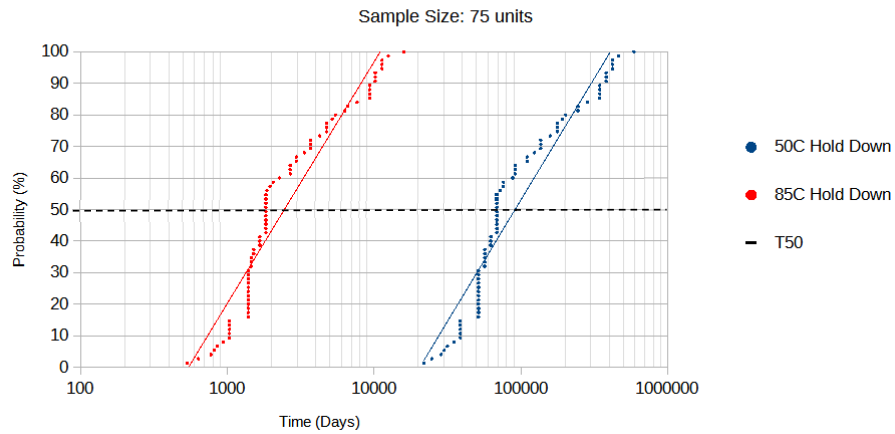


**Figure 12. RF On Switching Time (GPIO Mode)**

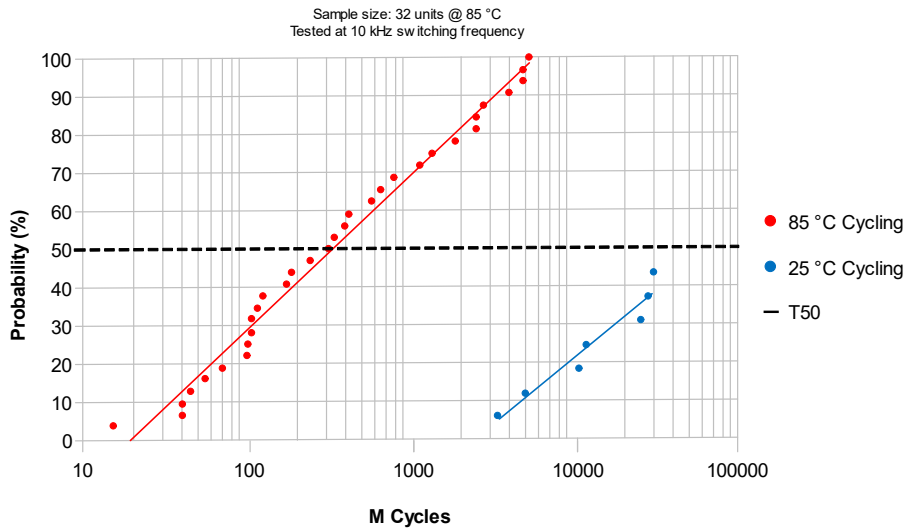
## Switch Reliability

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) @ 50°C and >1800 days (>4.9 years) @ 85°C. 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°C and 320 million cycles @ 85°C.



**Figure 13. Hold Down: Days to Failure**



**Figure 14. Cycling: M Cycles to Failure<sup>1</sup>**

**Notes:**

1. Failure definition is stuck closed failure.

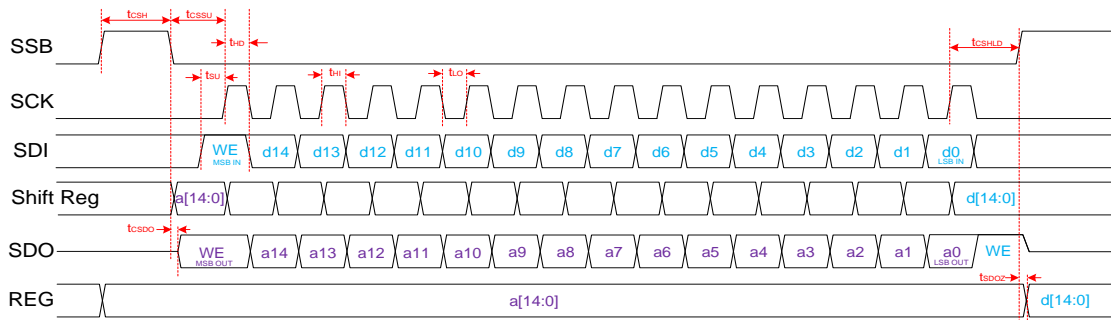
# Programming

## Communication Interface

The driver interface has two modes of operation, SPI and GPIO, selected by the MODE input pin.

All the SPI pins except the SSB and the MODE pin have an internal pull-down resistor to ensure that no digital input pins can float.

The SSB pin has a pull-up current source in SPI mode. This ensures that the IC defaults to a disabled state in SPI mode. In GPIO mode, this pin is CTL4. In this case, the SSB pin has a pull-down resistor. This ensures that the input is low by default in GPIO mode.



**Figure 15. SPI Timing Diagram**

## SPI Communication

MODE = 0, activates the 16-Bit Serial Peripheral Interface (SPI) module for operation. Multiple devices can be daisy-chained to drive multiple ICs using one SPI bus. In [Daisy Chain Operation](#) see [Figure 18](#), [Figure 19](#), and [Figure 20](#).

The SPI works at any frequency up to a maximum of 33 MHz and may operate at significantly lower frequencies if the logic signals adhere to the data setup and hold requirements.

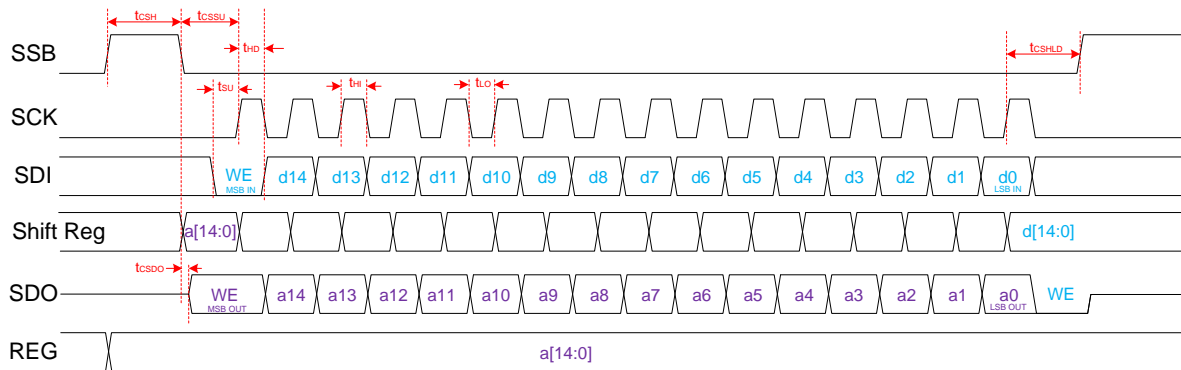
## SPI Interface Mode

SPI timing diagrams are provided in [Figure 15](#) through [Figure 20](#). In SPI mode, data transmission starts when SSB goes Low, causing the Target to output the Most Significant Bit (MSB) of data to the SDO (MISO) pin. Data transfer from Host to Target takes place during the rising edge of the clock (SCK), which is idle when SSB is High. This mode of operation requires data for Host and Target to be present on SDI (MOSI) before the rising edge of the clock (defining SDI to SCK setup time). Data is pushed out of the SDO (MISO) pin during the falling edge of the clock. After the first 16-bit transaction, Host writes the latest data (DN) to

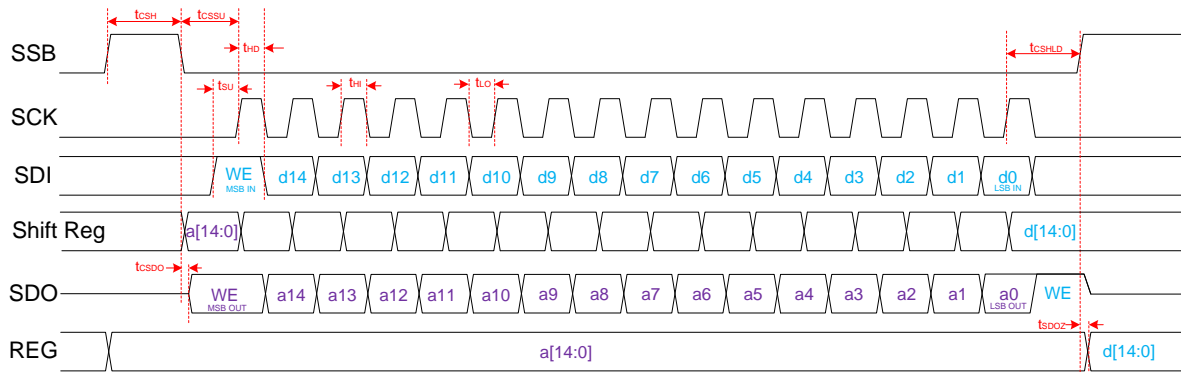
the Target, while the Target passes its previous (DN-1) stored data to the Host. Data is latched into the internal registers at the rising edge of SSB, if  $WR\_EN = 1$ .

## SPI Data Format

SPI data is sent in a 16-bit format. The first MSB bit (WE), if high, enables the Write mode. The following 7 MSB bits hold the Control and Fault Status bits. The 8 LSB bits hold the Switch State bits.



**Figure 16. SPI Read Only (1 IC, No Daisy Chain)**



**Figure 17. SPI Read & Write (1 IC, No Daisy Chain)**

## SPI Control Registers

The SPI interface provides access to two 8-bit Internal Registers: Register STATE and Register CONTROL that are Read/Write registers. Register data is read by toggling SSB low and monitoring the data at the MISO pin while clocking the SCK pin.

Register STATE holds the state of the 4 switches and is updated when SSB goes from LOW to HIGH if the Write Enable bit is high. Register CONTROL holds four control bits (CPEN, VPPCOMP, FLT\_MODE, and SLEEP), and the fault status bit (FSTAT). The MSB bit enables the Write mode if high.

In SPI mode, the CP\_EN and FLT\_MODE pins are ignored. Settings in the CONTROL register are used instead. The first row of the register tables below shows the read/write type, and default state. At power-on-reset (POR), all bits in both registers are set to LOW internally.

### State Register

|         |         |         |         |         |         |         |         |
|---------|---------|---------|---------|---------|---------|---------|---------|
| R/W - 0 | R/W - 0 | R/W - 0 | R/W - 0 | R/W - 0 | R/W - 0 | R/W - 0 | R/W - 0 |
| 0       | 0       | 0       | 0       | RF4     | RF3     | RF2     | RF1     |
| bit 7   |         |         |         |         |         |         | bit 0   |

bit 7: **Low:**

Set this bit low.

bit 6: **Low**

Set this bit low.

bit 5: **Low**

Set this bit low.

bit 4: **Low**

Set this bit low.

bit 3: **RF4**

1 = RFC to RF4 is enabled

0 = RFC to RF4 is disabled

bit 2: **RF3**

1 = RFC to RF3 is enabled

0 = RFC to RF3 is disabled

bit 1: **RF2**

1 = RFC to RF2 is enabled

0 = RFC to RF2 is disabled

bit 0: **RF1**

1 = RFC to RF1 is enabled

0 = RFC to RF1 is disabled



## Control Register

|         |         |         |         |         |         |         |         |
|---------|---------|---------|---------|---------|---------|---------|---------|
| R/W - 0 | R/W - 0 | R/W - 0 | R/W - 0 | R/W - 0 | R/W - 0 | R/W - 0 | R/W - 0 |
| WR_EN   | FSTAT   | SLEEP   | FLTMODE | VPPCOMP | X       | CPEN    | X       |
| bit 7   |         |         |         |         |         |         | bit 0   |

**bit 7: WR\_EN**

- 1 = Enable write mode
- 0 = Disable Write mode (read only)

**bit 6: FSTAT** (see Note 1 below)

- 1 = VPP OR VDD Fault status = faulted
- 0 = VPP OR VDD Fault status = NOT faulted

**bit 5: SLEEP**

- 1 = SLEEP mode active (all analog circuits disabled)
- 0 = SLEEP mode inactive (all analog circuits enabled)

**bit 4: FLTMODE**

- 1 = Fault Mode Disabled (shutdown Disabled)
- 0 = Fault Mode Enabled (shutdown Enabled)

**bit 3: VPPCOMP**

- 1 = VPP under-voltage comparator is disabled
- 0 = VPP under-voltage comparator is active

**bit 2: Do Not Care**

This bit can be set to either state without effecting performance.

**bit 1: CPEN**

- 1 = Charge Pump is enabled
- 0 = Charge Pump is disabled

**bit 0: Do Not Care**

This bit can be set to either state without effecting performance.

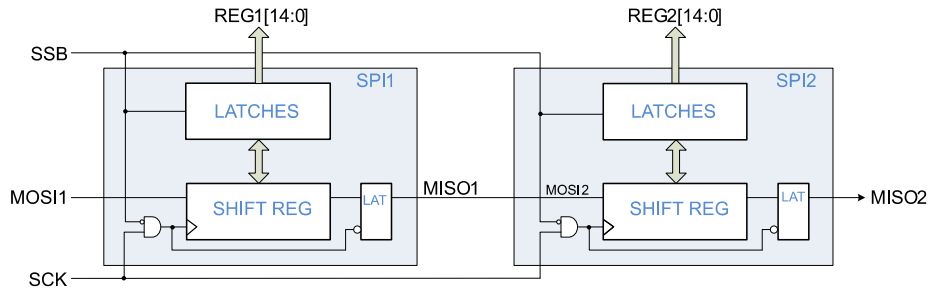
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**Notes:**

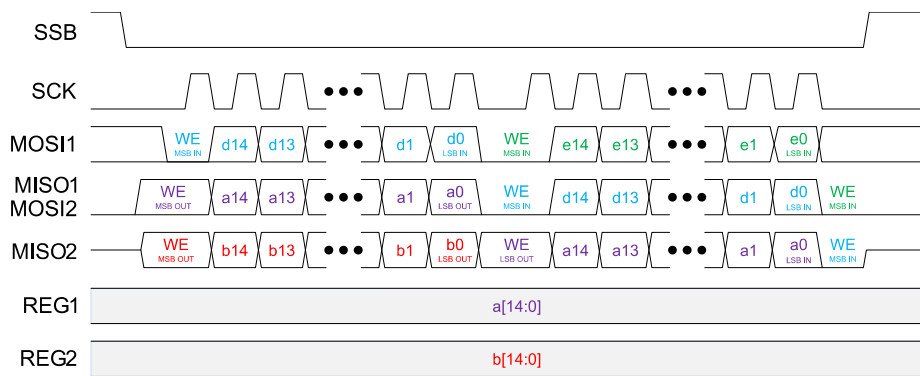
1. After this bit is set high, it must be written to 0 to clear the fault. If fault mode is enabled, CPEN must be toggled to restart the charge pump. See [Fault Conditions](#) for more information.
-

## Daisy Chain Operation

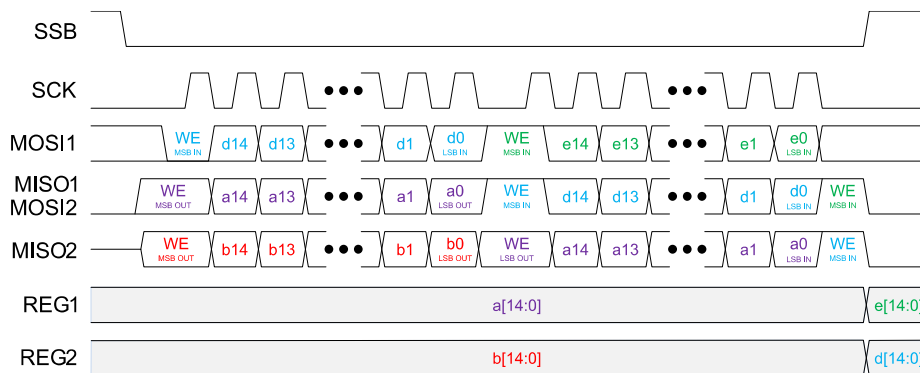
Daisy chaining the ICs is permitted and involves connecting the MISO of one chip to the MOSI of the next chip in the chain, as shown in [Figure 18](#). SPI timing diagrams with daisy-chained devices are provided in [Figure 19](#) and [Figure 20](#).



**Figure 18. SPI with Two ICs Daisy-chained**



**Figure 19. SPI Read Only (Two ICs Daisy-chained)**



**Figure 20. SPI Read & Write (Two ICs Daisy-chained)**

## GPIO Communication

MODE = 1 activates the GPIO (General Purpose Input Output or Parallel Mode) Communication Mode. In this mode of operation, the SPI Interface pins act as parallel inputs.

**Table 8. Switch State Table in GPIO Mode**

| #  | FLIP_BIT | CTL4 | CTL3 | CTL2 | CTL1 | RF4       | RF3       | RF2       | RF1       |
|----|----------|------|------|------|------|-----------|-----------|-----------|-----------|
| 0  | 1        | 0    | 0    | 0    | 0    | OFF       | OFF       | OFF       | OFF       |
| 1  | 1        | 0    | 0    | 0    | 1    | OFF       | OFF       | OFF       | <b>ON</b> |
| 2  | 1        | 0    | 0    | 1    | 0    | OFF       | OFF       | <b>ON</b> | OFF       |
| 3  | 1        | 0    | 0    | 1    | 1    | OFF       | <b>ON</b> | OFF       | OFF       |
| 4  | 1        | 0    | 1    | 0    | 0    | <b>ON</b> | OFF       | OFF       | OFF       |
| 5  | 1        | 0    | 1    | 0    | 1    | OFF       | OFF       | OFF       | OFF       |
| 6  | 1        | 0    | 1    | 1    | 0    | OFF       | OFF       | OFF       | OFF       |
| 7  | 1        | 0    | 1    | 1    | 1    | OFF       | OFF       | OFF       | OFF       |
| 8  | 1        | 1    | 0    | 0    | 0    | OFF       | OFF       | OFF       | OFF       |
| 9  | 1        | 1    | 0    | 0    | 1    | <b>ON</b> | OFF       | OFF       | <b>ON</b> |
| 10 | 1        | 1    | 0    | 1    | 0    | OFF       | <b>ON</b> | <b>ON</b> | OFF       |
| 11 | 1        | 1    | 0    | 1    | 1    | <b>ON</b> | OFF       | <b>ON</b> | OFF       |
| 12 | 1        | 1    | 1    | 0    | 0    | <b>ON</b> | OFF       | <b>ON</b> | OFF       |
| 13 | 1        | 1    | 1    | 0    | 1    | <b>ON</b> | OFF       | <b>ON</b> | OFF       |
| 14 | 1        | 1    | 1    | 1    | 0    | OFF       | <b>ON</b> | OFF       | <b>ON</b> |
| 15 | 1        | 1    | 1    | 1    | 1    | OFF       | OFF       | OFF       | OFF       |
| 16 | 0        | 0    | 0    | 0    | 0    | OFF       | OFF       | OFF       | OFF       |
| 17 | 0        | 0    | 0    | 0    | 1    | OFF       | OFF       | OFF       | <b>ON</b> |
| 18 | 0        | 0    | 0    | 1    | 0    | OFF       | OFF       | <b>ON</b> | OFF       |
| 19 | 0        | 0    | 0    | 1    | 1    | OFF       | OFF       | <b>ON</b> | <b>ON</b> |
| 20 | 0        | 0    | 1    | 0    | 0    | OFF       | <b>ON</b> | OFF       | OFF       |
| 21 | 0        | 0    | 1    | 0    | 1    | OFF       | <b>ON</b> | OFF       | <b>ON</b> |
| 22 | 0        | 0    | 1    | 1    | 0    | OFF       | <b>ON</b> | <b>ON</b> | OFF       |

| #         | FLIP_BIT | CTL4 | CTL3 | CTL2 | CTL1 | RF4       | RF3       | RF2       | RF1       |
|-----------|----------|------|------|------|------|-----------|-----------|-----------|-----------|
| <b>23</b> | 0        | 0    | 1    | 1    | 1    | OFF       | <b>ON</b> | <b>ON</b> | <b>ON</b> |
| <b>24</b> | 0        | 1    | 0    | 0    | 0    | <b>ON</b> | OFF       | OFF       | OFF       |
| <b>25</b> | 0        | 1    | 0    | 0    | 1    | <b>ON</b> | OFF       | OFF       | <b>ON</b> |
| <b>26</b> | 0        | 1    | 0    | 1    | 0    | <b>ON</b> | OFF       | <b>ON</b> | OFF       |
| <b>27</b> | 0        | 1    | 0    | 1    | 1    | <b>ON</b> | OFF       | <b>ON</b> | <b>ON</b> |
| <b>28</b> | 0        | 1    | 1    | 0    | 0    | <b>ON</b> | <b>ON</b> | OFF       | OFF       |
| <b>29</b> | 0        | 1    | 1    | 0    | 1    | <b>ON</b> | <b>ON</b> | OFF       | <b>ON</b> |
| <b>30</b> | 0        | 1    | 1    | 1    | 0    | <b>ON</b> | <b>ON</b> | <b>ON</b> | OFF       |
| <b>31</b> | 0        | 1    | 1    | 1    | 1    | <b>ON</b> | <b>ON</b> | <b>ON</b> | <b>ON</b> |

## Fault Conditions

There are two comparators that can signal a fault condition - VDD under voltage fault and VPP under voltage fault. Faults are reported differently depending on the mode of communication - SPI or GPIO.

---

**Note:** The VPP under voltage comparator can be disabled. In SPI mode, it is disabled when the VPPCOMP bit in the CONTROL register is high. In GPIO mode, the comparator is disabled when CP\_EN pin is set low.

---

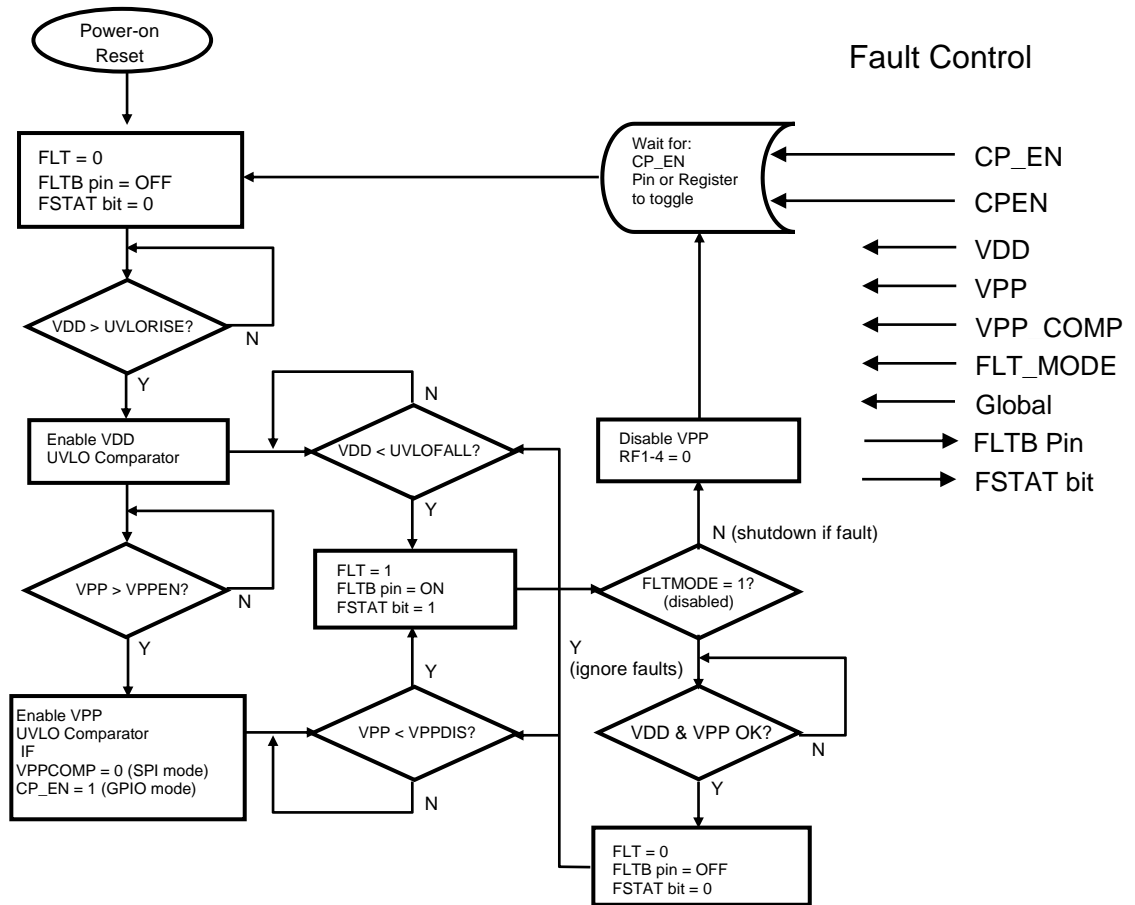
The outputs of the VDD and VPP fault comparators are logically OR'ed. The output of the OR gate controls the FLTB pin. FLTB is an open-drain output and is ON (low impedance) if either fault is detected. In SPI mode, bit 6 of the CONTROL register provides VDD and VPP fault status.

At start-up, the FLTB pin is held OFF (high impedance). It is allowed to change state only after each voltage goes past its Enable threshold (VDD goes higher than  $UVLO_{RISE}$  and VPP goes higher than  $V_{EN}$ ). This prevents a race condition at startup.

Once VDD and VPP go above their thresholds, the comparators monitoring VDD and VPP actively monitor for faults. If VDD goes below  $UVLO_{FALL}$  or VPP goes below  $VPP_{DIS}$ , a fault condition is signaled by setting the FLTB pin low and the Fault Status bit high (bit 6 in the CONTROL register). The FLTB pin returns to an open state when the fault condition is cleared – the FSTAT bit remains latched high until it is cleared via a SPI write.

If Fault Mode is enabled (in GPIO mode, FLT\_MODE pin = 0, in SPI mode, FLT\_MODE bit = 0), the outputs are all set low and the charge pump is turned off. The user must toggle the CP\_EN pin (GPIO mode) or the CPEN register bit (SPI mode) low and then high to re-start the device.

If Fault Mode is disabled (in GPIO mode, FLT\_MODE pin = 1; in SPI mode, FLT\_MODE bit = 1), no action is taken by the IC. The fault condition is reported but does not affect the charge pump operation or switch states.



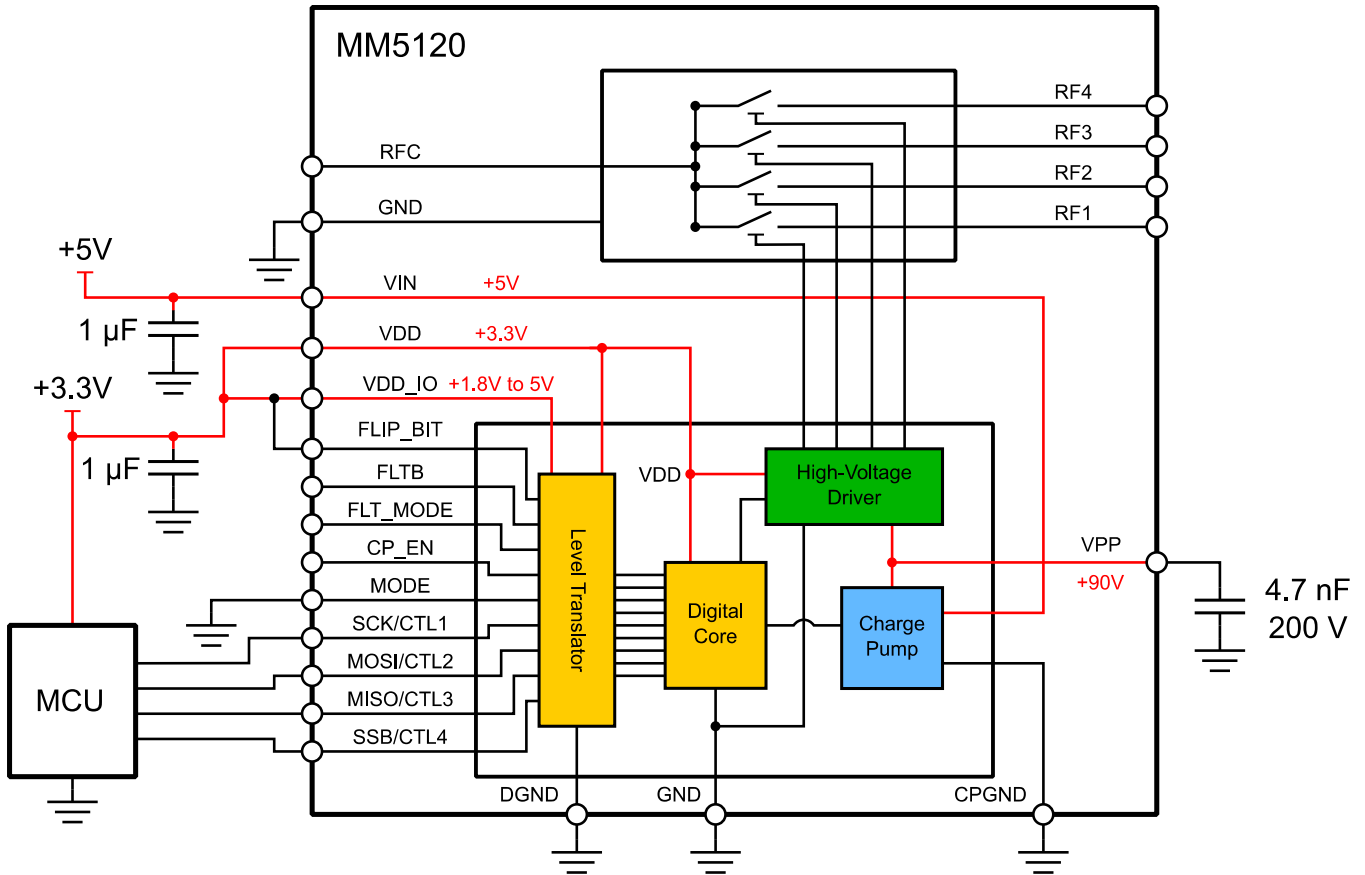
**Figure 21. Flowchart for Fault**

**Notes:**

1. The un-faulted supply continues to be monitored when a fault occurs. The FLT signal remains faulted until both supplies are above their brownout trip level.
2. VDD\_IO is not monitored unless it is connected to VDD.
3. VPP is not monitored if: VPPCOMP = 1 in SPI mode OR the CP\_EN pin is low In GPIO mode.

## External Circuitry

The MM5120's internal driver requires external circuitry to operate its charge pump. The diagram below shows the suggested bypass capacitors that have been used with good results. Menlo Micro recommends selecting components with equal or better performance.

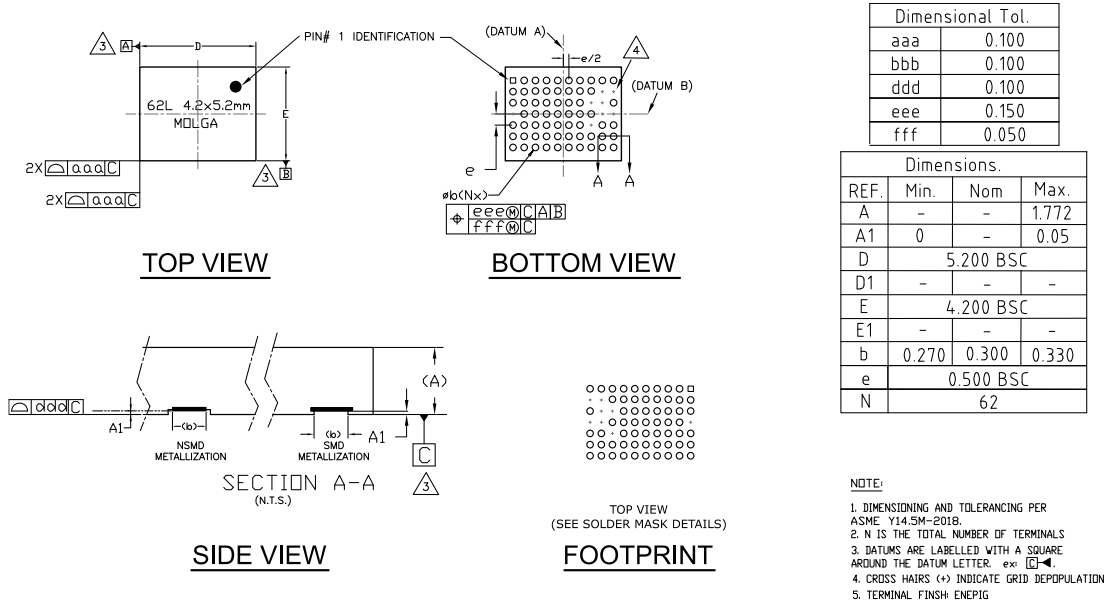


**Figure 22. MM5120 Application Diagram**

## Package Drawing

### 62 Pin LGA Package

Dimensions are given in millimeters.

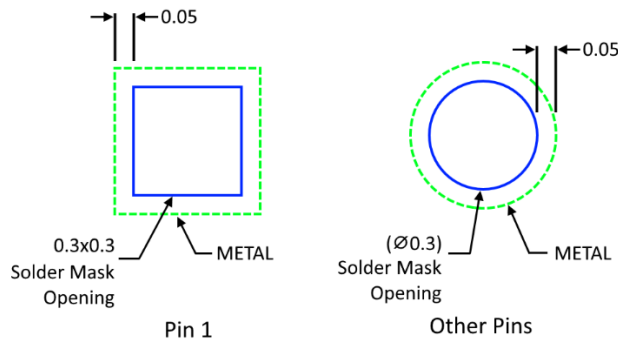


**Figure 23. Package Drawing**

The pin array is located symmetrically on the package body as specified in JEDEC Design Guide 4.25B for JEDEC LGA. An exception to JEDEC LGA guidelines is made for the letter axis and number axis. See Figure 2.

### Solder Mask Details

Dimensions are given in millimeters.



**Figure 24. Solder Mask Details**



## Recommended PCB Layout and SMT Parameters

- Use solder mask defined pads to allow a solid grounding plane under the part. See [Figure 24](#) for recommended solder mask opening.
- Open space around the package can have grounded through holes.
- Use Type 5 solder paste.

[Figure 25](#) below shows an example layout. This example uses a Rogers 4350b core with a thickness of 254 microns. 50 $\Omega$  coplanar waveguide transmission lines are used to route the RF, with a trace thickness of 383 microns, and ground spacing of 152 microns.

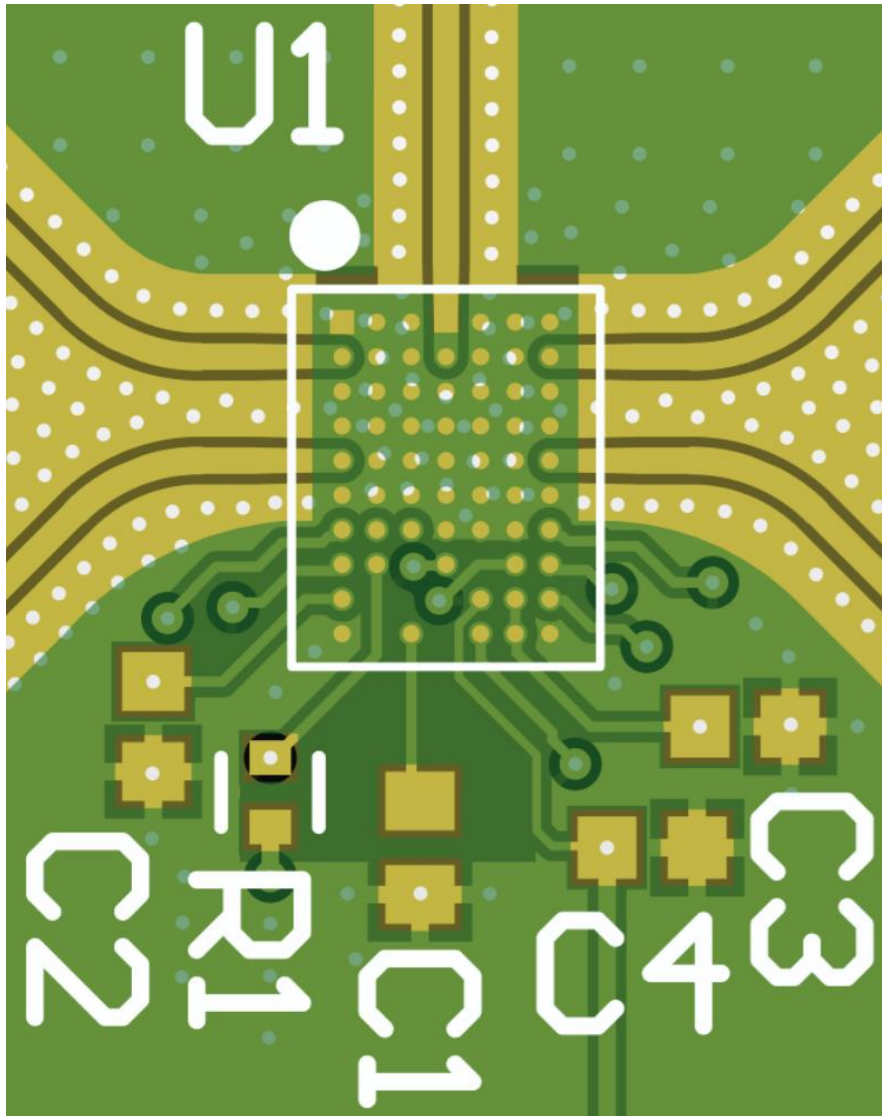
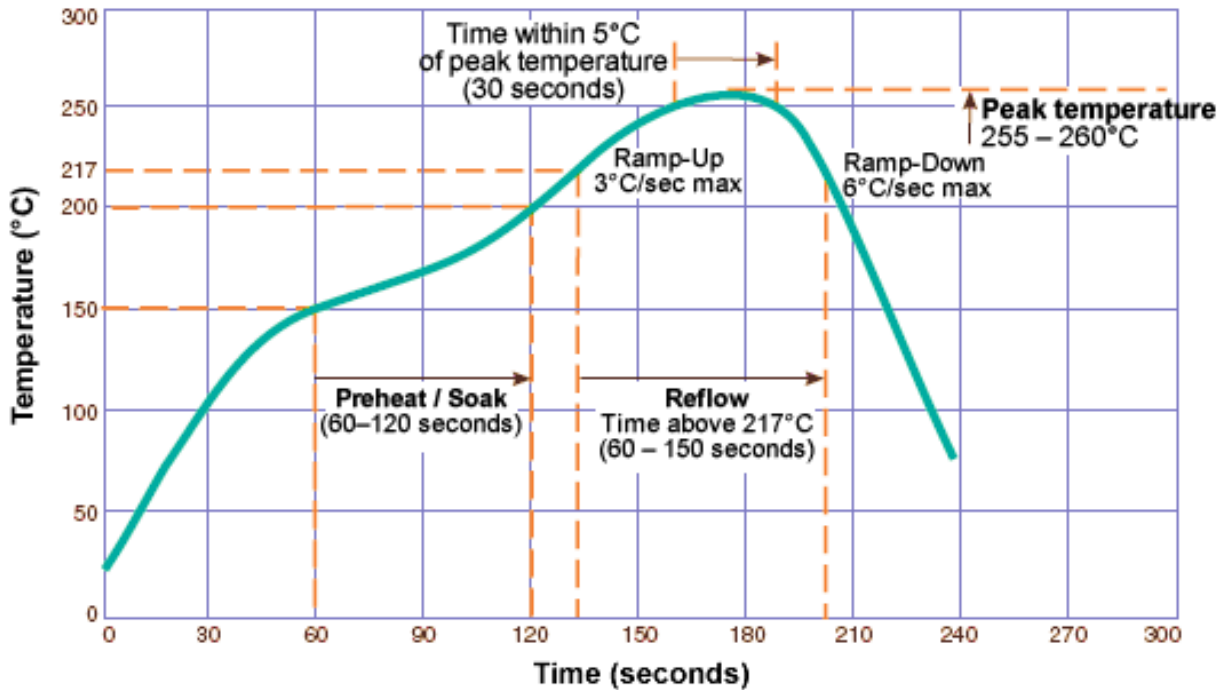


Figure 25. Example PCB Layout

## Recommended Solder Reflow Profile



**Figure 26. Recommended 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.

Follow Moisture Sensitivity Level (MSL) 3 handling precautions specified in IPC/JEDEC J-STD-020.<sup>1</sup>

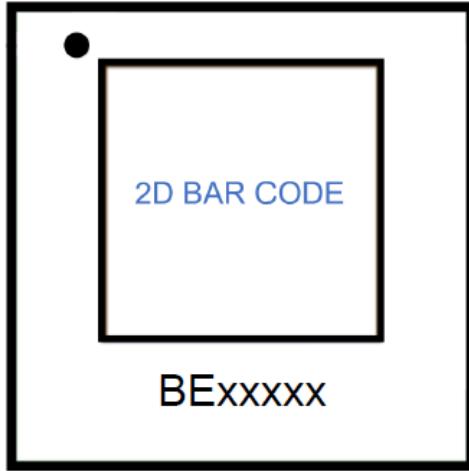
## Storage and Shelf Life

Under typical industry storage conditions (  $\leq 30$  °C/60% RH ) in Moisture Barrier Bags the following is 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.

<sup>1</sup> Parts labeled prior to July 13th, 2023 may be labeled as MSL 4 rating based on rating at the time of manufacturing/packaging.

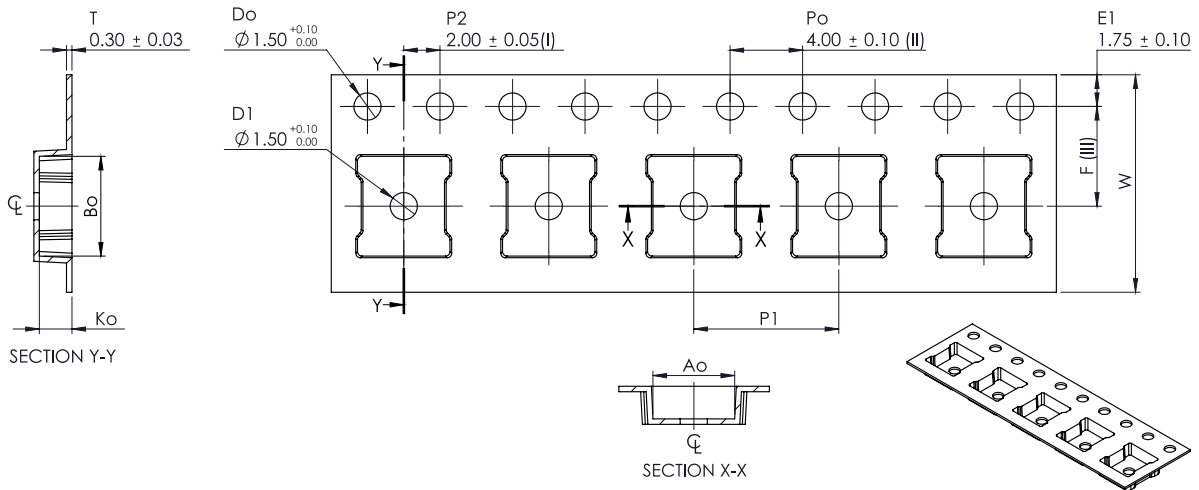
## Package Marking Information



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

Figure 27. Package Marking Drawing

## Package Materials Information



|    |       |               |
|----|-------|---------------|
| Ao | 4.50  | +/- 0.10      |
| Bo | 5.50  | +/- 0.10      |
| Ko | 1.80  | +/- 0.10      |
| F  | 5.50  | +/- 0.05      |
| P1 | 8.00  | +/- 0.10      |
| W  | 12.00 | +0.30 / -0.10 |

- (I) Measured from centreline of sprocket hole to centreline of pocket.
- (II) Cumulative tolerance of 10 sprocket holes is  $\pm 0.20$ .
- (III) Measured from centreline of sprocket hole to centreline of pocket.
- (IV) Other material available.
- (V) Dimension with ( ) is used for design reference purposes. No measurement required.

ALL DIMENSIONS IN MILLIMETRES UNLESS OTHERWISE STATED.

Figure 28. Tape and Reel Drawing

## Package Options and Ordering Information

All Menlo Micro solutions are EAR99 compliant.

| Part Number            | Package Description   | Temp Range     | Device Marking <sup>1</sup> |
|------------------------|---|----------------|-----------------------------|
| <b>MM5120-01NDB</b>    | DC-18GHz - SP4T - 5mm x 4mm LGA, Industrial Temp                          | -40°C to +85°C | BExxxxx                     |
| <b>MM5120-01NDB-TR</b> | DC-18GHz - SP4T - 5mm x 4mm LGA, Industrial Temp, Tape and Reel (Qty 250) | -40°C to +85°C | BExxxxx                     |
| <b>MM5120EVK1</b>      | Evaluation board for MM5120 DC-18GHz - SP4T - 5mm x 4mm LGA               |                |                             |

**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.

| Legacy Product    | New Product Name    |                            |
|-------------------|---------------------|----------------------------|
| Name              | Bulk                | Tape and Reel <sup>1</sup> |
| <b>MM5120-01C</b> | <b>MM5120-01NDB</b> | <b>MM5120-01NDB-TR</b>     |

**Notes:**

1. 250pcs standard tape and reel increment.

## Important Information

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For product technical questions and application information: [support@menlomicro.com](mailto:support@menlomicro.com).