

## Cool Down with a Smaller, Lower Power Temperature Sensor

### Introduction

Engineers are constantly designing temperature measurement circuits to support applications over the entire electrical equipment spectrum. A common request across industries for the electrical thermometer is to have the temperature sensing system use smaller packages and lower power. This applies to the circuits of wearable equipment, consumer mobile devices, industrial factory automation and sensors, and field instruments that require these characteristics. And so, the list goes on into numerous industries and systems. The combination of a smaller package and lower power, coupled with reliable communications, brings the silicon thermometer to a new level.



Figure 1. Smartphones Use Remote Temperature Sensors

In this article, you will see how the advancements in packaging technologies, an aggressive attack on power dissipation, and the implementation of SMBus Packet Error Checking bring these three elements together in a single thermometer IC chip. The combination of these three features allows the implementation of multiple thermometer sites across the printed circuit board (PCB) or the entire application site. This is done with minimal PCB real estate or power penalties.

### WLP Package Revolution

Through the years, the evolution of electronic circuit package sizes has moved from the metal can, to the plastic dual-in-line (PDIP), to SOT23 and then smaller ceramic or plastic

encasements. In all packaging situations, the silicon die is encapsulated after the dicing process.

In standard packaging technology, the circuits on a silicon wafer are diced into chip form. Once this process is complete, the individual chips are epoxied to a lead frame and encapsulated inside a plastic or ceramic package.

But given this manufacturing process, the encapsulation process occurs after the wafer circuits are in chip form. A new paradigm might be to encapsulate the entire wafer before the dicing process.

In all paradigm shifts, everything changes, allowing for the next step to be taken. The new revolutionary, integrated circuit package is the wafer-level packaging (WLP). The WLP process adds solder bumps to the integrated circuit, while still in the wafer form. The WLP process allows the manufacturer to provide a product that is closest to the actual die size, which brings the package-thermal theta junction-ambient to an all-time low of 103°C/W. Now die dimensions are the limiting factor in terms of the package size.

Table 1 shows a list of some typical thermometer packages.

**Table 1. A Comparison of the Four Smallest Maxim Digital Out Thermometers**

Device	Package	No. of Pins	Package Dimensions (L x W x H {mm})	PCB Area (mm <sup>2</sup> )
<a href="#">MAX31875</a>	WLP	4	0.87 x 0.87 x 0.35	0.76
<a href="#">MAX6604</a>	TDFN	8	2 x 3 x 0.75	6
<a href="#">MAX31725</a>	μMAX®	8	3 x 3 x 1	9
<a href="#">DS1775</a>	SOT23	5	2.9 x 2.9 x 1.25	9

The [MAX31875](#) low-power I<sup>2</sup>C temperature sensor is available in a WLP package and surpasses the sizing of the other standard thermometer packages. The comparison between a standard

capacitor package (0603) and the WLP product is astounding (Figure 2).

Device	Package	No. of Pins	Package Dimensions (L x W x H {mm})	PCB Area (mm <sup>2</sup> )
MAX31875	WLP	4	0.87 x 0.87 x 0.35	0.76
0.1μF Capacitor	SMT (0603)	2	1.55 x 0.85 x 4.5	1.32

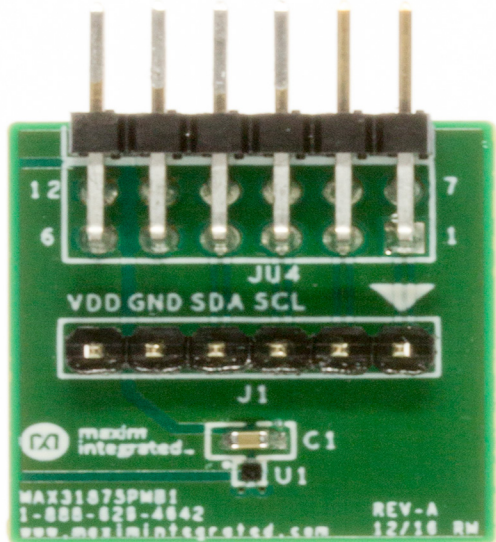


Figure 2. WLP temperature sensor (U1, MAX31875) is smaller than the SMT, 0.1μF capacitor (C1)

### Turn Down the Power

When power is evaluated, start by examining the power supply specifications and then the current demands during operation. Then, multiply these two values to calculate the power dissipation of the product.

The MAX31875 power supply specifications are carefully positioned to operate in battery-powered circuits with a range of 1.6V to 3.6V.

The amount of MAX31875 current generated is calculated under two conversion conditions: automatic continuous or one-shot.

The automatic continuous conversion mode continually creates conversion results. The conversion rate bits (Configuration Register D2:D1) select the rates of 0.25sps, 1sps, 4sps, and 8sps for automatic continuous conversions. In the automatic conversion mode, a conversion is started every 4, 1, 0.25, or 0.125 seconds, and shutdown mode is entered between conversions to reduce average power supply current. The typical MAX31875 producing a 10-bit output at 0.25 conversions per second requires 1.2μA (Figure 3).

In Figure 3, if you have a 10-bit output result at 0.25 conversions per second, using a 1.8V battery power supply, the power dissipation is 2.16μW.

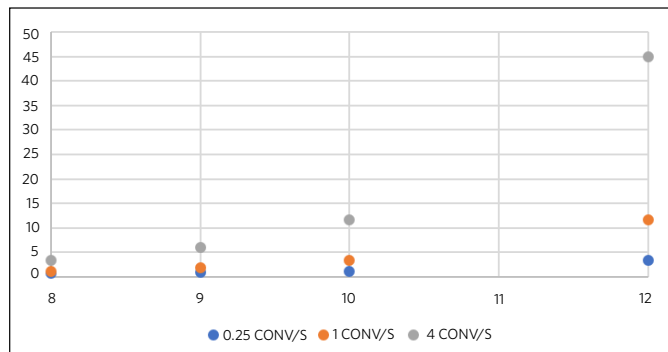


Figure 3. Typical Supply Current (μA) vs. Resolution (bit)

As expected, the maximum supply current versus resolution increases. As a maximum specification, the MAX31875 producing a 10-bit output at 0.25 conversions per second requires 4.3μA (Figure 4).

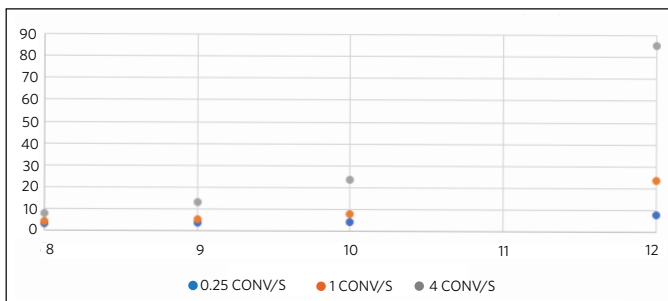


Figure 4. Maximum Supply Current (μA) vs. Resolution (bit)

In Figure 4, if you have a 10-bit output result at 0.25 conversions per second using a 1.8V battery power supply, the power dissipation is 6.45μW.

### Reliability Times Three

The MAX31875 temperature sensor measures temperature using a bandgap cell. Also, embedded in the circuit is a selectable-resolution ΔΣ converter and a conversion oscillator. The MAX31875 transmits converted data through an I<sup>2</sup>C-compatible two-wire serial interface. The data is read and configured through standard I<sup>2</sup>C, SMBus commands.

With the SMBus protocol, you can use the Packet Error Checking feature to improve reliability and communication robustness. A normal transaction requires 2-byte reads and writes. To enable Packet Error Checking, an additional byte must be appended. Packet Error Checking is implemented by appending a Packet Error Code (PEC) at the end of each message transfer. The master receives this code and registers the slave as PEC-compliant.

The other tools that the MAX31875 offers to ensure accurate conversions are a Temperature Threshold (TOS), Temperature Hysteresis (THYST), and Fault Queue.

There are two, two-byte, user-configured temperature threshold registers. These two-byte registers are the TOS and THYST. The TOS register is a maximum user-defined temperature and THYST is a minimum user-defined temperature below TOS. These two registers along with counter bits (Fault Queue) determine the number over temperature events.

The on-chip comparator measures an overtemperature condition and the fault queue defines the number of allowable consecutive overtemperature events.

## Conclusion

Temperature measurement circuits commonly appear in sensor systems ranging from industrial automation to wearable devices. The challenge of these temperature systems is to have a thermometer in a smaller package and with lower power, coupled with reliable communications. The electrical thermometer, MAX31875, is a shoe-in for this type of application with a small WLP housing and extremely low-power performance.

## Glossary Terms

**PDIP:** Plastic dual-inline package

**WLP:** Wafer-level packaging

**PEC:** Packet error code

**TOS:** Temperature threshold

**THYST:** Temperature hysteresis

Learn more:

[MAX31875 Low-Power I<sup>2</sup>C Temperature Sensor in WLP Package](#)

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