Intel® Atom™ Processor E6xx Series Thermal Test Board

User Guide

September 2010

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Revision History

Rev. No.	Description	Rev. Date
1.0	Initial Release	June 2010
2.0	First SKU launch	September 2010

1 Introduction

A thermal test board is provided by Intel to aid in embedded system thermal designs for the latest Intel embedded processor product, Intel® Atom™ Processor E6xx Series. Figure 1 and Figure 2 show a side, and top/bottom view of the Intel® Atom™ Processor E6xx Series thermal test vehicle (FCBGA package).

Figure 1. Side View of Thermal Test Vehicle Package

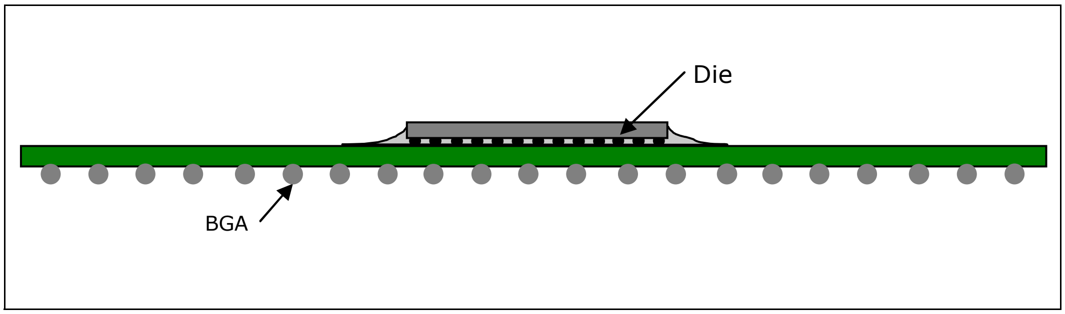
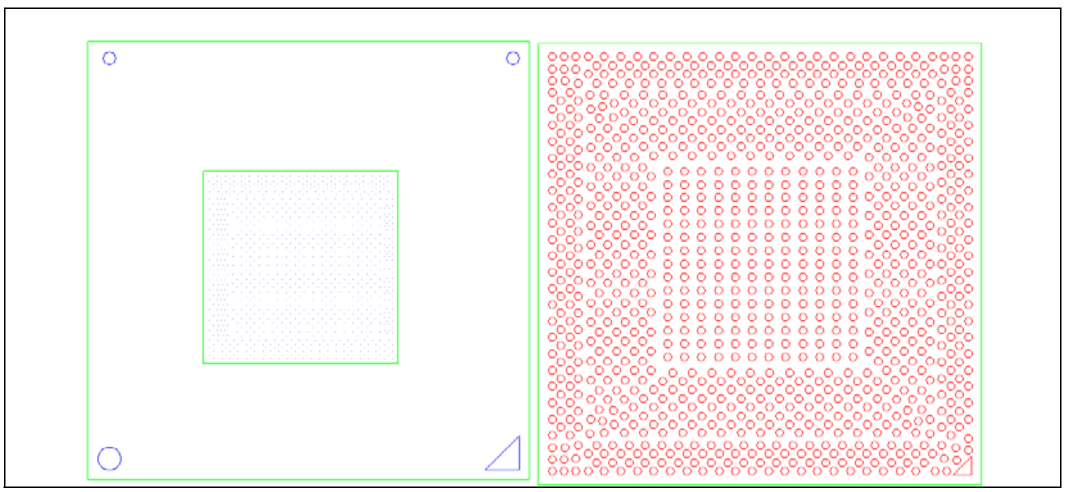


Figure 2. Top and Bottom View of Thermal Test Vehicle Package



The thermal test board (TTB) is designed to be used with an FCBGA thermal test vehicle to facilitate proper connections to the various heaters and temperature sensor structures. Test vehicle structures are accessible through TTB as per information given in Appendix A. Additionally, a Gerber file for the TTB can also be available from your Intel representative. This Gerber file can be modified to resemble a notebook planar board. Please contact your Intel representative for obtaining any TTB boards, or its Gerber file.

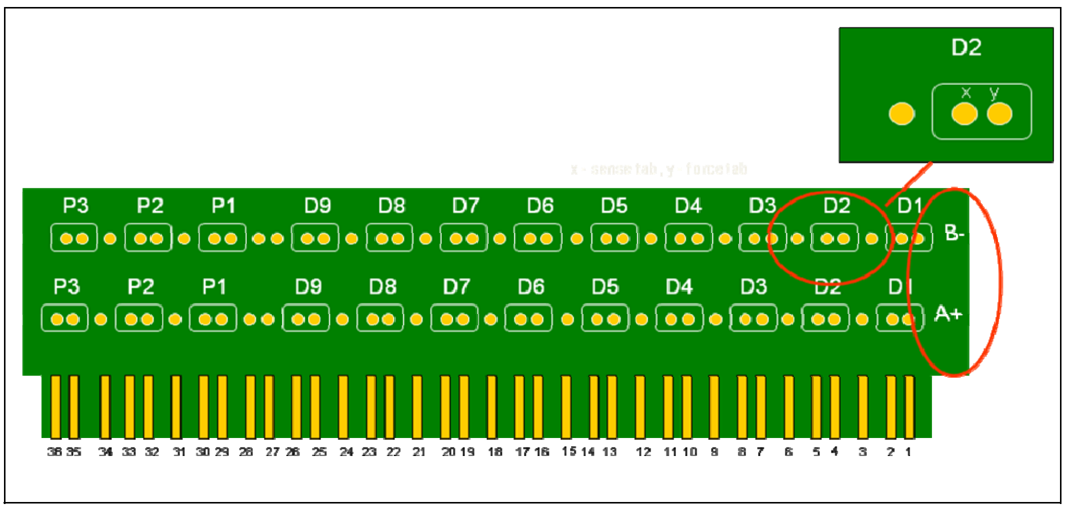
To use an FCBGA thermal test vehicle, it must be surface mounted onto a test board. The test vehicle structures can be accessed as per the pin/ball map, as shown in Appendix A.

2 Intel® Atom™ Processor E6xx Series Thermal Test Board

The enabling thermal test board (TTB), designed for FCBGA type packages, is 5.5 inches long, and 4 inches wide. Figure 3 shows the layout for the PCB (designed by Intel) to power and read temperature from the Intel® Atom™ Processor E6xx Series thermal test vehicle through edge connector, from 1 to 36. The connections are also designed for through-hole pin headers temperature measurement from D1 to D9, for both A+ and B-, where A+ is the set of top tabs and B- are connected to the tabs on the lower side of board. The through via-pairs are separately routed and are distinguished as x and y, x being the on the higher tab number or placed to the left side of the y. P1 to P3 are designed for heater connection.

There are a total of 4 holes provided in the TTB for heat sink/thermal solution attachment (refer to Figure 13).

Figure 3. Thermal Test Board Designed for the Intel® Atom™ Processor E6xx Series Thermal Vehicle



3 Intel® Atom™ Processor E6xx Series Thermal Test Vehicle

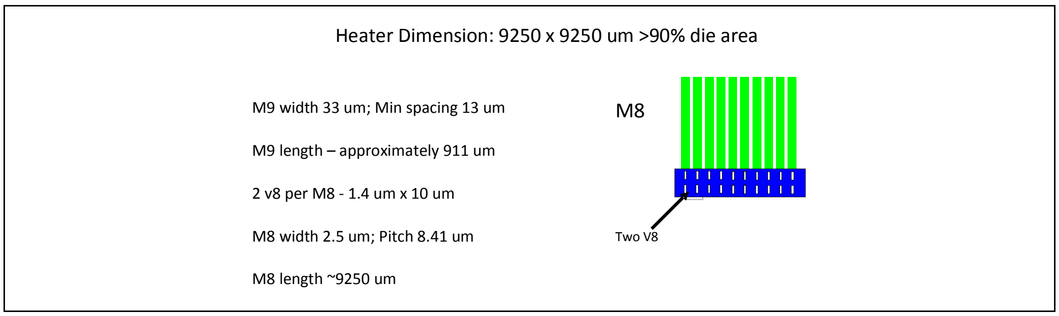
3.1 Thermal and Electrical Vehicle Characteristics

This section describes the thermal attributes of the thermal test vehicle (TTV), electrical connections of the heater and temperature sensors, temperature measurements, and test vehicle specifications. The thermal test vehicle includes heaters to simulate component power levels and temperature sensors to monitor the component temperatures.

3.1.1 Heaters

3.1.1.1 Heater Dimension

Figure 4. Heater Dimension on the Test Chip



3.1.1.2 Heater Connectivity and Locations

- Each group of five FH and five FL bumps are shorted together on substrate and connected to 3 BGA each.
- 5 uvias and PTH is required on each layer for each FH and FL pinouts.
- For whole die heating connect HTR_FH/MH and HTR_FL/ML. Otherwise, half die heating.

Table 1. Heater Connectivity on the Thermal Test Vehicle

Net Name	Package Pin
HTR_FH	A1.G13 A1.H12 A1.J13
HTR_MH	A1.H15
HTR_FI_FH	A1.G25 A1.H24 A1.J25
HTR_FI_MH	A1.H26
HTR_FL	A1.G39 A1.H40 A1.J39
HTR_ML	A1.H37

Figure 5. Heater Layout on the Test Chip

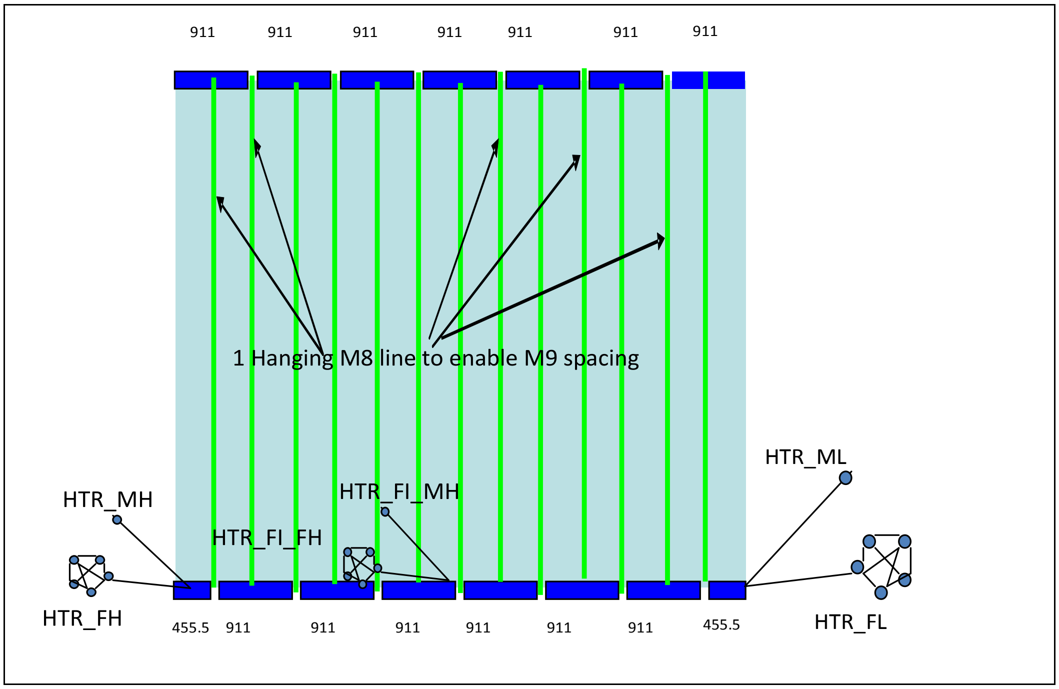
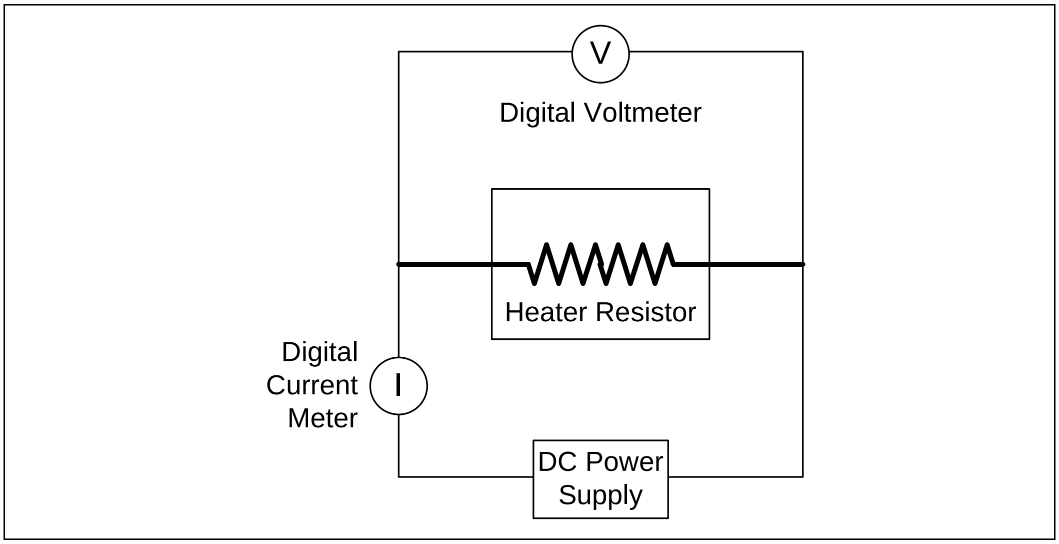


Figure 6. Electrical Connections to Power the Heater on the Test Chip While Monitoring Voltage and Current



3.1.2 Temperature Sensors

Resistive Temperature Detector (RTD) type temperature sensors are used. Here the temperature sensors measure the die temperature by using a linear relationship between either the sensor resistance, or the voltage drop across the resistor, and the sensor temperature. For example, as the temperature increases, the measured voltage drop across the temperature sensor increased for a given constant current condition. By calibrating this sensor voltage drop with respect to temperature, one can determine the device temperature from voltage measurements.

Note: Both measurement methods (constant current, and 4-wire resistance measurement) produce comparable accuracy. The choice of measurement method can be decided by the user depending upon the available instrumentation.

There are a total of 6 temperature sensors on the test chip. TS_DC is recommended to mimic hot-spots location on the actual processor silicon.

Table 2. Electrical Connections of the Temperature Sensor for 4-Point Measurement

Test Type	Test Name	Netnames		Package Pin			
		Force	Measure	Force High	Measure High	Force Low	Measure Low
RES	TS_BL	TS_BL_FH	TS_BL_FL	A1.V7	A1.T7	A1.U6	A1.W6
RES	TS_BR	TS_BR_FH	TS_BR_FL	A1.L45	A1.R46	A1.N45	A1.M46
RES	TS_DC	TS_DC_FH	TS_DC_FL	A1.BE16	A1.BD17	A1.BD15	A1.BE18
RES	TS_RE	TS_RE_FH	TS_RE_FL	A1.AE45	A1.AH44	A1.AF44	A1.AG45
RES	TS_TL	TS_TL_FH	TS_TL_FL	A1.AY6	A1.BB6	A1.AW7	A1.BA7
RES	TS_TR	TS_TR_FH	TS_TR_FL	A1.AW45	A1.BB46	A1.AY46	A1.BA45

An example of the electrical connection schematic for the temperature sensors is illustrated in Figure 8. Here, for 4-wire measurement, a 1 mA constant current source is applied to the temperature sensor while a multi-meter is used to measure the voltage across the temperature sensor.

Figure 7. Schematic of Temperature Sensor Locations

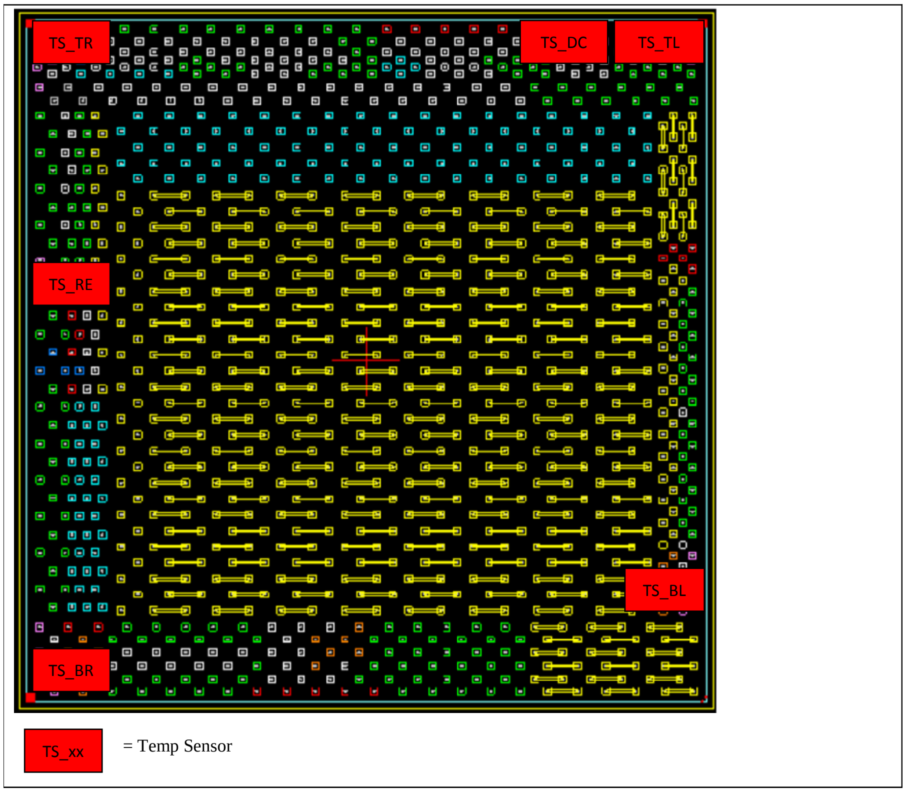
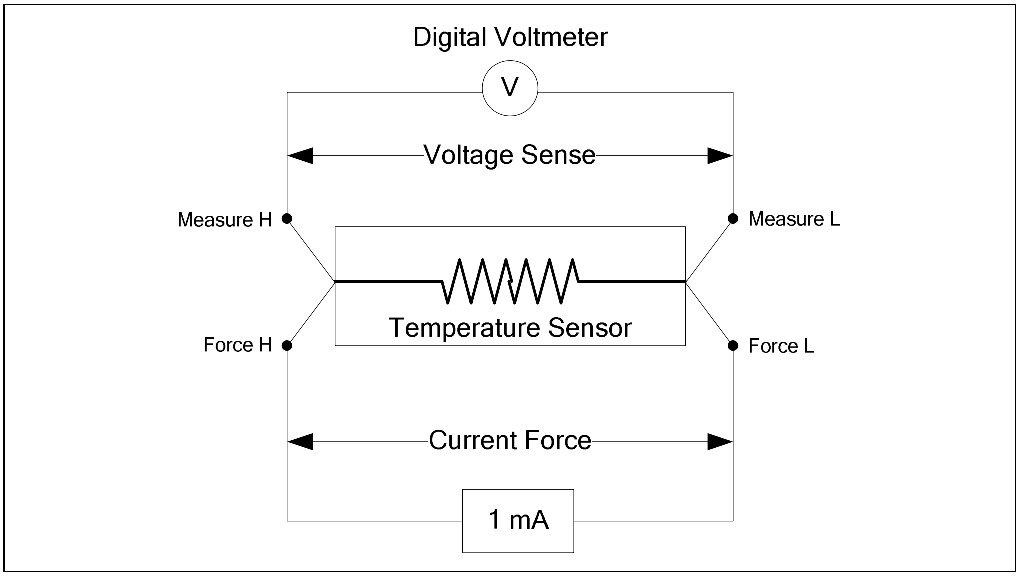


Figure 8. Example of Electrical Connections of 'Die-Center' Temperature Sensor for 4-Point Measurement



3.2 Temperature Sensor Usage

This section describes temperature sensor calibration and measurements.

3.2.1 Temperature Sensor Calibration

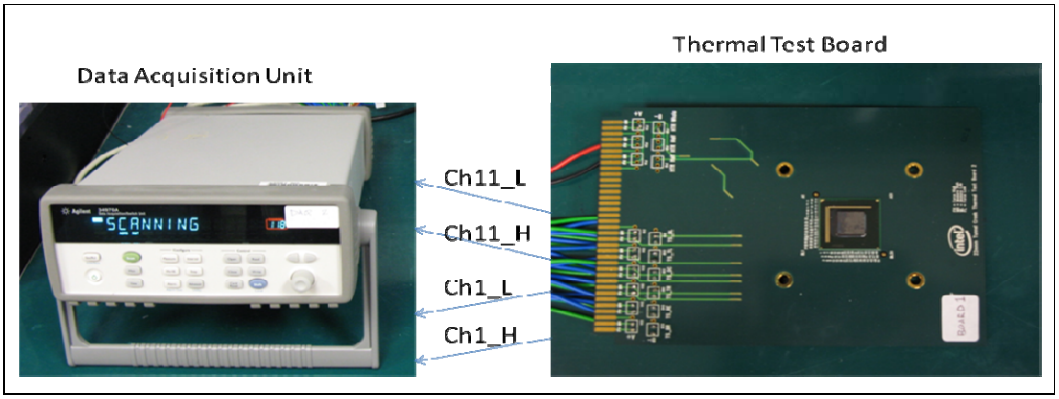
Before the thermal vehicle can be used for system thermal characterization, the temperature sensors must be calibrated in the manner described in one of the following sections. The sensors should be calibrated preferably in a constant temperature chamber, otherwise the sensor will require a larger amount of time to soak and reach steady state.

3.2.1.1 Four-Wire Resistance Calibration

A four-wire resistance calibration requires the use of a multi-meter or a data acquisition unit that is designed to accept inputs for a four-wire measurement. Each of the sensors should be instrumented in a manner similar to the one shown in Figure 9.

Warning: Do not use a two-wire resistance measurement for calibration or thermal testing because it may result in inaccurate temperature measurements. For more details on the differences between a two-wire and four-wire measurement, refer to Appendix D.

Figure 9. Example of Four-Wire Resistance Measurement Setup



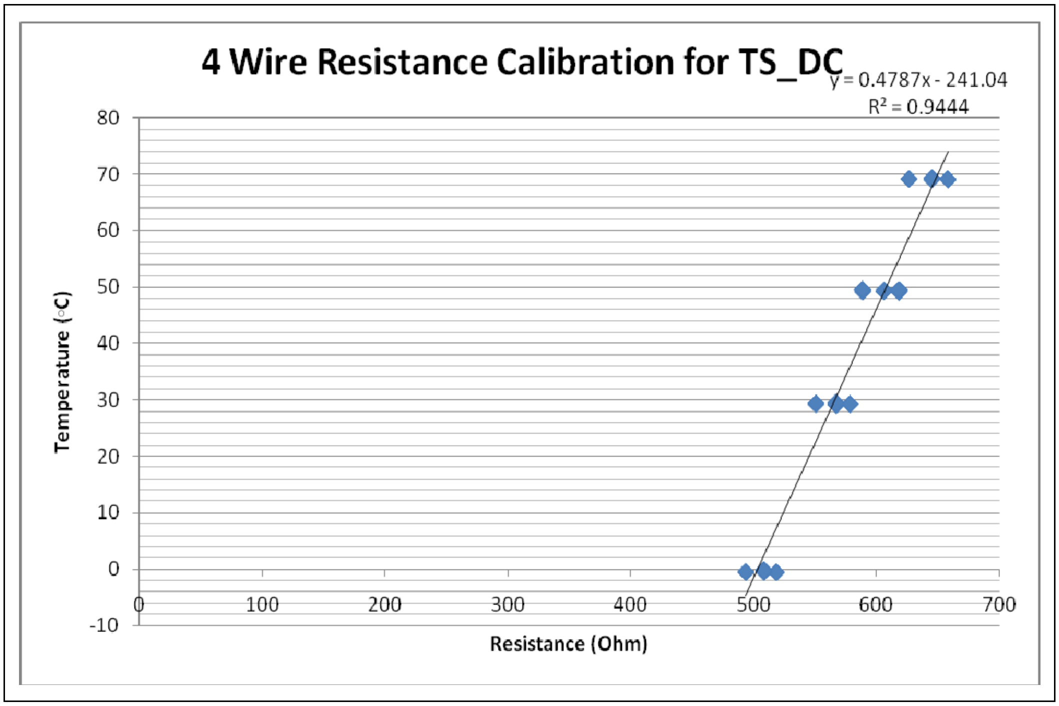
The calibration procedure is as follows:

1. Connect the temperature sensor to a multi-meter or a data acquisition unit that is capable of taking four-wire resistance measurements. Refer to the example shown in Figure 9.
2. Place the thermal vehicle in a constant temperature bath, using 0º C as the initial temperature setting. Soak the unit for a sufficient amount of time in order to allow the thermal vehicle to reach thermal equilibrium with the bath.
3. Measure the resistance of the temperature sensor and record the thermal bath temperature.
4. Reset the temperature of the thermal bath to 30º C and continuously monitor the bath temperature and temperature sensor resistance. Wait for a sufficient amount of time until the bath and thermal vehicle reach thermal equilibrium. At thermal equilibrium, the bath temperature and temperature sensor resistance will not change. Record the bath temperature and temperature sensor resistance.
5. Repeat step 4 for 50º C and 70º C.
6. Perform a linear regression analysis on the measured data to determine a linear calibration curve.

```
(Sensor Temperature) = (Sensor Resistance) * SLOPE + INTERCEPT
```

7. Refer to Figure 10, for the temperature sensor TS_DC calibration plot for the four-wire measurement method. Y = 0.4787X – 241.04.
8. Each sensor will vary from this performance curve and thus the example plot must not be used to determine temperature on any other sensors.

Figure 10. Example of Thermal Die Sensor (TS_DC) Characteristics Using a Four-wire Resistance Calibration



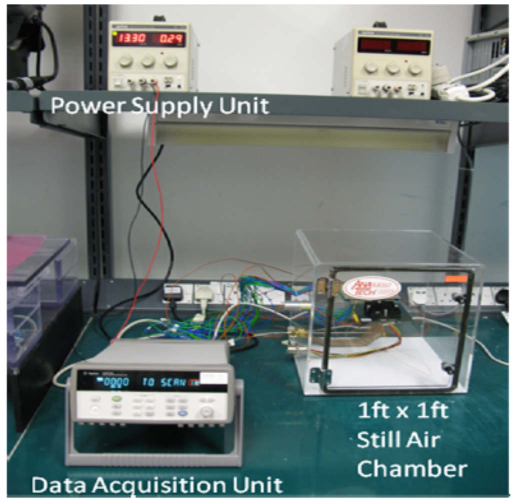
3.2.2 Temperature Measurements

After the temperature sensors are calibrated, they can be used to determine sensor temperatures during thermal testing with the following procedure:

1. Place the test vehicle in the system or thermal solution to be tested.
2. For a constant current method, connect the temperature sensors of the test vehicle to a 1-mA constant current source and a voltage meter as shown in Figure 9. and Figure 12. For a 4-wire measurement use a setup similar to Figure 10.
3. Power up the heaters in the test vehicle to the desired power level.
4. Wait for the system to reach thermal equilibrium.

Record the sensor voltage drop (or resistance) for each of the temperature sensors. Calculate the temperature being measured by using the sensor voltage drop (or resistance) and temperature calibration charts for each sensor.

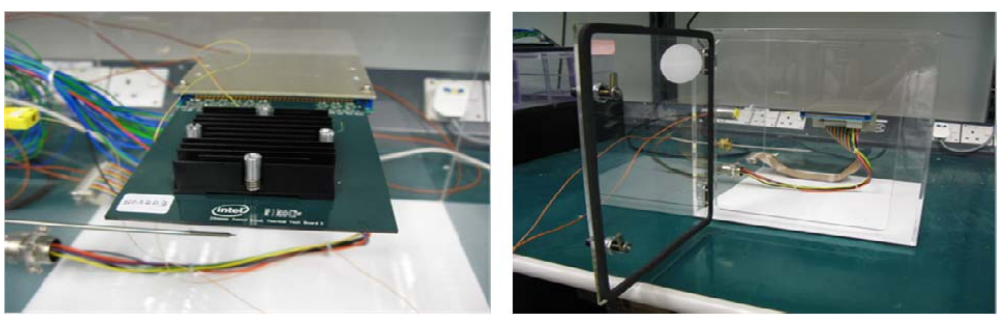
Figure 11. Temperature Measurement Setup



3.2.3 Thermal Solution and Still Air Chamber

Characterization has to be done with thermal solution. Attached the thermal solution on the thermal test vehicle, and place the thermal test board into still air chamber (dimension 1ft x 1ft), see Figure 12. Do not power the heaters without a system thermal solution attached to the die.

Figure 12. Thermal Solution and Still Air Chamber for Temperature Measurement



Thermal Solution 1ft x 1ft Still Air Chamber

4 Summary

This document describes how to use the Intel® Atom™ Processor E6xx Series thermal test vehicle provided by Intel to aid in the design of embedded system thermal solutions. To use the FCBGA thermal test vehicles, a test board and sensor calibration is required. To use FCBGA test vehicles, it must be directly attached to a test board, and then calibrated.

Note: The information in this document is preliminary and subject to change. Please contact your Intel representative for the latest available information or with any questions related to the usage of this product.

Appendix A - Thermal Test Board Design

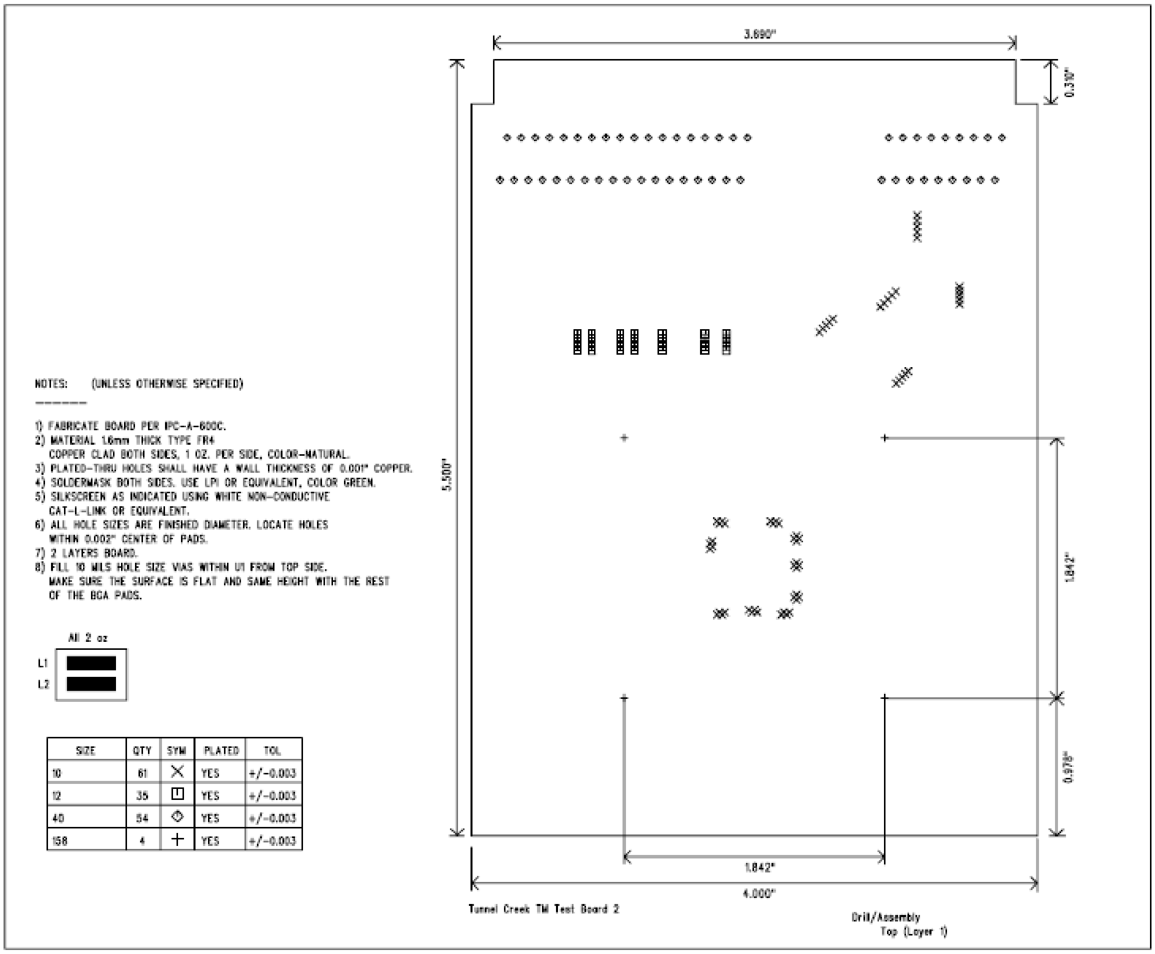
Table 3. Temperature Sensors and Heaters Connectivity

TS / Heater	Tab Pair on Board	Side of Board	Edge Finger #	Net Name	Package Pin Number	Polarity	Function
TS_BR	D2	Top A+	1	TS_BR_FH	A1.L45	+	Force High
		Top A+	2	TS_BR_MH	A1.R46	+	Measure High
		Bottom B-	1	TS_BR_FL	A1.N45	-	Force Low
		Bottom B-	2	TS_BR_ML	A1.M46	-	Measure Low
TS_RE	D4	Top A+	4	TS_RE_FH	A1.AE45	+	Force High
		Top A+	5	TS_RE_MH	A1.AH44	+	Measure High
		Bottom B-	4	TS_RE_FL	A1.AF44	-	Force Low
		Bottom B-	5	TS_RE_ML	A1.AG45	-	Measure Low
TS_TR	D6	Top A+	7	TS_TR_FH	A1.AW45	+	Force High
		Top A+	8	TS_TR_MH	A1.BB46	+	Measure High
		Bottom B-	7	TS_TR_FL	A1.AY46	-	Force Low
		Bottom B-	8	TS_TR_ML	A1.BA45	-	Measure Low
TS_DC	D3	Top A+	10	TS_DC_FH	A1.BE16	+	Force High
		Top A+	11	TS_DC_MH	A1.BD17	+	Measure High
		Bottom B-	10	TS_DC_FL	A1.BD15	-	Force Low
		Bottom B-	11	TS_DC_ML	A1.BE18	-	Measure Low
TS_TL	D5	Top A+	13	TS_TL_FH	A1.AY6	+	Force High
		Top A+	14	TS_TL_MH	A1.BB6	+	Measure High
		Bottom B-	13	TS_TL_FL	A1.AW7	-	Force Low
		Bottom B-	14	TS_TL_ML	A1.BA7	-	Measure Low
TS _BL	D1	Top A+	16	TS_BL_FH	A1.V7	+	Force High
		Top A+	17	TS_BL_MH	A1.T7	+	Measure High
		Bottom B-	16	TS_BL_FL	A1.U6	-	Force Low
		Bottom B-	17	TS_BL_ML	A1.W6	-	Measure Low

TS / Heater	Tab Pair on Board	Side of Board	Edge Finger #	Net Name	Package Pin Number	Polarity	Function
HTR Half Silicon	P1	Top A+	29	HTR_FH	A1.G13 A1.H12 A1.J13	+	Force High
		Top A+	30	HTR_MH	A1.H15	+	Measure High
		Bottom B-	29	HTR_FI_FH	A1.G25 A1.H24 A1.J25	-	Force Low
		Bottom B-	30	HTR_FI_MH	A1.H26	-	Measure Low
HTR Half Silicon	P2	Top A+	32	HTR_FI_FH	A1.G25 A1.H24 A1.J25	+	Force High
		Top A+	33	HTR_FI_MH	A1.H26	+	Measure High
		Bottom B-	32	HTR_FL	A1.G39 A1.H40 A1.J39	-	Force Low
		Bottom B-	33	HTR_ML	A1.H37	-	Measure Low
HTR Whole Silicon	P3	Top A+	35	HTR_FH	A1.G13 A1.H12 A1.J13	+	Force High
		Top A+	36	HTR_MH	A1.H15	+	Measure High
		Bottom B-	35	HTR_FL	A1.G39 A1.H40 A1.J39	-	Force Low
		Bottom B-	36	HTR_ML	A1.H37	-	Measure Low

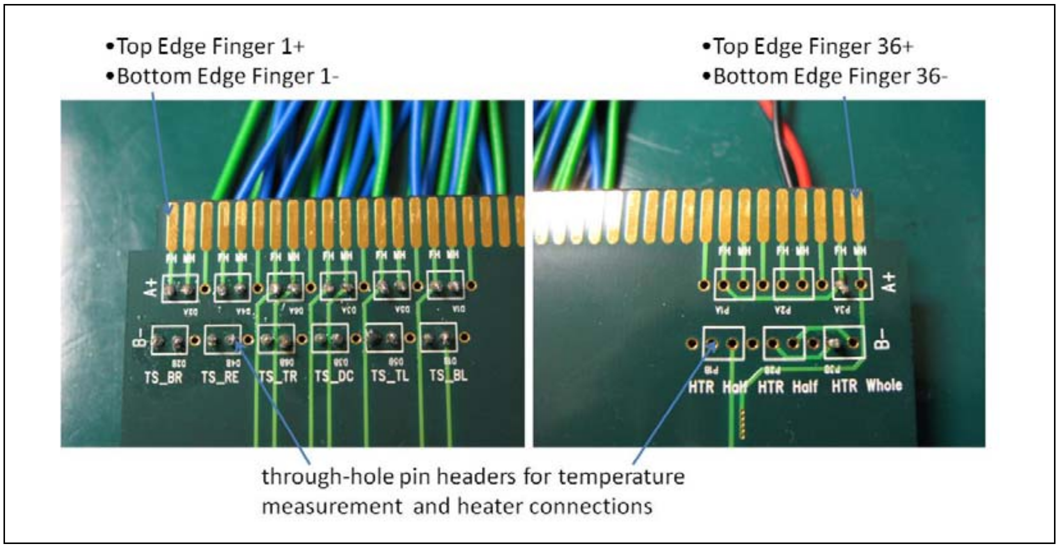
Appendix B – Thermal Test Board Dimensions

Figure 13. Mechanical Dimensions and Enabling Holes Location



Appendix C – Thermal Test Board Photos

Figure 14. Edge Fingers and Through-hole Pin Headers



Appendix D - 4-wire Constant Current Measurement Procedure

D.1 Constant Current Measurement Theory

A four-wire constant current temperature calibration and measurement method is recommended to obtain accurate temperature sensor resistance measurements. This is a good way to ensure that any added resistances in the sensor circuit are excluded from the sensor resistance measurement.

Four wires are provided for each sensor. Two of the wires are used to provide a constant current through the temperature sensor to induce a voltage potential across the sensor. The current supplied is ~1mA[1].

The second pair of wires is used to measure the voltage drop across the temperature sensor. This voltage drop is measured at the appropriate point on the ETB board and is equivalent to the voltage drop across the sensor. The resistance in the sensor wiring will not affect the voltage measurement at the point on the ETB board. The true resistance of the sensor can be calculated by applying the following expression: Sensor Resistance = Voltage/Current. In the example figure shown below, the measured voltage is 0.195 V and the calculated sensor resistance is 195 Ω (0.195 V/0.001 A).

1 *The current supplied is ~1 mA and it is maintained at a small amount to avoid heating up of the temperature sensor elements. Recall that the power dissipated through a resistive element is calculated by: (Power = Current^2 x Resistance). So for a sensor resistance of~195Ω, and a measuring current of 0.001 Amps, total power dissipated through the sensor= ~0.0002 Watts. This power level is small and does not significantly affect the temperature of the sensor.*

Figure 15. Constant Current Measurement Wiring Diagram