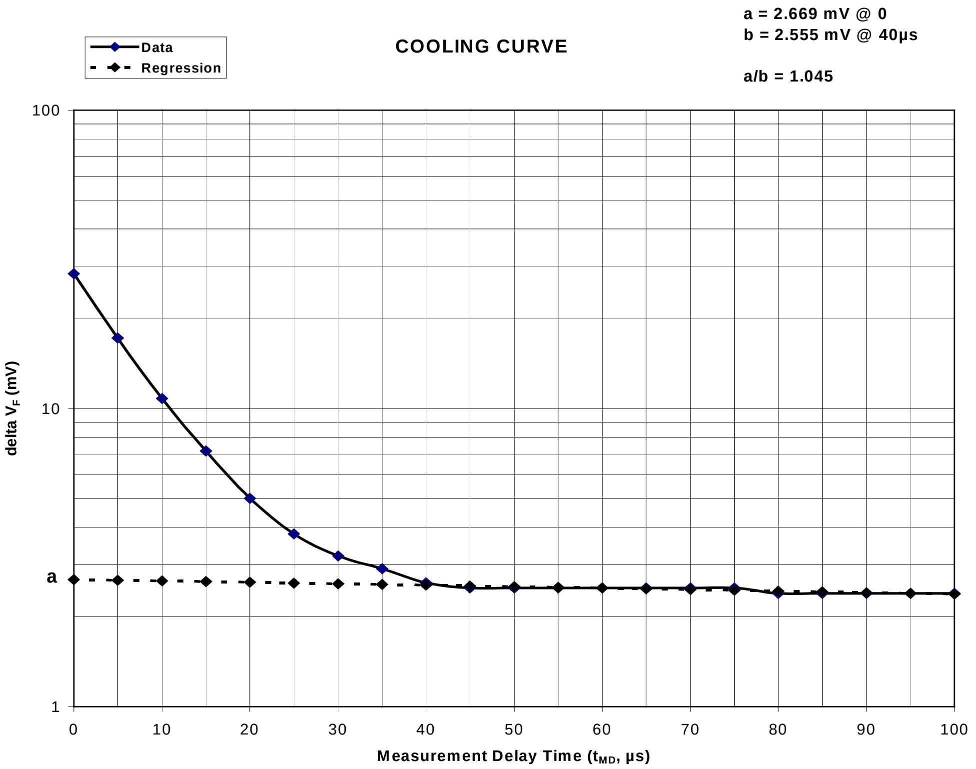
TEA

TECH BRIEF
(TB-06)

COOLING CURVES CORRECT MEASUREMENT DATA

The electrical method for semiconductor thermal measurements relies on the ability to quickly measure the TSP (temperature-sensitive parameter) of the device-under-test (DUT) after removing power applied to DUT. The DUT junction temperature (T_J) starts decreasing immediately but measurement difficulties usually make reading the TSP at the exact cessation of applied power next to impossible. Thus, if measurement data is not corrected for junction cooling, then the resultant junction temperature thermal resistance values will be too low - in some cases by a significant amount.

The Cooling Curve is a tool for correcting the measured results for junction cooling effects. It is based on the exponential nature of junction cooling. When T_J (or some related parameter) is plotted on the logarithmic axis of a semi-log graph with Measurement Delay Time (t_{MD}) - defined as the time from cessation of applied heating power to the start of the TSP measurement - on the linear axis, the data should result in straight line with a negative slope. However, as shown in the graph below, until non-thermal switching effects (associated with test system limitation, DUT switching capabilities, and inductance in the test leads from the system to the DUT) are overcome, the curve declines at a steep non-exponential pace. Use of data taken in this range (up to 40 µs in the graph shown below) will lead to T_J and thermal resistance values considerably higher than real values.



Once TSP data is taken as a function of different t_{MD} values and plotted on a semi-log graph, it should be reasonably obvious where the curve flattens out into a straight line. The t_{MD} value at this point or just beyond should be used for thermal resistance and T_J measurements.

The next step is use the data from this t_{MD} point on to created a best-fit (regression) line and extrapolate

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that line back to the Y-axis. Then the Y-axis intercept point value (labeled 'a' on the graph) is divided by the t_{MD} value used for testing (referred to as 'b'; using 40 µs in this example). This ratio of a/b is used to correct the data for junction cooling effects.

The measurement data can be corrected in two ways. It can be manually corrected after data collection. Or it can be corrected automatically during the testing so that the final data reflects the correction. The easiest way to do this is by modifying the K Factor value. (Refer to TB-02 DIODE TEMPERATURE SENSING for a discussion of K Factor.) Then K' can be programmed into the thermal test system to yield corrected data values directly.

$$\theta_{JX} = \left[\frac{\left(\frac{a}{b}\right) \times K \times \Delta V_F}{I_H \times V_H} \right] = \left[\frac{K' \times \Delta V_F}{I_H \times V_H} \right] \qquad K' = \left(\frac{a}{b}\right) \times K$$

where - θ_{JX} is the thermal resistance for the defined test condition
ΔV_F is the change in the TSP change (in this case diode forward voltage)
I_H is the applied heating current
V_H is the applied heating voltage
K is the K Factor
a/b is the junction cooling correction factor
K' is the modified K Factor to account for junction cooling

The correction factor should always be 1.0 or higher because of the negative slope of the straight portion of the cooling curve. The magnitude of the correction factor depends on the thermal test system, the DUT, the test fixture and the inductance in the wires connecting the fixture to the system. Very small devices, such as laser diodes or microwave diodes with junction areas very small compared to the chip size, often have large values of correction factor.

When testing a batch of devices that are all the same physically and electrically, cooling curves and correction factors from a small sample of devices can typically be used to determine K' for the entire batch. When the cooling curve and correction factor varies significantly from device-to-device, it is necessary to determine and apply the correction factor for each device on a device by device basis.

Some thermal test systems, such as the TEA TTS-1000 and TTS-4000/4200 systems, have an option for automatic determination and application of the correction factor for each device tested.