

R A Q ' s

Rarely Asked Questions

Strange but true stories from the call logs of Analog Devices

What's Your Amplifier's Febricity Due to Electricity? (or Accurate temperature measurement ... it's all a matter of degree)

Q. What's the best way to measure the die temperature of a small package op amp or similar device?

A. There are a few ways to get at the junction or die temperature of a device, some better than others. The first uses the classic junction temperature equation shown below.

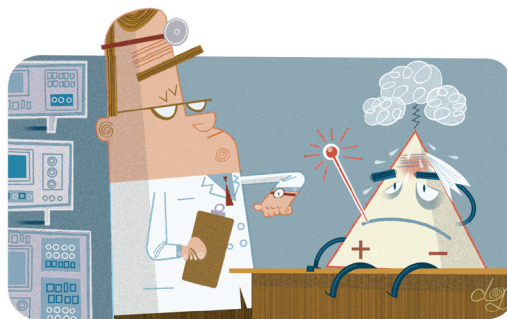
$$T_J = T_A + P_D \theta_{JA}$$

The junction temperature, T_J , is equal to the ambient temperature, T_A , plus the power dissipated by the device, P_D , multiplied by device's thermal resistance, θ_{JA} . In my experience, this calculation is fairly conservative, and yields junction temperatures approximately 30% to 50% higher than the actual junction temperature, depending on the manufacturer.

Another method is to use a thermocouple, which provides good results for larger packages, but has problems when trying to use it on smaller packages. For example, small packages such as the SC70 or SOT do not provide much area to attach a thermocouple. Even if you could attach one to the package, the thermal mass of a thermocouple actually acts as a heat sink, robbing the device of some of its heat and giving an erroneous result.

A third method uses an infrared (IR) camera. This method accurately measures the outside case temperature of a package and gives a good indication of the die temperature on smaller packages. In most cases, the difference between case and junction temperature is only a few degrees. A drawback to this method is IR cameras tend to be rather pricey, costing tens of thousands of dollars.

The last option is the least expensive and most accurate way to measure die temperature by using an on-chip diode as a



temperature sensor. From semiconductor physics, we recall that with a constant current applied to a PN junction, the junction voltage will change approximately -1 to -2 mV/°C over temperature. Characterizing the diode voltage over temperature enables the user to measure the diode voltage and readily determine the die temperature. The trick is finding a diode that can be used as the sensor on the op amp. Most op amps do not provide a dedicated diode for such purposes, but you can re-task existing diodes to perform this task. Most, if not all, of today's amplifiers have built in electrostatic discharge (ESD) protection diodes as well as input protection diodes. ESD diodes are connected from op amp inputs and output to the supply rails. Therefore it is possible to access these diodes and use them as outlined to measure the die temperature of the op amp. For a more detailed explanation of how to accomplish this measurement, please see "ESD Diode Doubles as Temperature Sensor" by clicking on or entering the link to the Analog Devices' RAQ page listed below.

**To learn more about
Die Temperature**

Go to: <http://rbi.ims.ca/5411-100>



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