TEA

**TECH BRIEF**
**(TB-01)**

# Integrated Circuit Thermal Measurement Concepts

The electrical measurement technique for making semiconductor thermal measurement is well described in EIA/JEDEC JESD51-1 [Integrated Circuit Thermal Measurement Method (Single Component Device)]. The basic concepts of device heating and junction temperature measurements are presented below for a quick understanding without having to refer to JESD51-1.

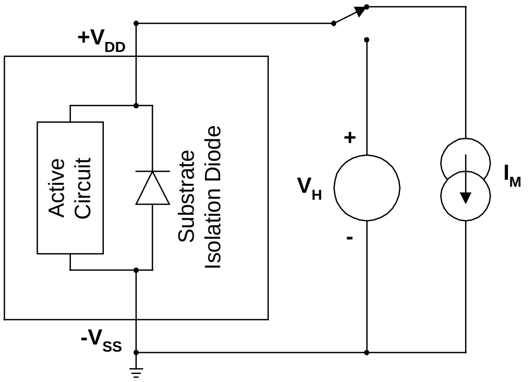

Figure 1

Figure 1 shows the measurement circuit for a typical integrated circuit (IC). Most ICs consist of an active circuit with many individual transistors and resistors that are combined together to perform a specific function. The individual elements of the circuit are isolated from each other by use of a reverse-biased diode isolation. The substrate isolation diode can be used to sense junction temperature by monitoring its forward voltage under a small bias current. Knowing the relationship between the forward voltage and junction temperature, referred to as K Factor, allows for changes in voltage to be converted to changes in junction temperature.

In cases where the integrated circuit uses a substrate bias generator to maximize performance, a lead for the most negative potential may not be available. In this case, it may be possible to use an input protection diode for junction temperature sensing, as shown in Figure 2.

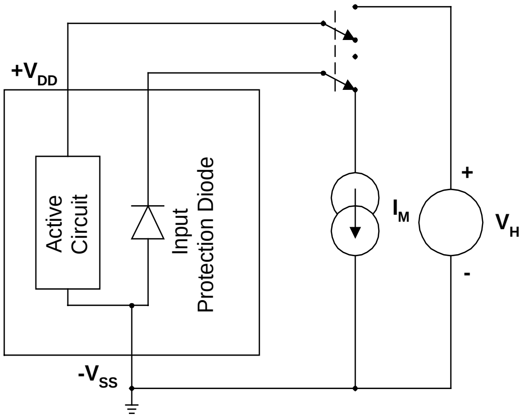

Figure 2

The difficulty in thermal testing of complex integrated circuits has lead to the use of a thermal test die in the package instead of the actual application die. The test die, shown in Figure 3, has two internal components – a resistive heater for generating the internal power dissipation and a temperature sensing diode. In some cases, there may be more than one heater for modifying the die temperature profile to better simulate actual application die operation. Additionally, there may be more than one temperature sensing diode in order to monitor the temperature profile and determine the highest temperature.

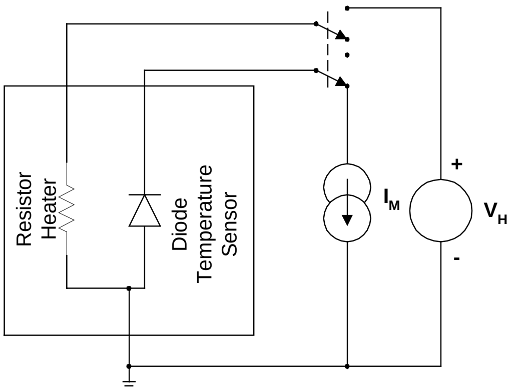

Figure 3

# Integrated Circuit Thermal Measurement Concepts (cont'd)

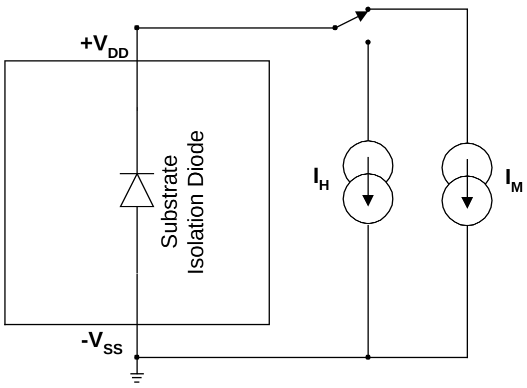

Figure 4

The circuit shown in Figure 4 uses the substrate isolation diode for both heating and temperature sensing. It is used for several reasons. First, it allows for testing of actual application devices without concern for the interface circuitry normally required to cause power dissipation within the device. Second, unlike the difficulty of finding a thermal test die to match the size of the actual application die, this is the actual application die. Third, the power dissipation for thermal testing usually can be easily matched by adjusting the current applied to the substrate isolation diode. Fourth, from a practical point-of-view, comparatively few contacts have to be made to the package – usually only the most positive (i.e., $V_{DD}$ or $V_{CC}$) and most negative (i.e., $V_{SS}$ or Gnd). There are drawbacks to this test configuration however. The primary drawback is that the power dissipation topology in the substrate isolation diode may not match that of actual operation of the device in normal operation. This could be of concern if there are known hot spots on the die when operating in the normal application mode. A secondary drawback is the fact that many devices use a substrate bias generator to put the substrate voltage at a level below the externally applied most negative signal, making it difficult to get to electrically connect tot he substrate.

The switches shown in each of the four figures are actually high-speed electronic switches capable of handling the measurement voltages and currents at sub-microsecond switch rates.