Control Chip Temperature During VLSI Device Burn-in

Harold Hamilton - April 01, 1999
High-power VLSI devices exhibit a wide disparity in heat dissipation. Variations in semiconductor fabrication processes contribute to differing rates of dissipation among devices with identical part numbers operating under identical conditions. Such devices can exhibit as much as 50% variation in heat dissipation during burn-in. Moreover, varying packaging conditions (such as frequency) contribute to power-dissipation variations within a single part. To compensate for these power-dissipation variations, you can provide independent temperature regulation for individual devices during burn-in. Such regulation keeps you from damaging good parts with high dissipation and ensures that you adequately stress devices having inherently low dissipation.

The traditional bathtub curve (Fig. 1) represents semiconductor device failure rates as a function of time. The initial failure rate is high, but devices that survive the first few hours—the infant-mortality period—operate reliably until they reach the end-of-life stage many years hence.

![Image](image1.jpg)

**Figure 1.** The traditional bathtub curve describes semiconductor device failure rates with respect to time. Devices that survive the first few hours will likely last years.

The burn-in process uses power and temperature extremes to compress the infant-mortality period, forcing failures to occur quickly, thus saving time and money. The more extreme the power and temperature, the sooner natural failures occur, reducing the required burn-in time. Ultimately, increasing voltage and temperature will not only compress the infant-mortality period but also weaken good devices that will survive the burn-in yet fail well before their anticipated end-of-life. In the past, an increase in power and temperature worsened the burn-in times and money determining the optimum burn-in temperature for production devices. An effective production burn-in system forces all devices to stay close to that optimum temperature. It compensates for variations in the dissipation characteristics of the devices undergoing simultaneous burns as well as for variations in each device's dissipation in response to varying electrical inputs during the burn-in and subsequent use.

**Burn-in Strategies**

Burn-in strategies include static, dynamic, and burn-in with test. Static burns in systems apply extremes of voltage and temperature to each device but do not exercise the device. Thus, static burn-in—the least expensive of the burn-in strategies—does not stress all the potential failure mechanisms.

Dynamic burn-in systems exercise the device inputs and properly terminate the outputs in addition to applying extremes of voltage and temperature. With dynamic systems, electrons change transfers occurring at the exercised device's circuit nodes initiate failure mechanisms that would escape static burn-in.

Burn-in-with-test systems stress both devices and sockets during stressing. They provide test vectors to a device and compare actual device outputs with expected outputs while the device under test (DUT) operates at its voltage and temperature limits. Burn-in-with-test systems can identify devices that fail to meet open conditions but that would pass a post-burn-in in-room temperature test.

Burn-in-with-test systems also verify that a device under test gets exercised—that is, the device is powered up and test vectors are applied. Keep in mind that burn-inocket—frail high-pin-count components subjected to the repeated insertion/removal cycles of production burns—has them oslo fail in service, just a few bad socket pins could prevent test vectors or supply voltages from reaching the device undergoing burn-in, resulting in your dropping or using parts that haven't been electrically stressed.

In one approach to independent burn-in, a computer plays devices into sockets on one side of a burn-in board (Fig. 2). A dedicated or other press-fitted type brings a heat-sink assembly (Fig. 3) into contact with each device.

![Image](image2.jpg)

**Figure 2.** The burn-in board accommodates 24 DUTs. A burn-in-with-test strategy ensures that supply voltages and test vectors pass through the fragile burn-in-board sockets to the DUT.

The heat-sink assembly consists of a temperature-sensing, heater. The sensor holds the temperature-sensor tightly against the device package to ensure good thermal contact. The control circuitry monitors the device temperature and supplies the proper heater power to maintain the required temperature.

**Maintaining Die Temperature**

The die inside the DUT is the active component whose temperature is most important. The high power burn-in system monitors and controls the package temperature, which in turn controls the die temperature in accordance with its thermal impedance between die and package. This thermal impedance is typically less than 0.2°C/W, depending on package, die, and the mounting method. Although this thermal impedance varies by device type, it's usually uniform for a given part number.

You can calculate the package temperature (TP) required to maintain a specific die temperature (TD) from the thermal impedance (q) and the DUT heat dissipation (P):

\[
T_P = T_D - q \times P
\]

For example, the package temperature required to provide a die temperature of 150°C for a device with the thermal impedance equal to 0.25°C/W and a heat dissipation of 10 W is as follows:

\[
T_P = 150°C - (0.25°C/W \times 10 W) = 147.5°C
\]

**Air Temperature and Velocity**

A heat-sink assembly transfers heat from the DUT to the air. The heat-sink assembly maintains a constant temperature over the full potential range of heat dissipation. The heat-sink assembly transfers heat from the DUT to the air. The heat-sink assembly transfers heat from the DUT to the air. The heat-sink assembly transfers heat from the DUT to the air. The heat-sink assembly transfers heat from the DUT to the air.

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**Control Software**

A high-power burn-in system's software can provide individual device temperature control and monitoring. In the 5 example, the software provides color-coded information about each device; test codes provide details. The software also shows global temperature settings for the burn-in board as well as actual maximum, minimum, and average temperatures and heater duty cycles. This allows you to provide real-time monitoring of the burn-in process, ensuring that each device is being stressed to its full potential without exceeding its temperature limits. Burn-in-with-test systems can identify devices that fail to meet open conditions but that would pass a post-burn-in in-room temperature test.

![Image](image3.jpg)

**Figure 3.** A heat-sink assembly attaches to each DUT on a burn-in board. A sensor provides temperature information to a control subsystem, which regulates device temperature by controlling heater duty cycle. Thermal foam ensures good thermal contact between DUT and heat-sink assembly.

**Figure 4.** Many combinations of air temperature and velocity will remove a given amount of heat. Each of the three lines here represents the various combinations of air temperature and velocity that will provide the required heat flow from a heat-sink assembly.

Air temperature and velocity are generally set so that the heater runs at half power (50% duty cycle) when the device is operating at nominal power. This choice centers the heater output relative to the device power range. As the heat-gain of the device increases, the control circuitry senses the temperature increase and reduces the heater power, allowing the package temperature to settle back to the setpoint temperature. Similarly, as the device dissipates less heat, the heater will dissipate more. The total heat dissipation of the heat-sink assembly is directly related to the power dissipation of the device under test. Thus, the air temperature and velocity, once appropriately set, need not be changed during testing. The heating effect of the heat-sink assembly on the air stream is proportional to \( T_1 - T_2 \), where \( T_1 \) is the heat-sink ambient temperature, \( T_2 \) is the air stream temperature, and \( y \) is air velocity. Figure 4 illustrates airflow rates and air-temperature settings for three rates of heat flow from a heat-sink assembly.

![Image](image4.jpg)

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![Image](image5.jpg)

**Figure 5.** Burn-in control software can provide individual device temperature control and monitoring. In the example, the display provides color-coded information about each device; test codes provide details. The display also shows global temperature settings for the burn-in board as well as actual maximum, minimum, and average temperatures and heater duty cycles. This allows you to provide real-time monitoring of the burn-in process, ensuring that each device is being stressed to its full potential without exceeding its temperature limits.