AMD

Methodologies for Measuring Temperature on AMD Athlon™ and AMD Duron™ Processors

Application Note

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Revision History

Date	Revision	Description
December 2002	E	Updated Public Release
October 2001	D	Initial Public Release

Introduction

This application note describes repeatable, accurate methodologies for measuring the processor-die temperature for pin grid array (PGA) packaged AMD Athlon™ and AMD Duron™ processors in desktop and mobile personal computers.

Audience

This document is intended for thermal engineers testing systems based on AMD Athlon and AMD Duron processors.

Intent of Document

This application note describes methodologies for measuring processor-die temperature in desktop and mobile systems using AMD Athlon and AMD Duron PGA processors. Separate chapters describe the methodology for the following situations:

- Processor has an on-die thermal diode but the motherboard has no temperature sensor
- Processor has an on-die thermal diode and the motherboard has a temperature sensor
- Measuring die temperature indirectly on a desktop processor without an on-die thermal diode
- Measuring die temperature indirectly on a mobile processor without an on-die thermal diode

Life of Document

This document is valid for any AMD Athlon or AMD Duron processor.

Additional Documents

- *AMD Thermal, Mechanical, and Chassis Cooling Design Guide*, order# 23794
- *Thermal Testing Methodology for Characterized AMD Desktop Processors*, order# 24362

Limitations and Disclaimers

These methodologies are intended only for characterization; they are not intended for use in production systems.

The methodologies in this document have been successfully tested for processors with an on-die thermal diode and a motherboard with an on-board temperature sensor. *However, the methodologies presented are provided on an "as is" basis and AMD makes no express or implied warranties as to its effectiveness or fitness for a particular purpose.*

Ceramic Pin Grid Array (CPGA) Processor Package

If the CPGA processor package has an on-die thermal diode, use it. To verify that the diode is operating correctly, attach a thermocouple to the backside of the ceramic PGA package as described in Chapter 3 "Indirect Die-Temperature Measurement—Processor Package Thermocouple."

If a thermal diode is not available, use the die temperature correlations provided within this document.

Note: *AMD no longer sells ceramic substrate packages. The information in Chapter 4 and Chapter 5 is for reference and should not be applied to organic substrate packages.*

Organic Pin Grid Array (OPGA) Processor Package

If the OPGA processor package has an on-die thermal diode, use it.

If a thermal diode is not available, use the underpackage thermocouple measurement in lieu of the diode measurement. The underpackage temperature on organic packages can be used without an offset. The die temperature correlations provided for CPGA processors do not apply to OPGA processors.

Chapter 1 On-Die Thermal Diode With Motherboard Temperature Sensor

This chapter describes three methods for temperature measurement for a pin grid array (PGA) processor that has an on-die thermal diode and is used on a motherboard that has an on-board temperature sensor. These methods are:

- Read the on-board temperature sensor with a software utility.
- Use an evaluation kit to read the on-board temperature sensor through the SMBus.
- Disconnect the traces from the on-board temperature sensor and read the sensor using an evaluation kit.

Note: *These methods may not work on all systems.*

1.1 Method 1—Use a Software Utility

Reading the on-board temperature sensor with software is the easiest method to use if a utility is available that works with the motherboard. However, no general purpose utility that works with all motherboards is currently available.

Note: *The temperature sensor on the motherboard may not provide an accurate reading of the thermal diode. Be sure that the on-board temperature sensor uses dual-sourcing currents. Single-sourcing current does not provide suitable accuracy for thermal testing.*

If the motherboard does not come with such a utility, try some other software, such as Motherboard Monitor, available at *http://mbm.livewiredev.com/*, to read the on-board temperature sensor. If the temperature value is not displayed in the BIOS setup screen, this utility typically is not able to find and read the on-board temperature sensor.

Note: *Current versions of Motherboard Monitor do not typically work on notebook computers.*

If no availabe utility works with the motherboard, you can write software that communicates with the temperature sensor across the SMBus. This method requires that the temperature sensor be connected to an SMBus controller. It also requires knowledge of how the temperature sensor is connected to the SMBus.

1.2 Method 2—SMBus and Evaluation Kit

Method 2 and Method 3 both allow the measuring and recording of the junction temperature if the on-board temperature sensor is not accessible through software on the test computer.

To read the on-board temperature sensor through the SMBus, connect an evaluation kit to the SMBus data, clock, and alert pins on the sensor. This method requires soldering onto small pins. With proper soldering, it causes no permanent damage to motherboard.

This method uses the evaluation kit software to read the temperature sensor on the motherboard instead of the temperature sensor on the evaluation kit.

Notes:

1. *Do not remove the temperature sensor on the motherboard of the computer to be tested. The computer may not start if the on-board temperature sensor is removed.*
2. *This technique may not work with all implementations of an on-motherboard temperature sensor. AMD has successfully used this technique with the Maxim 1617A temperature sensor.*

1.2.1 Connecting the Evaluation Kit to the On-Board Sensor

To connect the evaluation kit to the on-board sensor, do the following:

1. Attach wires to the clock (SMBCLK or SCLK), data (SMBDATA or SDATA), and ground (GND) pins on the on-board temperature sensor.

   Figure 1 shows the connections for the Maxim 1617A thermal sensor, which are the same for the Maxim 6654 and the Analog 1023 sensors. Other temperature sensors may have a different pinout.

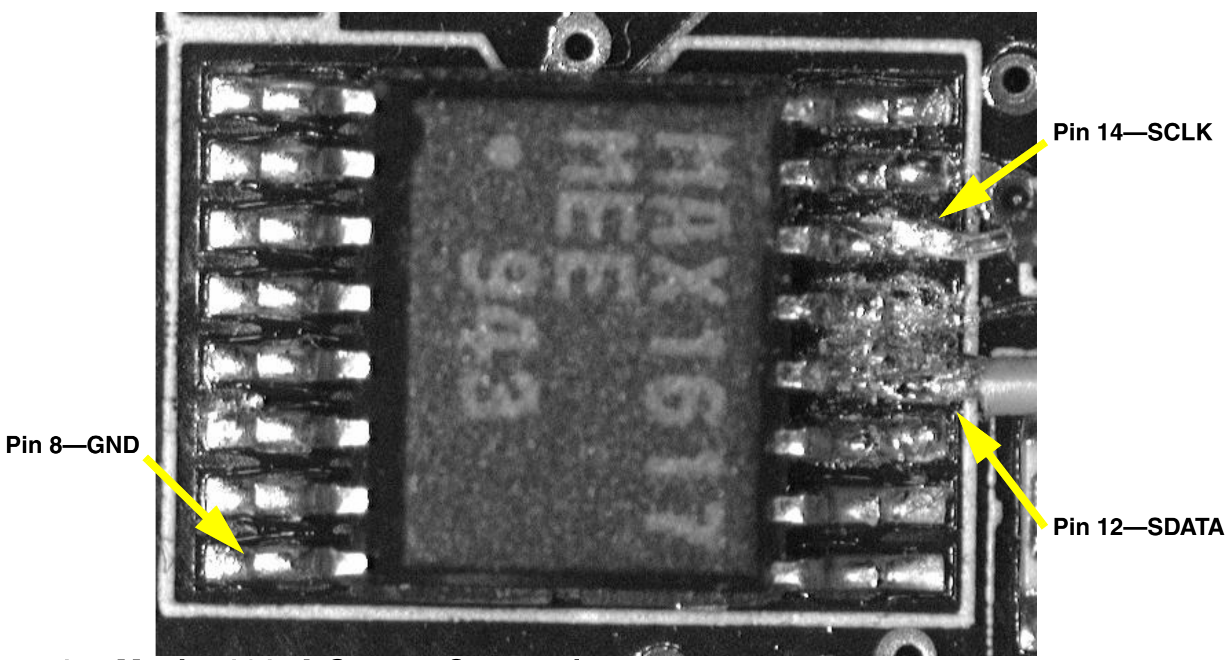


Figure 1. Maxim 1617A Sensor Connections

2. Connect the clock and data wires to the evaluation kit.

   Figure 2 shows the connections for the Maxim 1617A Evaluation Kit. Other evaluation kits have similar connections.

Note: *The Maxim 1617A evaluation kit does not require external power; it obtains power through the parallel port.*

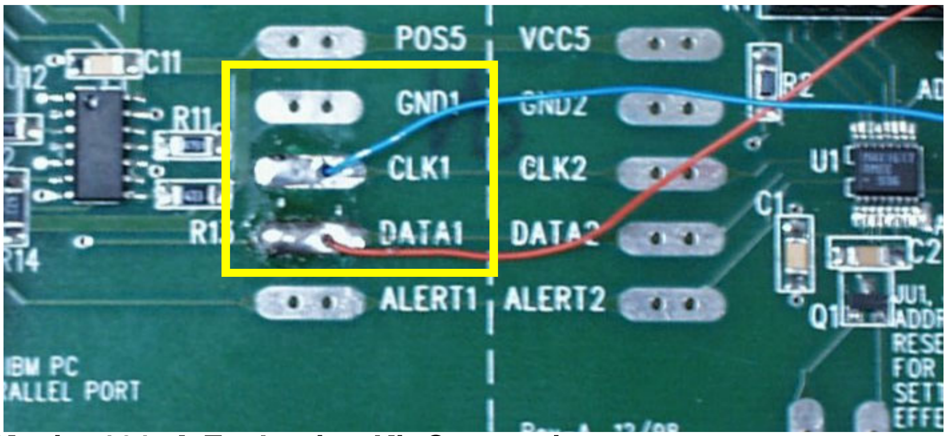


Figure 2. Maxim 1617A Evaluation Kit Connections

3. To minimize noise, connect the ground wire to the GND1 pad on the evaluation kit.

1.2.2 Reading the Temperature

To read the temperature, connect the evaluation kit to the data acquisition computer and install the software that comes with the kit, as outlined in the following steps:

1. Turn off the evaluation kit, the data aquisition computer, and the test computer.
2. Connect the evaluation kit to the parallel port on the data acquisition computer.
3. Turn on the evaluation kit and the data aquisition computer.
4. Install the evaluation kit software on the data acquisition computer using the instructions accompanying the software. The software works only with the evaluation kit it accompanys. Check the web site of the evaluation kit vendor for the latest version of the software.
5. Verify the evaluation kit software.

   (Running the software before turning on the test computer verifies the operation of the remote diode. The remote diode temperature should be steady and near the ambient temperature.)
6. Turn on the test computer. The remote temperature should rise immediately.

The evaluation kit software provides two measurements: the local temperature and remote. The remote temperature is the temperature of the processor. The local temperature is the temperature of the on-board temperature sensor.

1.3 Method 3—Evaluation Kit

This method involves disconnecting the on-board temperature sensor and connecting an evaluation kit directly to the on-die thermal diode. To use this method, the traces to the processor thermal diode must be accessible on the top or bottom surface of the board.

Notes:

1. *This method causes permanent damage to the board.*
2. *This method is possible only if both thermal diode traces are routed on an external layer.*
3. *If the test system uses the processor temperature to control cooling fans, those fans must be powered externally when using this method because the on-board temperature sensor is no longer measuring the die temperature.*

1. Cut the traces to both the THDA (pin S7) and THDC (pin U7) socket pins on the motherboard, as shown in Figure 3, thereby disconnecting the on-die thermal diode from the on-board sensor.

Note: *Cut only the surface traces. Cutting too deeply may penetrate and damage other layers of the board.*

Alternatively, unsolder and lift the thermal diode pins on the temperature sensor to disconnect the diode from the sensor.

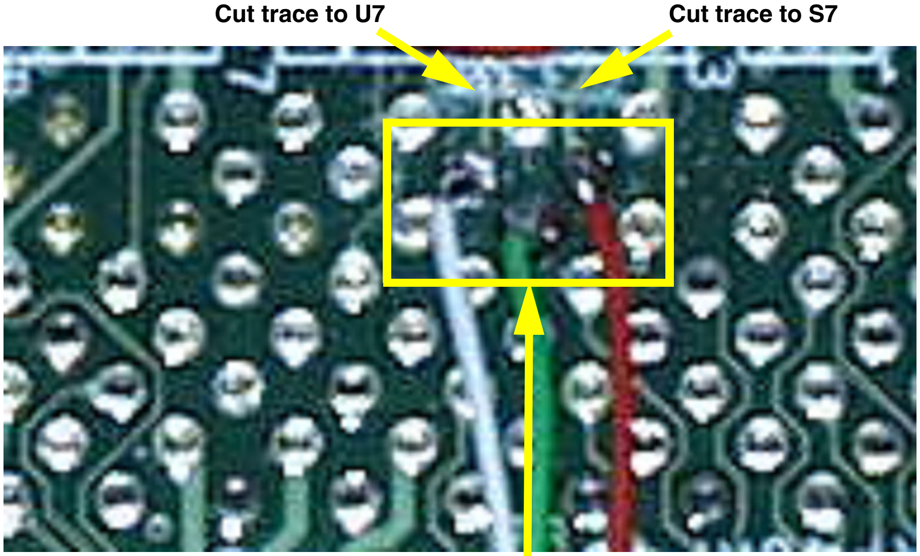


Figure 3. Cut On-Die Thermal Diode Traces and Connect Wires

2. Use an evaluation kit as described in Chapter 2, "On-Die Thermal Diode Without Motherboard Temperature Sensor."

Some systems may not boot without a diode attached to the on-board temperature sensor. If this is the case with the system under test, connect a discrete diode to the thermal diode pins on the on-board temperature sensor.

Table 1 shows the diode wiring assignments for a 2N3904 transitor and a 2N3906 transistor.

Table 1. Transistor Diode-Wiring Assignments

Diode Connected Transistor	2N3904	2N3906
Emitter	Negative	Positive
Collector/Base	Positive	Negative

Figure 4 shows a 2N3904 transistor in a TO-92 package.

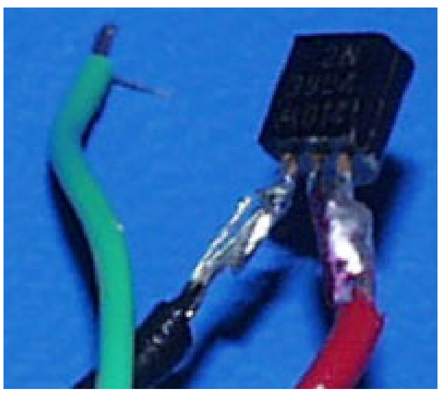


Figure 4. 2N3904 Transistor

1.4 Verifying On-Die Thermal Diode Results

To verify the results obtained from the on-die thermal diode, attach a thermocouple to the backside of the processor package beneath the die. For instructions on how to attach and measure the thermocouple, see Chapter 3 “Indirect Die-Temperature Measurement—Processor Package Thermocouple.” The under-package temperature should read within 2°C of the diode temperature, and the thermocouple temperature should increase with increasing power at a similar rate to the diode temperature. If the difference between the diode and underpackage readings is large, ensure that there are no issues with the diode measurement, such as a poor solder joint or EMI interference. For additional help, see “Troubleshooting Tips.”

1.5 Troubleshooting Tips

This section describes possible solutions to common problems.

- **Remote temperature reads 127°C.** The temperature sense wires may be reversed. Switch the pins to which the wires are connected (U7 wire to S7 and S7 wire to U7).

- **Remote temperature reading rapidly changes without a change in processor power.** Check that the evaluation kit is properly grounded to the digital ground (Pin T6 on the processor or some other V_{SS} source). The voltage difference between digital ground and the evaluation card should be within a few millivolts of 0 V.

  Look for sources of electromagnetic interference, such as power supplies, and minimize those sources. Use a clean lab power supply instead of a switching notebook AC/DC power brick.

- **Remote temperature is less than backside package.** If the difference is small, check with the evaluation kit manufacturer to ensure that the proper offset is being used. Diode temperature should be within 2°C of the package temperature.

  If the difference is large, then be sure that the processor thermal diode is being read and not another remote diode on the evaluation kit.

- **Remote temperature does not change with changes in processor power.** Be sure that the processor thermal diode is being read and not another remote diode on the evaluation kit.

  Check for other temperature sensors on the motherboard connected to the processor thermal diode.

  1. Remove the wires from the evaluation kit.
  2. Measure the resistance or voltage drop across the evaluation kit wires connected to the diode pins with no processor inserted in the socket. (Use either a resistance or a diode function multimeter).

  If the circuit is open, then no other temperature sensor is connected to the on-die thermal diode. If a resistance or voltage drop is present when the processor is not in the socket, then another device is connected to the processor thermal diode pins.

Chapter 2 On-Die Thermal Diode Without Motherboard Temperature Sensor

This chapter describes a temperature measurement methodology for a pin grid array (PGA) processor that has an on-die thermal diode and is used on a motherboard that does not have an on-board temperature sensor.

2.1 Choosing a Temperature Sensor Evaluation Kit

To read the temperature from the on-die thermal diode, use a temperature sensor evaluation kit that has been designed to read from a remote thermal diode. AMD recommends using a temperature sensor that sources two currents along a differential pair of wires. The dual sourcing current methodology limits the impact of external noise and provides more accurate readings than does a single sourcing current methodology.

AMD has successfully used the following evaluation kits with an on-die diode:

- Analog Devices 1023 Evaluation Kit (shown in Figure 5) *http://www.analog.com/*
- Maxim 6654 Evaluation Kit (shown in Figure 6 on page 14) *http://www.maxim-ic.com/*

Suitable evaluation kits are available from other vendors.

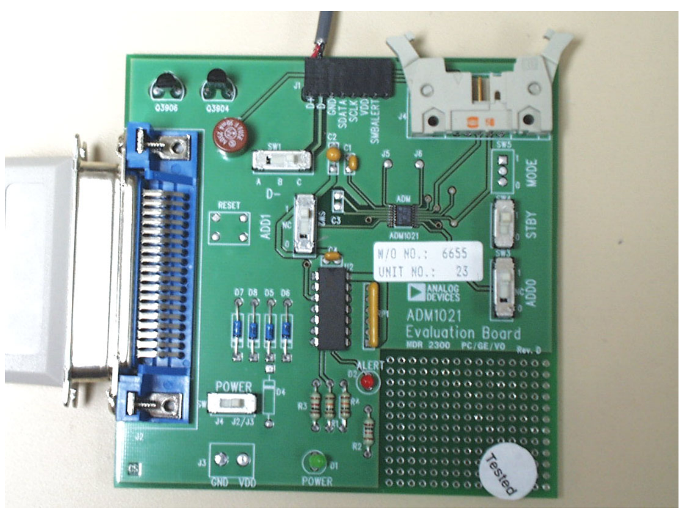
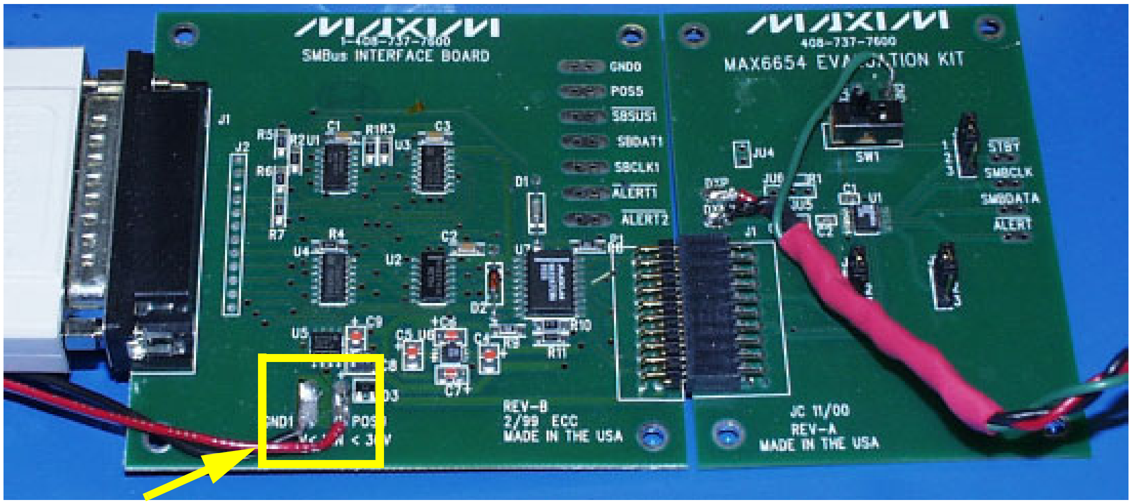


Figure 5. Analog Devices 1023 Evaluation Kit



Power Supply Connections

Figure 6. Maxim 6654 Evaluation Kit

2.2 Providing Power to the Evaluation Kit

The Analog 1023 kit receives power from the parallel port and does not require an external power source.

For the Maxim 6654 kit only, attach an external power source (7 V to 20 V) to the evaluation board as shown in Figure 6.

2.3 Connecting the Evaluation Kit to the On-Die Thermal Diode

Connect the evaluation kit to the on-die thermal diode, using high-quality shielded or twisted-pair wire. The resistance in the wire offsets the temperature measurement by 0.4 to 0.8 °C/Ω, depending on the temperature sensor used.

1. Attach temperature sense wires to the socket pins.
   - THDA (Pin S7) to D+ (Analog 1023) or DXP (Maxim 6654)
   - V_{SS} (Pin T6, or other V_{SS} pin) to GND
   - THDC (Pin U7) to D– (Analog 1023) or DXN (Maxim 6654)
   - No pins at locations A1 and AN1

   Figure 7 on page 15 shows the locations of the S7 (+), T6 (GND), and U7 (–) pins.

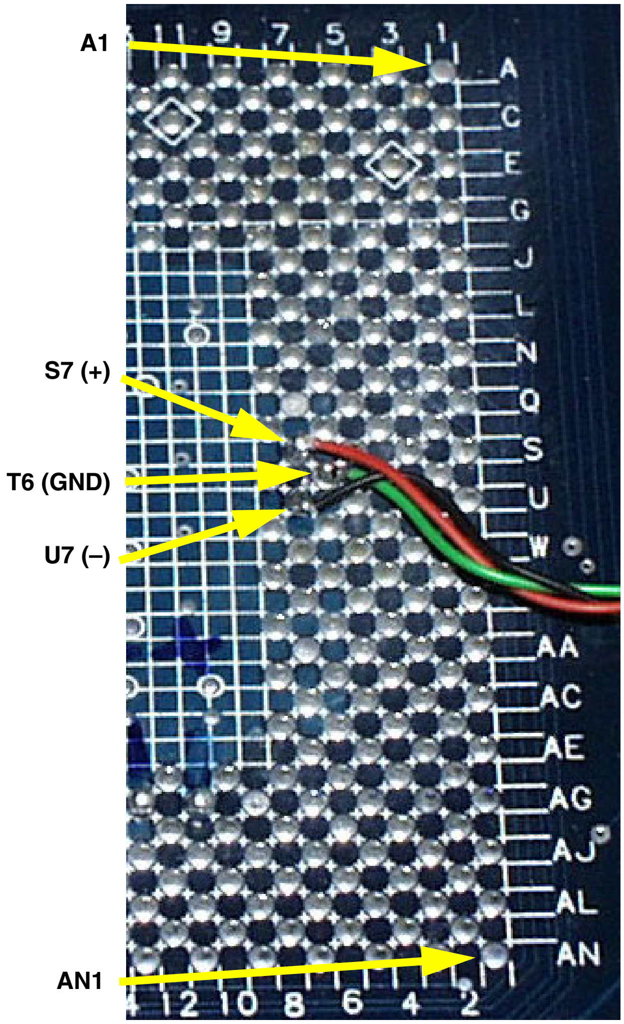


Figure 7. On-Die Thermal Diode Pin Locations

2. Connect the digital ground in the system to the evaluation kit using the V_{SS} pin (Pin T6).

Note: *Connecting the system digital ground (pin T6, V_{SS}) to the evaluation kit using V_{SS} pin (Pin T6) reduces the impact of external noise on the temperature measurements.*

3. Attach the temperature sense wires to the evaluation kit.

Table 2 and Figure 8 and Figure 9 show how to connect the temperature sense wires to the evaluation kit.

Table 2. Temperature Sense Wire Connections

Pin Location	Signal Name	Analog 1023 Connection*	Maxim 6654 Connection
S7 (+)	THDA	D+	DXP
T6 (GND)	V_{SS}	GND	GND
U7 (–)	THDC	D–	DXN

Note: **Attach wires to Analog 1023 Kit using the wire block.*

4. On the Analog 1023 Kit, put Switch 1 (SW1) in the C position, as shown in Figure 8.
On the Maxim 6654 Kit, cut the JU6 trace, as shown in Figure 9.

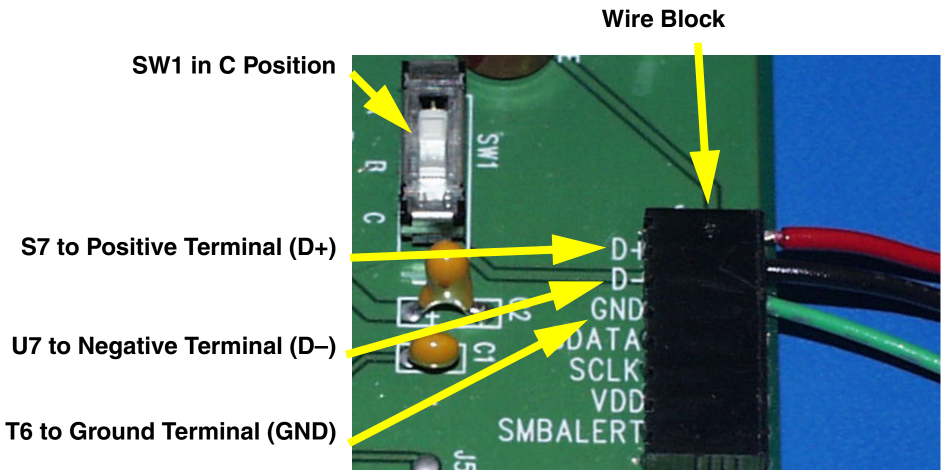


Figure 8. Connections to Analog 1023 Evaluation Kit

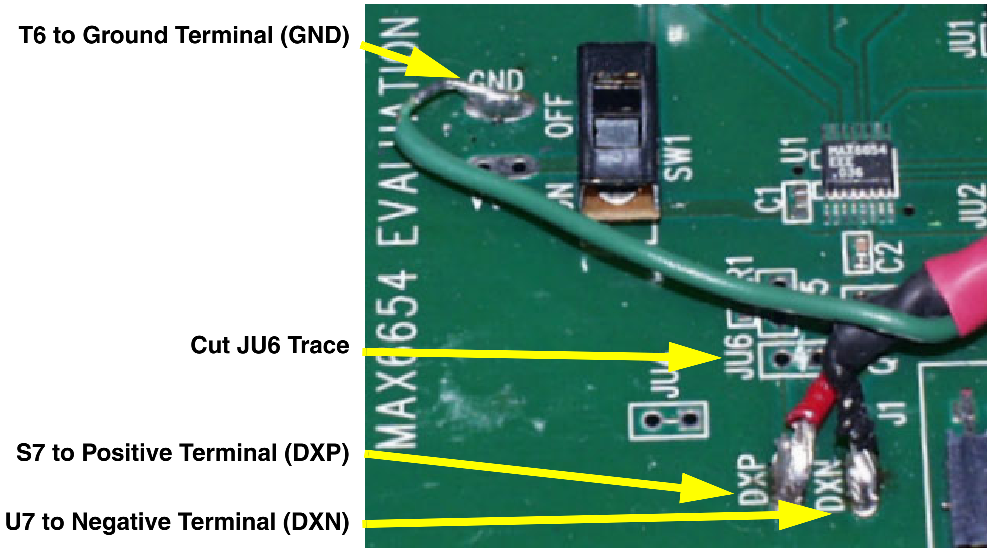


Figure 9. Connections to Maxim 6654 Evaluation Kit

Refer to the evaluation kit documentation for specific usage instructions.

2.4 Reading the Temperature

To read the temperature, connect the evaluation kit to the data acquisition computer and install the software that comes with the kit, as outlined in the following steps:

1. Turn off the evaluation kit, the data aquisition computer, and the test computer.
2. Connect the evaluation kit to the parallel port on the data acquisition computer.
3. Turn on the evaluation kit and the data aquisition computer.
4. Install the evaluation kit software on the data acquisition computer using the instructions accompanying the software. The software works only with the evaluation kit it accompanys. Check the Web site of the evaluation kit vendor for the latest version of the software.
5. Verify the evaluation kit software.

   (Running the software before turning on the test computer verifies the operation of the remote diode. The remote diode temperature should be steady and near the ambient temperature.)
6. Turn on the test computer. The remote diode temperature should rise immediately.

The evaluation kit software provides two measurements—local temperature and remote. The temperature of the sensor chip is the local temperature of the package (Analog 1023, Maxim 6654, etc.). If the evaluation kit is properly connected to the processor, the remote temperature is the temperature of the processor thermal diode. Check the installation of the evaluation kit to be sure the remote temperature is not coming from a diode on the evaluation kit.

Due to variations in temperature sensor designs, it may be necessary to account for a small offset. Contact the manufacturer of the temperature sensor for information on whether any offsets are needed. If necessary, correct for the temperature measurement offset.

2.5 Verifying On-Die Thermal Diode Results

To verify the results obtained from the on-die thermal diode, attach a thermocouple to the backside of the processor package beneath the die. For instructions on how to attach and measure the thermocouple, see Chapter 3 “Indirect Die-Temperature Measurement—Processor Package Thermocouple.” The under-package temperature should read within 2°C of the diode temperature, and the thermocouple temperature should increase with increasing power at a similar rate to the diode temperature. If the difference between the diode and underpackage readings is large, ensure that there are no issues with the diode measurement, such as a poor solder joint or EMI interference. For additional help, see “Troubleshooting Tips.”

2.6 Troubleshooting Tips

This section describes possible solutions to common problems.

- **Remote temperature reads 127°C.** The temperature sense wires may be reversed. Switch the pins to which the wires are connected (U7 wire to S7 and S7 wire to U7).
- **Remote temperature reading rapidly changes without a change in processor power.** Check that the evaluation kit is properly grounded to the digital ground (Pin T6 on the processor or some other V_{SS} source). The voltage difference between digital ground and the evaluation card should be within a few millivolts of 0 V.

  Look for sources of electromagnetic interference, such as power supplies, and minimize those sources. Use a clean lab power supply instead of a switching notebook AC/DC power brick.
- **Remote temperature is less than backside package.** If the difference is small, check with the evaluation kit manufacturer to ensure that the proper offset is being used. Diode temperature should be within 2°C of the package temperature.

  If the difference is large, then be sure that the processor thermal diode is being read and not another remote diode on the evaluation kit.
- **Remote temperature does not change with changes in processor power.** Be sure that the processor thermal diode is being read and not another remote diode on the evaluation kit.

  Check for other temperature sensors on the motherboard connected to the processor thermal diode.

  1. Remove the wires from the evaluation kit.

2. Measure the resistance or voltage drop across the evaluation kit wires connected to the diode pins with no processor inserted in the socket. (Use either a resistance or a diode function multimeter).

If the circuit is open, then no other temperature sensor is connected to the on-die thermal diode. If a resistance or voltage drop is present when the processor is not in the socket, then another device is connected to the processor thermal diode pins.

Chapter 3 Indirect Die-Temperature Measurement—Processor Package Thermocouple

For systems without an on-die thermal diode, the temperature must be measured indirectly. The die temperature is calculated from the package temperature and either the ambient temperature above the inlet side of the heatsink fan or the heatsink block temperature. Chapter 4 "Indirect Die-Temperature Measurement—Desktop" contains the procedure for attaching a thermocouple to read the ambient temperature above the inlet side of the heatsink fan. Chapter 5 "Indirect Die Temperature Measurement—Mobile" contains the procedures for attaching the thermocouple to read the heatsink block temperature.

This chapter describes the procedures for attaching a thermocouple to the back side of a pin grid array (PGA) processor that does not have an on-die thermal diode. This method involves attaching a thermocouple directly to the processor package.

For this method, use 36-gauge or smaller thermocouple (T/C). *Do not* twist the exposed wire of the thermocouple. For proper thermocouple usage, the tip should be welded together only with a thermocouple or fine wire welder. When completed, there should be no more than 3 mm of exposed wire.

3.1 Routing the Thermocouple Wire

There are two ways to route the thermocouple wire. The preferred method is to thread the wire under the socket. The alternative method is to route the wire between the pins of the processor package so that it ends up between the processor package and the socket. Use the alternative method only if you are unable to thread the wire under the socket.

3.1.1 Preferred Routing and Attachment

1. Thread the thermocouple (T/C) wire between the motherboard and socket along the line shown in Figure 10 on page 22 until it reaches the open area in the middle of the socket.
2. Pull enough wire through to ease the attachment of the thermocouple to the backside of the processor package, as shown in Figure 10 on page 22.
3. Measure and mark the center of the processor package with a pencil. Use calipers to assist in finding the center of the package.
4. Be sure the thermocouple is clean.

   See Figure 11 on page 23. Note the wire and package orientation; there are no corner pins on the left side.

5. Position the thermocouple bead over the center mark on the processor package.

Note: *For accurate temperature measurements, it is critical that the thermocouple bead is at the exact center of the package.*

6. Clean the surface of the package where the bead is located with isopropyl alcohol or acetone.
7. Attach the thermocouple to the package with a small piece of Kapton tape, as shown in Figure 12 on page 23.

   Press the tape down near the thermocouple bead with a dull instrument. In place of tape, you can use thermal epoxy.

Note: *For accurate temperature measurements, the thermocouple bead must be in contact with the package surface.*

8. Apply additional tape to prevent the thermocouple from moving.

   Do not tape all the way to the corner; leave some room. See Figure 13 on page 24.
9. Bend the thermocouple gently to allow the wire to follow a smooth path when it is placed in the socket. See Figure 13 on page 24.

Note: *Be careful not to kink or sharply bend the thermocouple wire.*

Figure 10 shows the path between the motherboard and the socket along which the thermocouple is threaded.

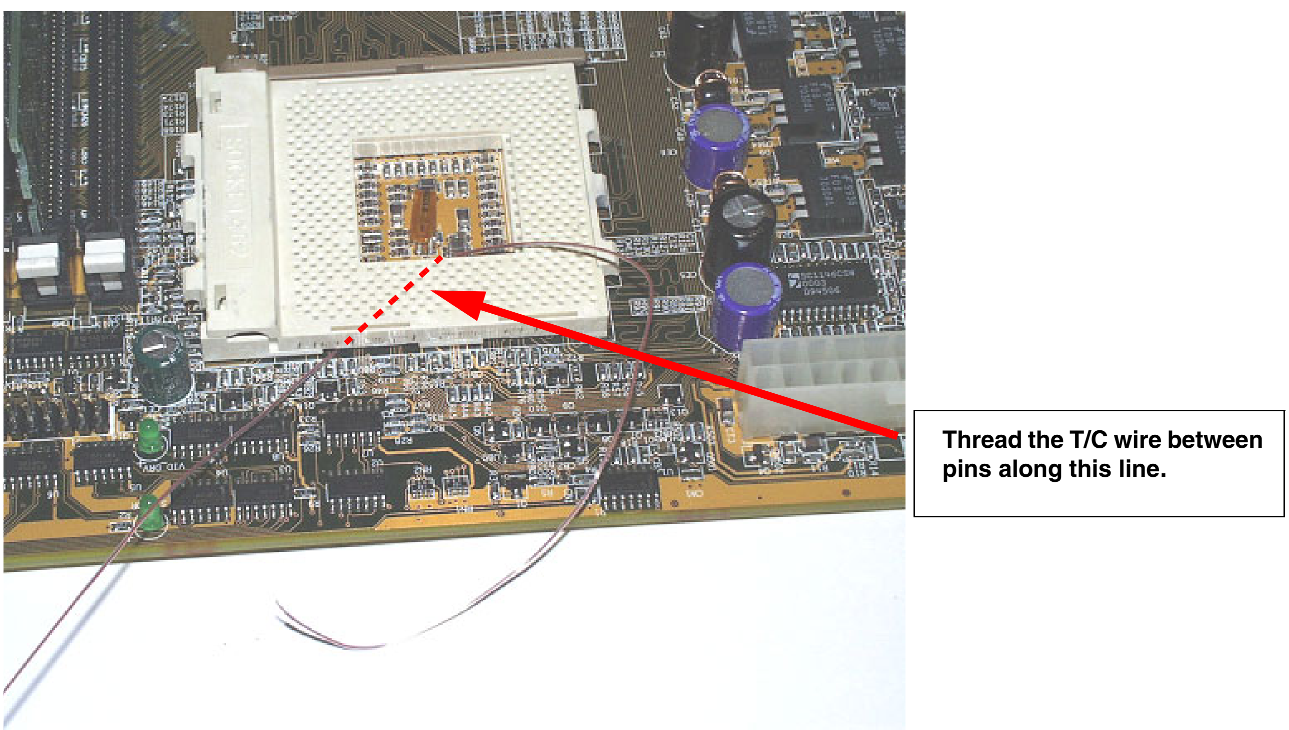


Figure 10. Thermocouple Wire Length

Figure 11 shows the placement of the thermocouple at the center of the processor die.

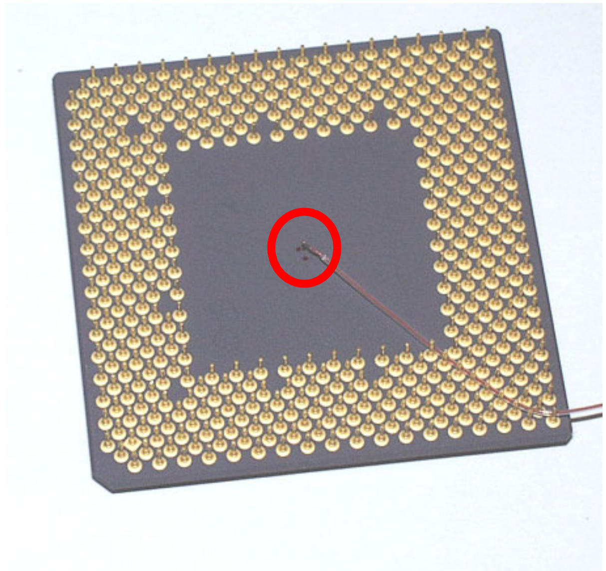


Figure 11. Placement of Thermocouple at Center of Package

Figure 12 shows the thermocouple attached to the processor die with Kapton tape.

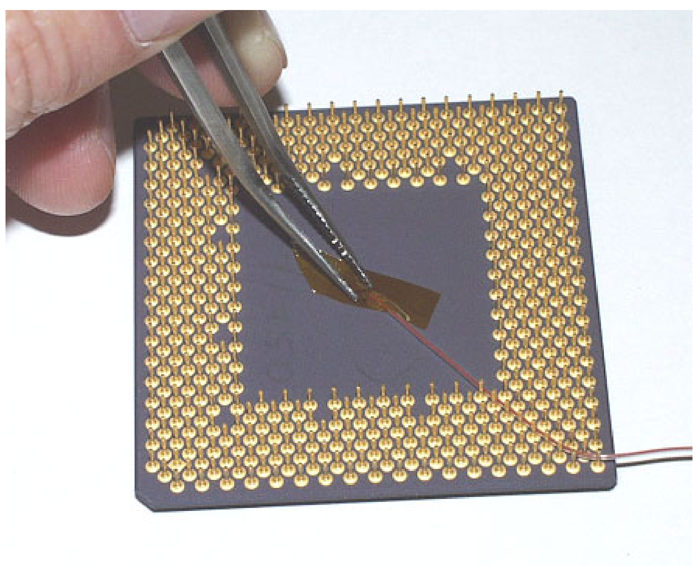


Figure 12. Thermocouple Attached with Kapton Tape

Figure 13 shows the thermocouple secured to the processor die with additional Kapton tape. The thermocouple is also bent to follow a smooth path when it is placed in the socket.

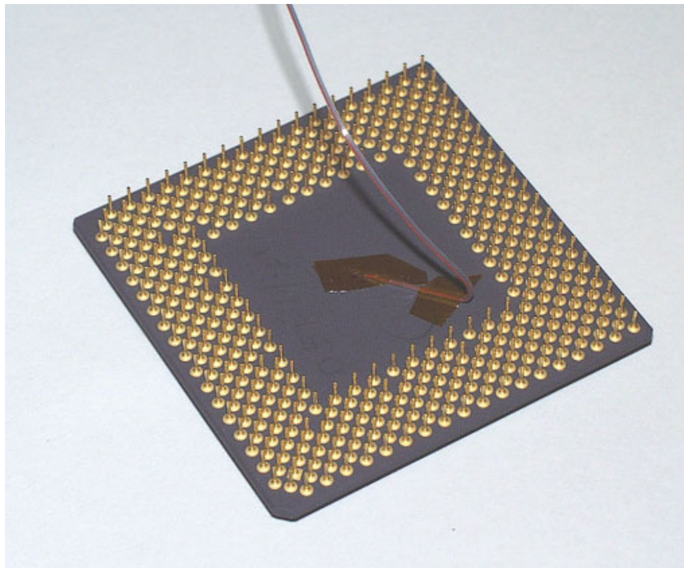


Figure 13. Thermocouple Secured with Kapton Tape and Bent

3.1.2 Alternative Routing and Attachment

The alternative method is to route the thermocouple wire between the pins of the processor package so that it ends up between the processor package and the socket. Use this alternative method only if the wire cannot be threaded under the socket. This method is often useful for low-profile sockets used in mobile applications.

1. Remove the Teflon insulation surrounding *both* thermocouple wires; do not remove the insulation from *each* individual wire.

   The insulation is removed to ensure that the processor can be seated properly in the socket.

2. Attach the thermocouple to the back of the processor as shown in steps 3 through 9 in “Preferred Routing and Attachment” on page 21”.

3. Place the thermocouple wires between the processor pins as shown in Figure 14 on page 25.

   After processor installation, the thermocouple wires are located between the processor and the socket.

Figure 14 shows the alternate placement of thermocouple wires between processor pins.

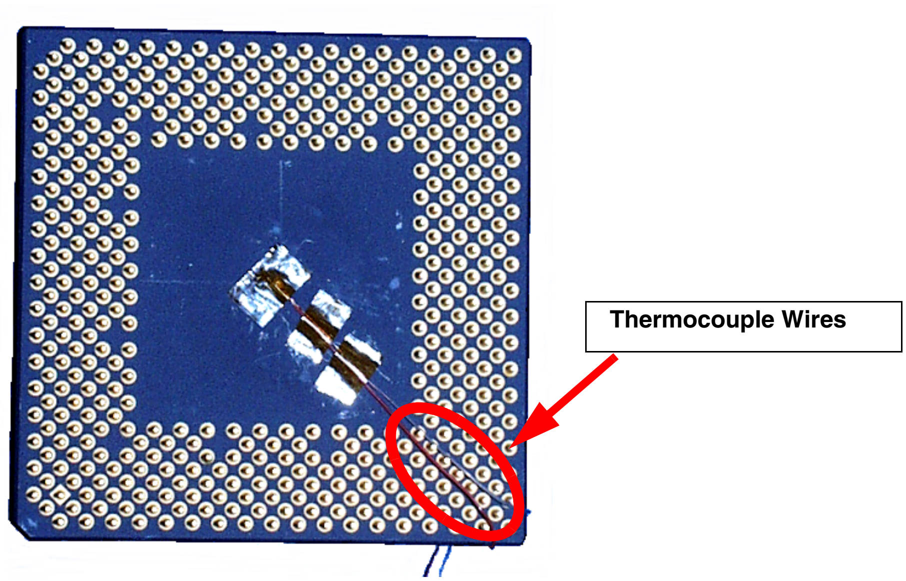


Figure 14. Alternate Thermocouple Placement

3.2 Processor Placement in the Socket

After the thermocouple has been attached to the back of the processor package, the package may be inserted into the socket. Figure 15 shows the relative position of the thermocouple wire "escape" route and the wire location on the back of the processor package.

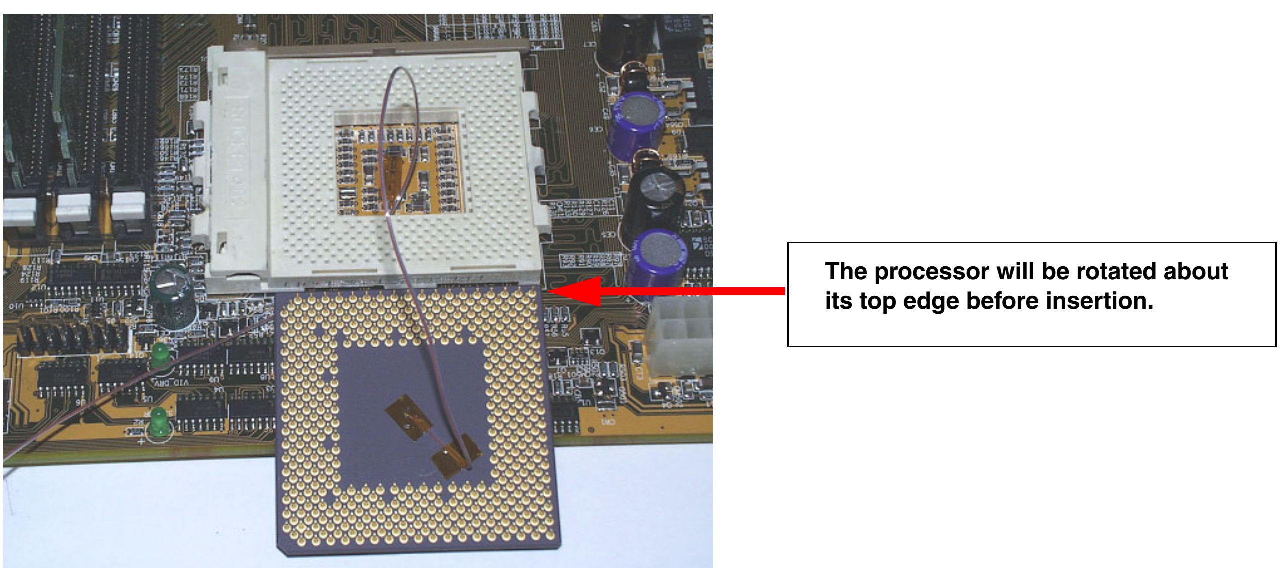


Figure 15. Processor Package and Thermocouple Ready for Insertion into Socket

1. Lower the processor package slowly onto the socket.
2. Pull the thermocouple wire carefully back through socket, removing excess wire slack as the processor is slowly lowered into position.

   Do not allow the thermocouple wire to get pinched between the processor package and its socket, and do not pull the thermocouple wire so hard as to undo the tape securing the wire to the processor package. Figure 16 shows the processor package being lowered into the socket.

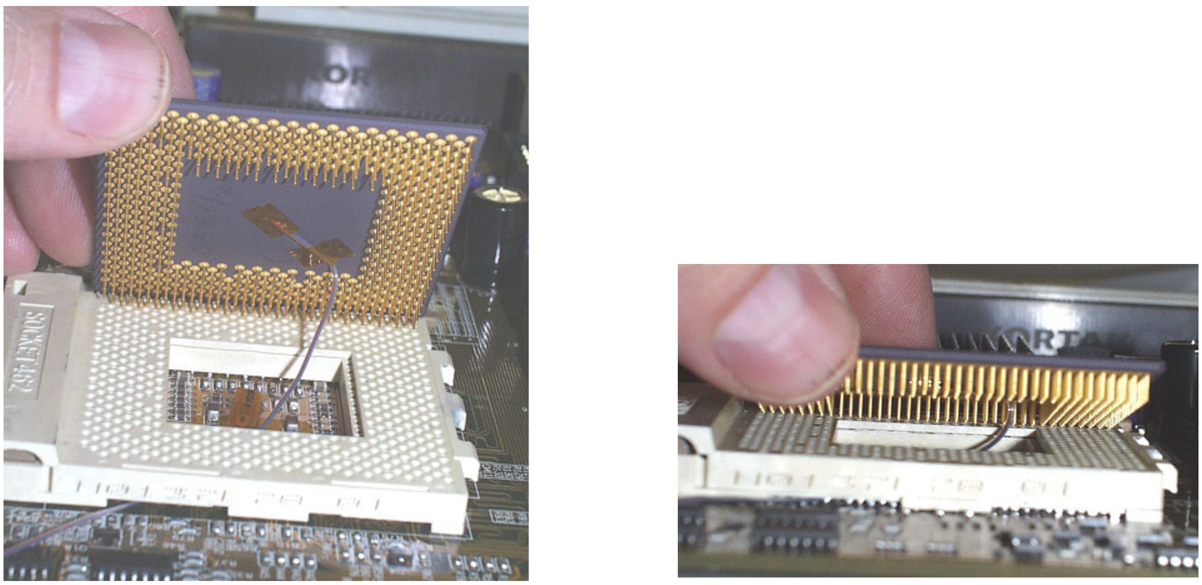


Figure 16. Lowering the Processor Package into the Socket

3. Insert the processor into the socket.

   The processor package should sit flat in the socket with no gap between the bottom of the package and the top of the socket.
4. Lower the cam-lever to lock the processor package into the socket.
5. Clean the processor die carefully, using a lint free cloth dipped in isopropyl alcohol.
6. Tape the wire near the socket for stress relief.

   Figure 17 on page 27 shows the processor package seated in the socket and the thermocouple wire extending from between the socket and the motherboard.

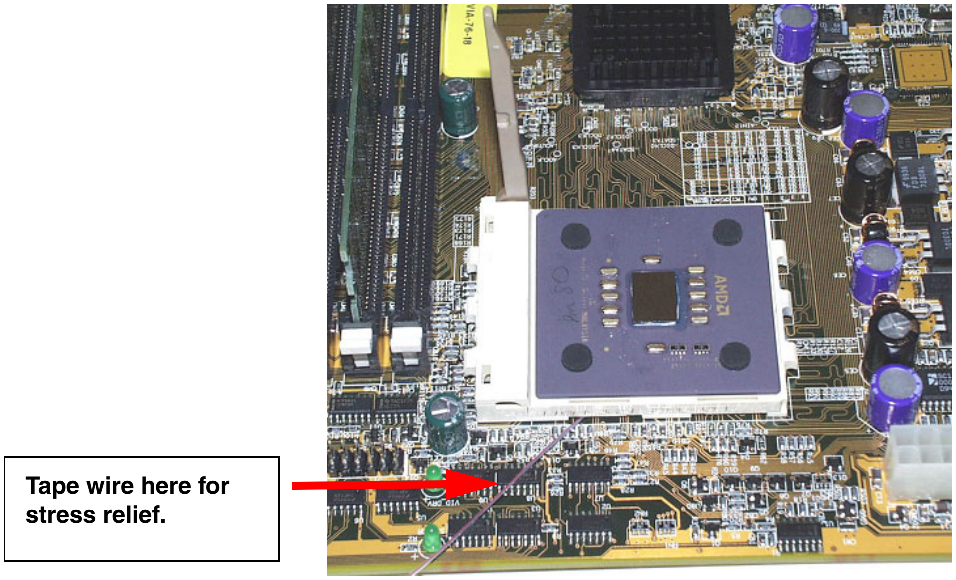


Figure 17. Processor Package Seated in Socket

3.2.1 Closing Low-Profile Socket 462 (Mobile)

Low-profile sockets do not have a cam lever to close the socket, instead, the socket is actuated using a flat-head screwdriver. Some sockets have the screwdriver contact the top lid of the socket that contacts the package to distribute the load. For sockets without this feature, distribute the actuation load to prevent damaging the package. The screwdriver should not contact the processor package when closing the socket.

Figure 18 shows a low-profile socket being closed with a screwdriver.

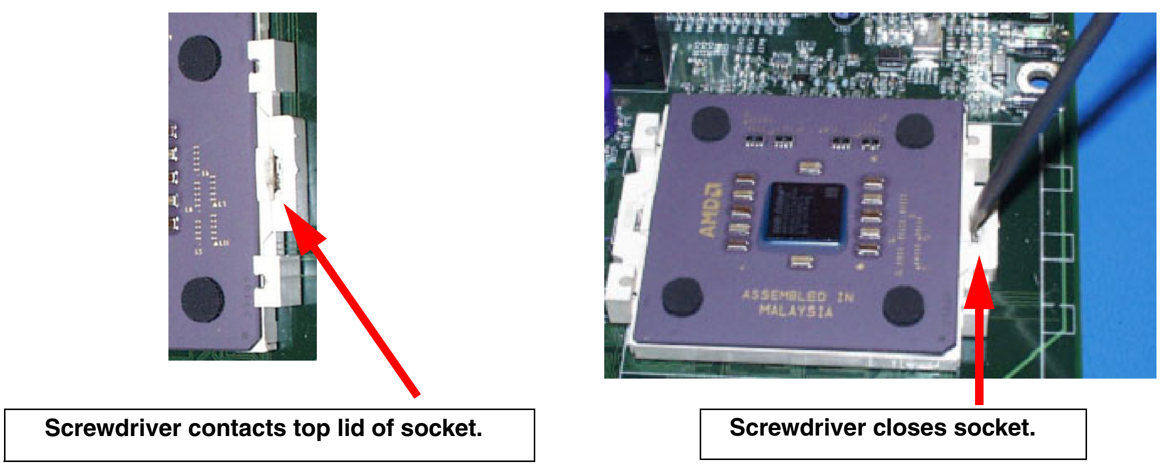


Figure 18. Low-Profile Socket 462

Chapter 4 Indirect Die-Temperature Measurement—Desktop

This chapter describes the method for indirect temperature measurement for a pin grid array (PGA) processor in a desktop form factor that does not have an on-die thermal diode and is used on a motherboard that does not have an on-board temperature sensor.

4.1 Indirect Die Temperature Measurement Steps

1. Attach thermocouple under the ceramic package and install processor as described in Chapter 3 “Indirect Die-Temperature Measurement—Processor Package Thermocouple.”
2. Install heat sink.
3. Add ambient thermocouple.
4. Measure under ceramic and ambient temperatures.
5. Find die temperature using desktop correlation for ceramic pin grid array.

4.2 Heat Sink Installation

The heatsink described in this section has a release liner protecting the phase-change interface material. Figure 19 on page 30 shows the release liner in place. Other heatsinks may differ in appearance.

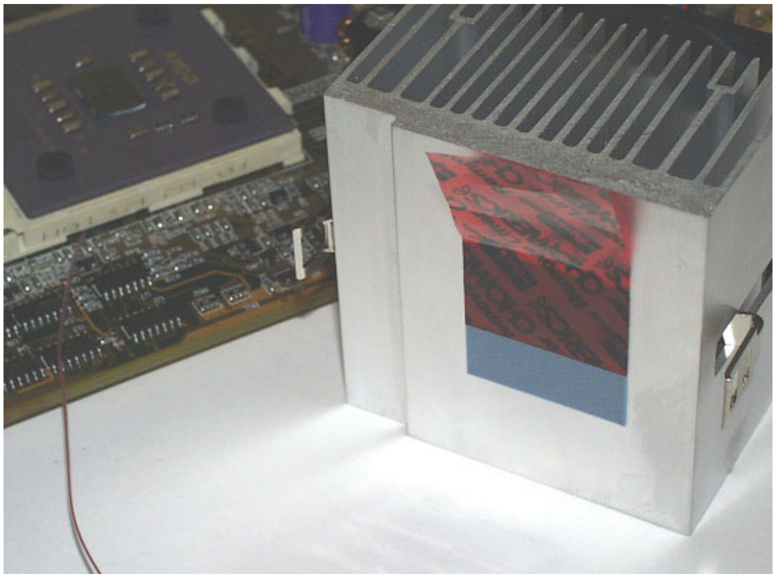
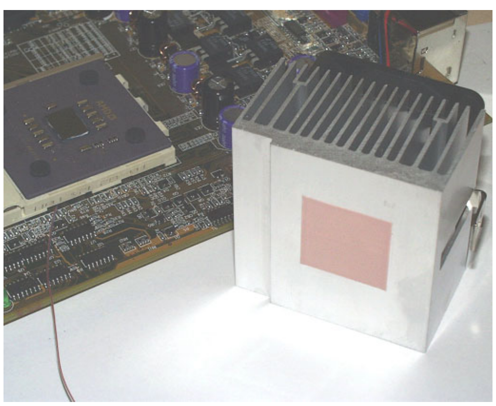
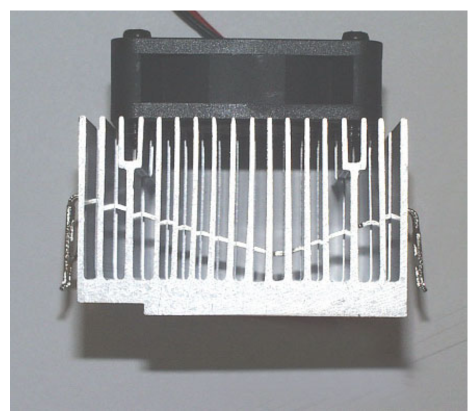


Figure 19. Heatsink with Release Liner in Place

Figure 20 shows bottom and side views of a single-point contact-clip heatsink.



Bottom-view showing the phase-change interface material without the release liner.



Side-view showing step for cam-box clearance

Side-view showing support pads that prevent an unclipped heatsink from touching the die.

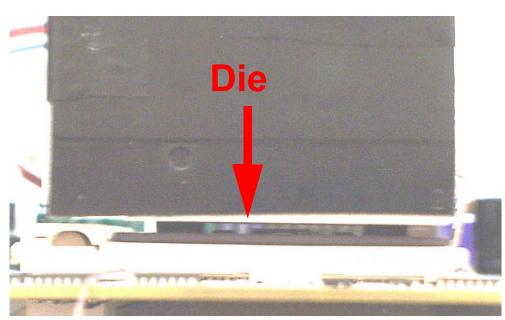


Figure 20. Bottom and Side Views of a Single-Point Contact-Clip Heatsink

Follow these steps to install the heatsink.

1. Remove the release liner from interface material with a quick 90° pull from the heat sink base.
2. Attach the clip to the non-cam side of socket.
3. Attach the clip on the cam-side of the socket using a small screwdriver.
   a. Position the clip over the socket tab with a screwdriver.
   b. Pull the screwdriver back and push down to install clip on the socket tab.

4.3 Ambient Thermocouple Installation

To record ambient temperature, a thermocouple must be installed above the inlet side of the heatsink fan. The thermocouple wire must be supported by a stiff yet bendable support wire.

1. Attach the support wire with tape to a convenient surface on the heatsink.

   Do not interfere with the natural airflow of the heatsink.
2. Bend the support wire to locate the thermocouple bead approximately 0.75 inch to 1 inch above the fan surface on the inlet side of the fan.

   This location avoids a dead zone of air.
3. Tape the thermocouple wire to the support wire so that the thermocouple is centered above the fan hub.

   For side-mounted fans, the thermocouple should be mounted on the inlet side and centered relative to the fan hub.

Figure 21 shows a support wire attached to the heatsink.

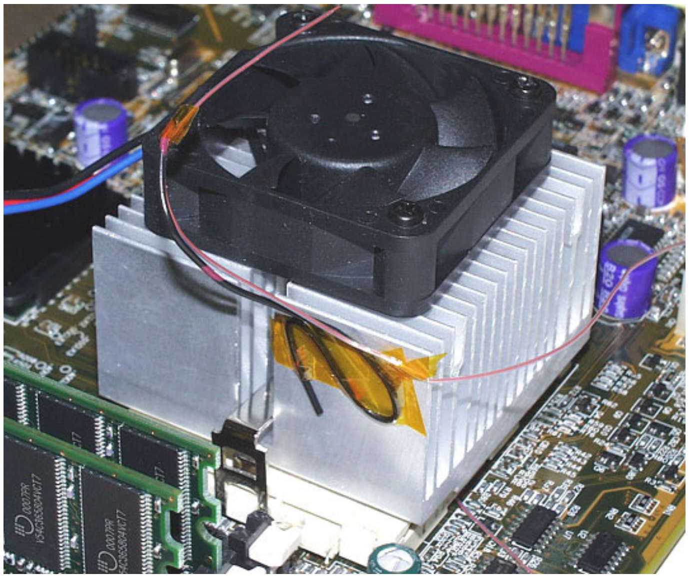


Figure 21. Thermocouple Support Wire

Figure 22 shows the thermocouple centered above the fan hub.

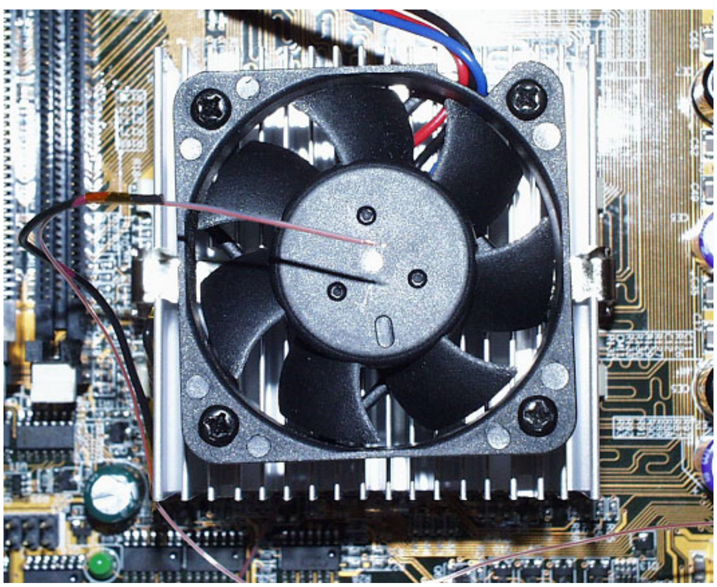


Figure 22. Thermocouple Centered Above the Fan Hub

4.4 Sample Desktop Correlation for Indirect Die-Temperature Methods for Ceramic PGA

Figure 23 shows an example of desktop correlation for indirect die-temperature methods for ceramic pin grid array (CPGA) processors. This example applies only to CPGA processors and is for reference only. The measurements were performed for one interface attachment to a thermal test vehicle in a natural convection environment. Power was varied to create correlation. The interface material used was Chometrics T725. An asymmetric single-point clip was used for loading. C3 and B3 are centered-diode locations; D2 is on the edge toward the CAM.

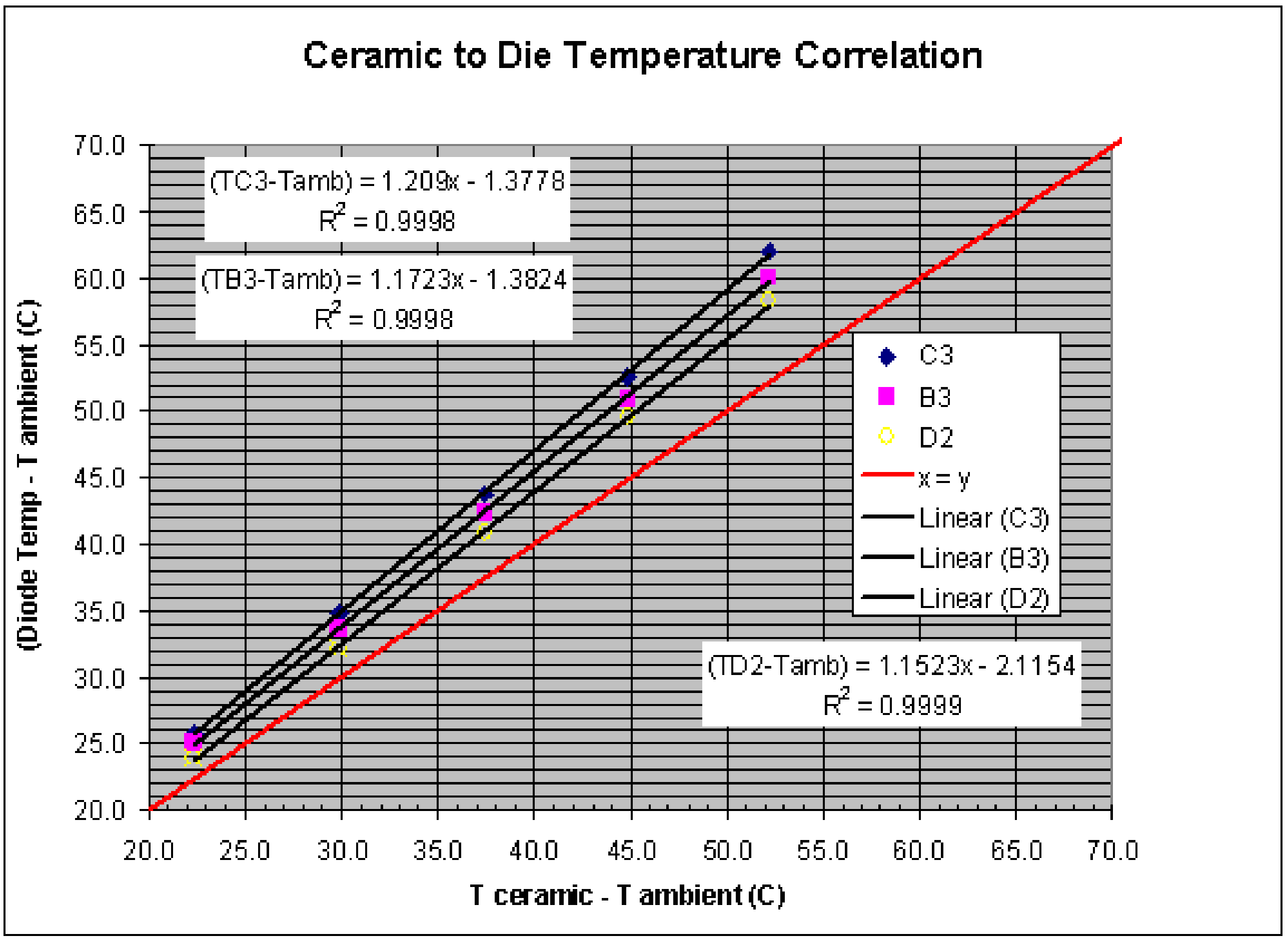


Figure 23. Sample Desktop Correlation—Typical Residual ±2ºC for Centered Clip

4.5 A Desktop Example for Ceramic Pin Grid Array Processors Only

Use the formula in Equation (1) to calculate the temperature of the processor die.

$$T_{die} = (1.209 \times (T_{ceramic} - T_{amb}) - 1.3778) + T_{amb} \quad \textbf{(1)}$$

Where T_{amb} is the ambient temperature, local to the heatsink (It is the measurement of inlet air temperature before the fan.), and $T_{ceramic}$ is the temperature measured on the back side of the processor.

For example, in one measurement $T_{ceramic}$ = 80ºC and T_{amb} = 45ºC.

From Equation (1) above,

$$T_{die} = (1.209 \times (80ºC - 45ºC) - 1.3778) + 45ºC$$

Therefore,

$$T_{die} = 40.9ºC + 45ºC = 85.9ºC$$

This example shows a 5.9ºC offset from the ceramic temperature to the die temperature (85.9ºC – 80ºC = 5.9ºC). A particular offset will vary depending on the processor power and the particular thermal performance of the heatsink used. Compare the T_{die} as determined by Equation (1) to the die temperature specification for the processor under test, and ensure that the system does not allow the processor to operate over its temperature rating.

4.6 How to Perform Desktop System Measurements

For information on how to perform desktop system thermal measurements, see *Thermal Testing Methodology for Characterized AMD Desktop Processors Application Note*, order# 24362.

4.7 Interface Analysis—Post Measurements

Remove the heatsink and compare the interface material on the bottom of the heatsink with that on the processor die. The interface thickness should be uniform, with voids on the one should matching excess material on the other. If the interface material is more transparent on one side, then the clip load may not have been applied in the center of the die.

Figure 24 shows the heatsink and the processor like a sandwich that has been "unfolded" along the hinge line.

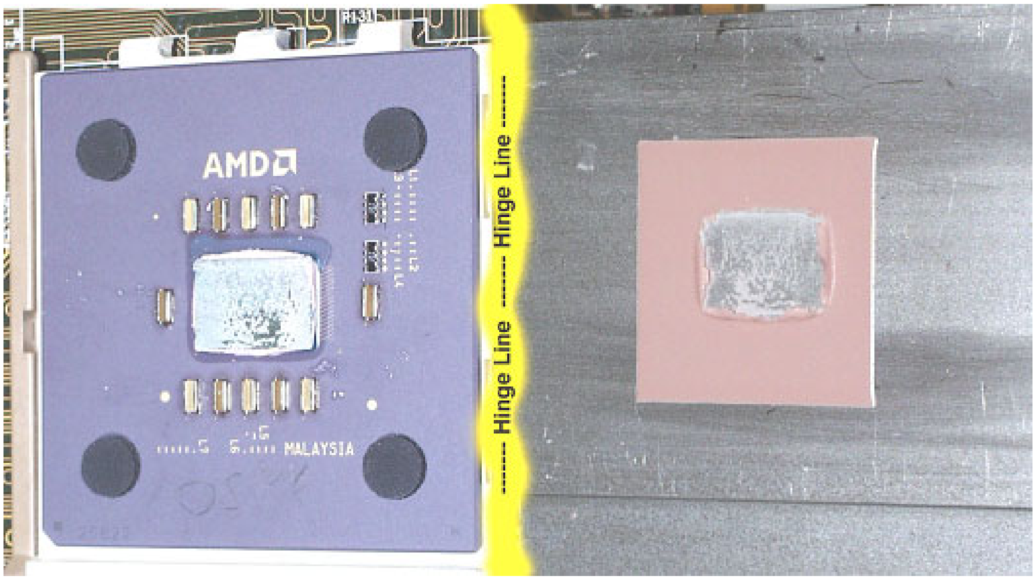


Figure 24. Interface Material After Measurements

4.8 Heatsink and Processor Clean-up

After measurements have been taken the interface material should be cleaned from the heatsink and the processor. The bulk of the material will be on the heatsink and may be scraped off with a plastic scraper or the edge of an old printed circuit board. Be careful not to mar the aluminum surface of the heatsink. Use alcohol to remove any remaining interface material from the heatsink. Very carefully clean the surface of the processor die with alcohol. Do not remove the support pads or contaminate them with the solvent.

Chapter 5 Indirect Die Temperature Measurement—Mobile

This chapter describes the method for indirect temperature measurement for a pin grid array (PGA) processor in a mobile form factor that does not have an on-die thermal diode and is used on a motherboard that does not have an on-board temperature sensor.

This mobile system temperature measurement methodology has been verified for single-sided thermal implementations that contact the back side of a ceramic pin grid array (PGA) processor. The back-side ceramic temperature is referenced to a temperature measurement in the heatsink block, about 2 mm above the die surface. Figure 25 shows a single-sided mobile implementation.

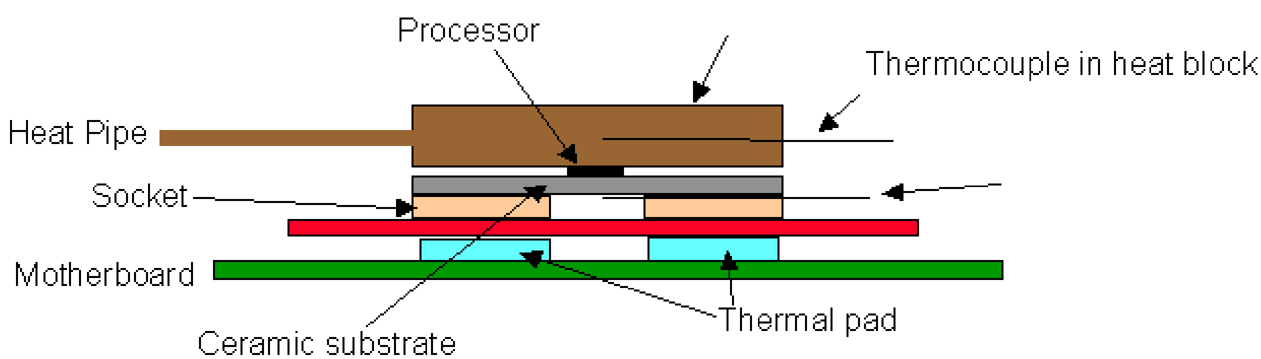


Figure 25. Single-Sided Mobile Implementation

This methodology does not apply to dual-sided ceramic designs where the design has an aluminum block in direct contact with the underside of the ceramic PGA package to remove heat to a heatsink below the motherboardas well as a heat block contacting the back of the processor die. Also, this methodology is inappropriate for organic PGA processors.

This methodology is intended for system characterization. It is not intended as a production measurement method for controlling the temperature of a processor.

5.1 Mobile System Temperature Measurement Procedures

There are two ways to measure the temperature in a mobile system. The preferred method involves drilling a hole in the heatsink block in which the thermocouple is placed. The alternative method is to attach the thermocouple to the side of the heatsink block that contacts the processor die. Use the alternative method only if the heatsink block cannot be drilled.

5.1.1 Preferred Mobile System Temperature Measurement Procedure

If the heatsink block can be drilled, use the following temperature measurement procedure.

1. Attach a thermocouple to bottom of the ceramic PGA package in the same fashion as previously shown in Chapter 3 "Indirect Die-Temperature Measurement—Processor Package Thermocouple."
2. Insert a thermocouple into the heatsink block.
   a. Drill 2 mm above the die to a position that is directly over the center of the processor.
      – Use a 0.053" diameter drill bit, or a comparable substitute.
      – Measure to verify the depth and position of the hole.
   b. Fill the hole with a high conductivity thermal grease.
   c. Mark on the thermocouple wire the depth needed to reach the end of the hole directly over the center of the processor.
   d. Insert thermocouple into hole.
   e. Ensure that thermocouple reaches the depth of the hole directly over the center of the processor by checking the mark on the thermocouple wire.

   See the *AMD Thermal, Mechanical, and Chassis Cooling Design Guide*, order# 23794, for more details.
3. Record backside ceramic and heatsink block temperatures during system characterization.
4. Calculate the die temperature using the correlation equations.

5.1.2 Alternative Mobile System Temperature Measurement Procedure.

If the heatsink block cannot be drilled, use the following temperature measurement procedure.

1. Attach the thermocouple to the heatsink block on the side that contacts the processor die.
2. Route the thermocouple out, so that it does not interfere with components on top of the processor package.

Figure 26 shows the thermocouple attached to the outside of the heatsink block.

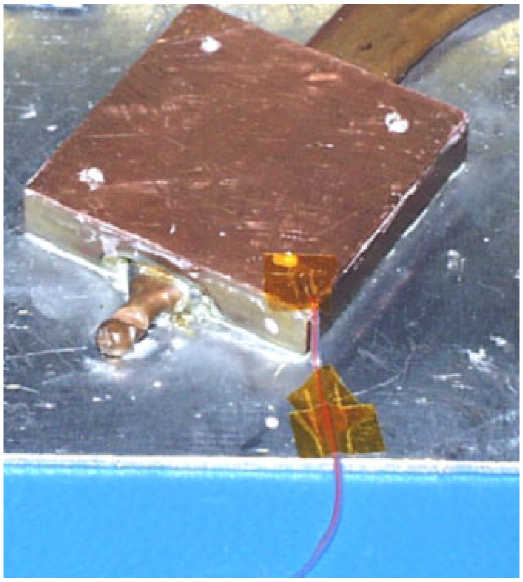


Figure 26. Thermocouple Attached to Heatsink Block

5.2 Sample Desktop Correlation for Indirect Die-Temperature Methods for Ceramic PGA

Figure 27 shows an example of mobile correlation for indirect die-temperature methods for ceramic pin grid array (CPGA) processors. This example applies only to CPGA processors and is for reference only. The measurements were performed for one interface attachment to a thermal test vehicle. Power was varied to create correlation. The interface material used was Chometrics T725.

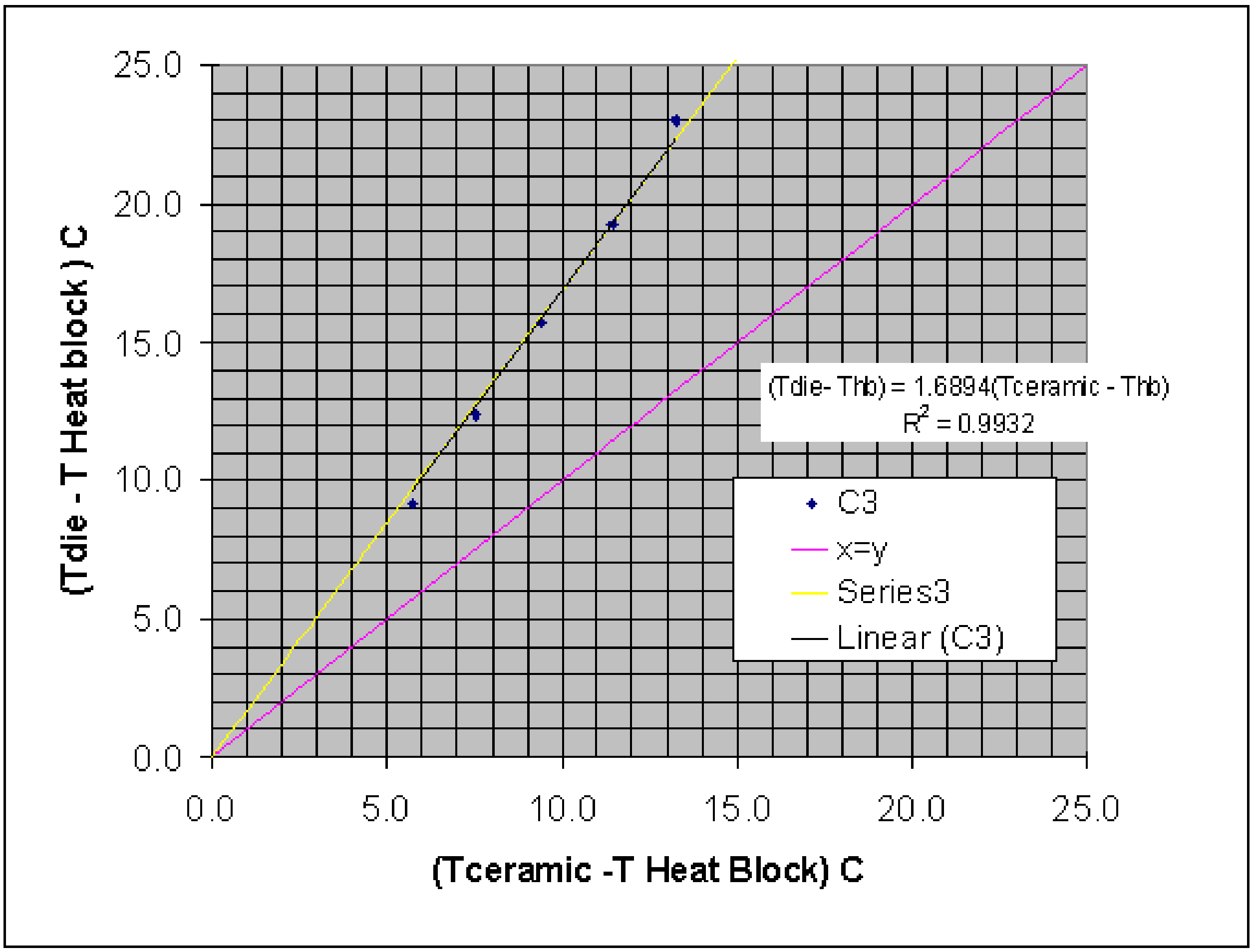


Figure 27. Sample Mobile Correlation

5.3 A Mobile Example for Ceramic Pin Grid Array Processors Only

Use the formula in Equation (2) to calculate the temperature of the processor die.

$$T_{die} = 1.6894 \times (T_{ceramic} - T_{heatsink\ block}) + T_{heatsink\ block} \quad \textbf{(2)}$$

Where $T_{heatsink\ bloc}$ is the temperature of the heatsink block, and $T_{ceramic}$ is the temperature measured on the back side of the ceramic PGA package.

For example, in one measurement $T_{ceramic}$ = 60ºC and $T_{heatsink\ block}$ = 52ºC.

From Equation (2) above,

$$T_{die} = 1.6894 \times (60ºC - 52ºC) + 52ºC$$

Therefore,

$$T_{die} = 13.5ºC + 52ºC = 65.5ºC$$

This example shows a 5.5ºC offset from the ceramic temperature to the die temperature (65.5ºC – 60ºC = 3.5ºC). This offset will vary depending on the processor power and the actual thermal performance of the heatsink.

Compare this number to the die temperature specification for the processor being tested, and ensure that the system does not allow the processor to operate over its temperature rating.

5.4 Interface Analysis and Clean-up

Remove the heatsink and compare the interface material on the bottom of the heatsink with that on the processor die. The interface thickness should be uniform, with voids on the one should matching excess material on the other.

After measurements have been taken the interface material should be cleaned from the heatsink and the processor. The bulk of the material will be on the heatsink and may be scraped off with a plastic scraper or the edge of an old printed circuit board. Be careful not to mar the aluminum surface of the heatsink. Use alcohol to remove any remaining interface material from the heatsink. Very carefully clean the surface of the processor die with alcohol. Do not remove the support pads or contaminate them with the solvent.