

SX1308 Thermal Dissipation: Technical Analysis and Recommendations

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1. SX1308 Thermal Properties

In Section 2.1 “Absolute Maximum Ratings” of the SX1308 datasheet [1], the absolute maximum rating of the junction temperature is stated as follows:

Table 1: Absolute Maximum Ratings of the Junction Temperature for SX1308

Parameter	Symbol	Value		Unit
		Min	Max	
Junction temperature	$T_{J,ABS\text{MAX}}$	-40	125	°C

The junction temperature “ $T_{J,ABS\text{MAX}}$ ” corresponds to the absolute maximum junction temperature, calculated from the ambient temperature. This is the maximum temperature that the device tolerates to guarantee reliable operation.

We always need to ensure that the operating junction temperature is below “ $T_{J,ABS\text{MAX}}$ ” to prevent reliability issue or permanent device failure. Here, the SX1308 operating junction temperature must always be below 125 °C.

In Section 2.3 “Operating Conditions” of the SX1308 datasheet [1], it is specified that the SX1308 chip can operate up to 70 °C ambient temperature only if the following recommendation is applied : “with chip paddle soldered to PCB ground plane with minimum 100 cm² air exposed area and heat sink”:

Table 2: Operating Conditions for SX1308

Parameter	Symbol	Conditions	Value		Unit
			Min	Max	
Ambient operating temperature	T_A	with chip paddle soldered to PCB ground plane with minimum 100 cm ² air exposed area and heat sink	0	70	°C

In addition, the thermal simulation properties of the SX1308 (QFN 64L 9x9 mm with exposed pad) as mounted using JEDEC 4-layer (2s2p) PCB with dimensions 31 mm x 73 mm are the following:

Table 3: Thermal Simulation Properties of the SX1308

Parameter	Symbol	Conditions	Value	Unit
			[PCB with 36 vias on a 6x6 grid]	
Junction-to-ambient thermal resistance at still air	Θ_{JA}	at 25°C ambient temperature	22.6	°C/W
Junction-to-ambient thermal resistance at still air	Θ_{JA}	at 70°C ambient temperature	20.6	°C/W

2. SX1308 Junction Temperature Calculation

The junction temperature is defined by the following formula:

$$T_J = T_A + (\Theta_{JA} \times P)$$

where

T_J = Junction temperature,

T_A = Ambient temperature,

P = Power dissipation in Watts,

Θ_{JA} = Thermal resistance from junction to ambient, measured as °C/W. Ambient is regarded as thermal "ground." Θ_{JA} depends on the package, board, airflow, radiation, and system characteristics.

Generally, the effects of radiation are negligible. Θ_{JA} values are listed for natural convection conditions (no forced air) only.

$$\text{SX1308 } P_{\text{max}} = 1.8 \text{ V} * 800 \text{ mA} + 3.3 \text{ V} * 10 \text{ mA} = 1.473 \text{ W}$$

From the SX1308 package simulation:

$$\Theta_{JA} = 22.6 \text{ }^\circ\text{C/W at } 25 \text{ }^\circ\text{C}$$

$$\Theta_{JA} = 20.6 \text{ }^\circ\text{C/W at } 70 \text{ }^\circ\text{C}$$

Both values are obtained with a natural convection on a PCB size of 31 mm x 73 mm x 1.6 mm.

This is the actual size of Semtech PicoCell GW reference design, for which:

$$T_{J,\text{MAX}} = 70 + (20.6 * 1.473) = 100.3 \text{ }^\circ\text{C}$$

This result is lower than the allowed $T_{J,\text{ABS MAX}} = 125 \text{ }^\circ\text{C}$

3. Practical Implementation and Measurements

The recommendation of a 100 cm² PCB size area from the SX1308 datasheet [1] comes from the simulation of the package heating dissipation, not from real measurements and seems most of the time quite unrealistic to achieve.

In a practical situation, we need to ensure that the SX1308 junction temperature is always less than 125 °C (maximum junction temperature) inside its housing when the PicoCell Gateway is running at the maximum ambient temperature of its application.

We strongly recommend mounting a heat sink on both top and bottom faces of the SX1308 chip for safe operation in all conditions. The energy dissipated is quite high. Keep in mind that the SX1308 chip can remain 100% of the time at 100% of clock speed and activity. The PicoCell GW is not a low-power device that only ramps up the clock from time to time, while absolute maximum ratings are for short term only.

We selected the Mini Aluminum Heat Sink for Raspberry Pi - 13 x 13 x 3 mm / 0.5" x 0.5" x 0.1" (product ID: Adafruit Industries LLC 3084) for our Semtech reference design :

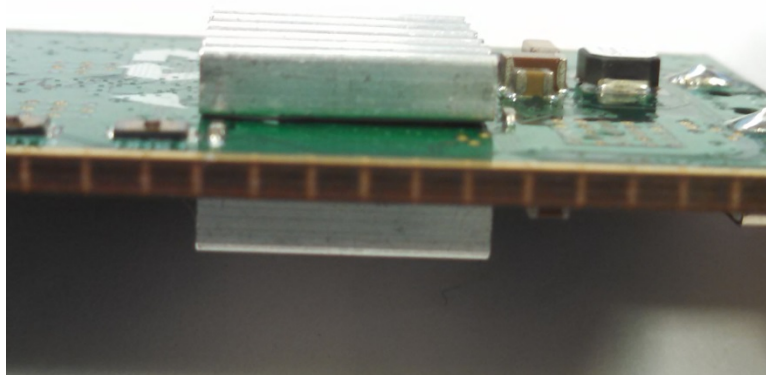


Figure 1: Heat Sink on Top and Bottom of SX1308 – Side View

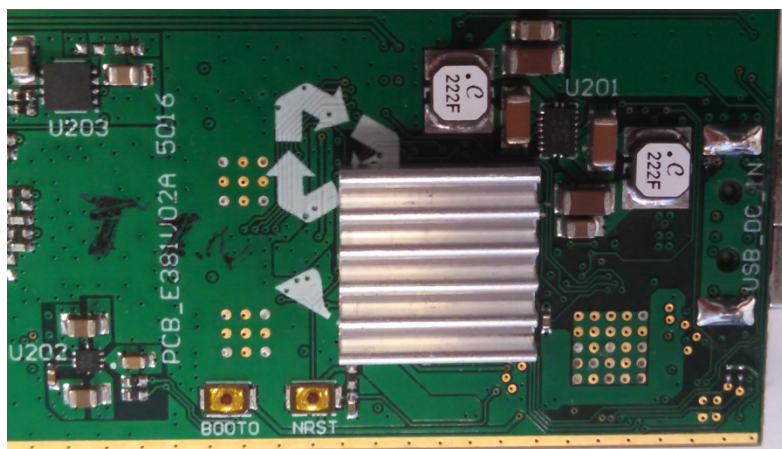


Figure 2: Heat Sink on Top and Bottom of SX1308 – Bottom View

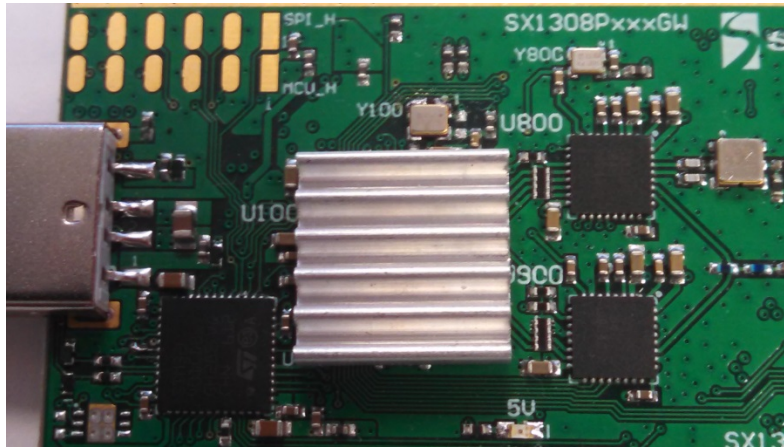


Figure 3: Heat Sink on Top and Bottom of SX1308 – Top View

Measurements Results:

- **For the SX1308 PicoCell GW without housing and without heat sink** at room temperature (25 °C), measured with a thermo-detector Bosch PTD:
72 °C on top and bottom surfaces of SX1308 after 24 hours of operation in normal mode (i.e. packet_forwarder mode)
- **For the SX1308 PicoCell GW without housing and with heat sink** on both top and bottom of SX1308 at room temperature (25 °C), measured with the same apparatus:
63.0 °C on both heat sinks, top and bottom, after 24 hours of operation in normal mode (i.e. packet_forwarder mode).

Finally, the influence of the heat sink results in a 10 °C lower surface temperature.

Measurements for the PicoCell GW inside its metal alloy housing:

The measurement was 55 °C on top of the housing after 24 hours of operating in normal mode (i.e. packet_forwarder mode) at 25 °C ambient temperature. Assuming that the temperature inside the housing is of the same order as the housing top temperature, we would then recommend limiting the ambient temperature to 40 °C when the PicoCell GW is mounted in its housing to ensure that the maximum 70 °C ambient temperature, per SX1308 datasheet recommendation [1], inside the housing is not exceeded.

The ambient temperature inside the PicoCell GW housing increases to 70 °C when the external ambient temperature is 40 °C.

The SX1308 top surface temperature will then increase to 108 °C. Indeed:

63 °C (with heat sink) + 45 °C (ambient temperature rise from 25 °C room temperature to 70 °C) = 108 °C

As a rule of thumb, we can estimate that the die (i.e. junction) temperature is roughly 10 % higher than the top surface temperature.

With a top surface temperature of 108 °C, the SX1308 junction temperature can be estimated to 119 °C at worst. The SX1308 chip is still in a safe operation mode as its maximum operating junction temperature is below 125 °C.

We advise to not exceed 110 °C as the top surface temperature of the SX1308 chip, so as to respect the 125 °C maximum junction temperature limitation.

4. Conclusion

It is strongly recommended to mount a heat sink on both top and bottom faces of the SX1308 chip for safe operation in all conditions. We advise to not exceed 110 °C as the top surface temperature of the SX1308 chip, so as to respect the 125 °C maximum junction temperature limitation.

5. References

- [1] SX1308 datasheet: <http://www.semtech.com/images/datasheet/sx1308.pdf>

6. Revision History

Version	Date	Modifications
1.0	September 2017	First Release



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