Improve Accuracy of the TMP006
With a Simple Transient Correction Algorithm

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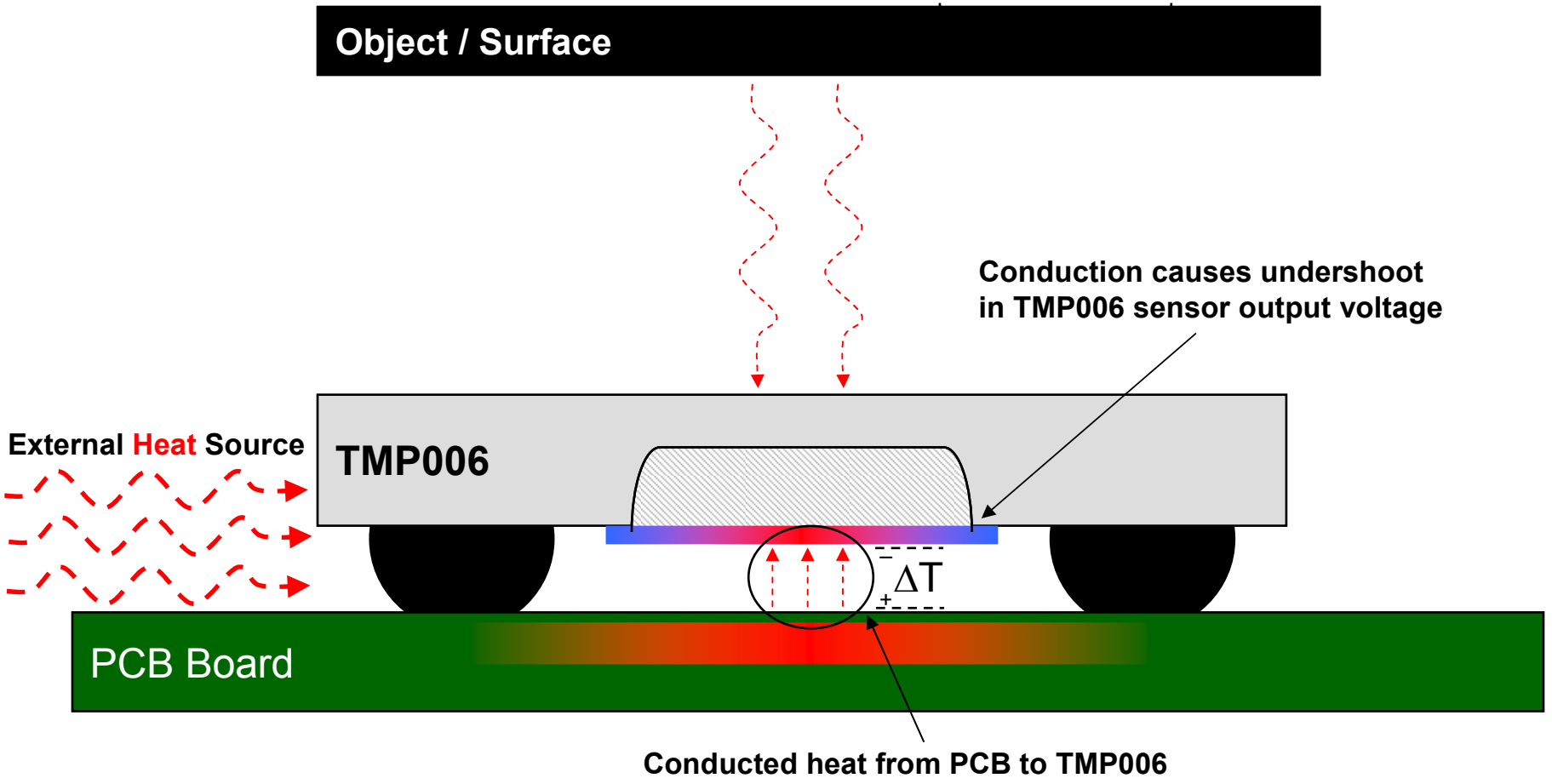
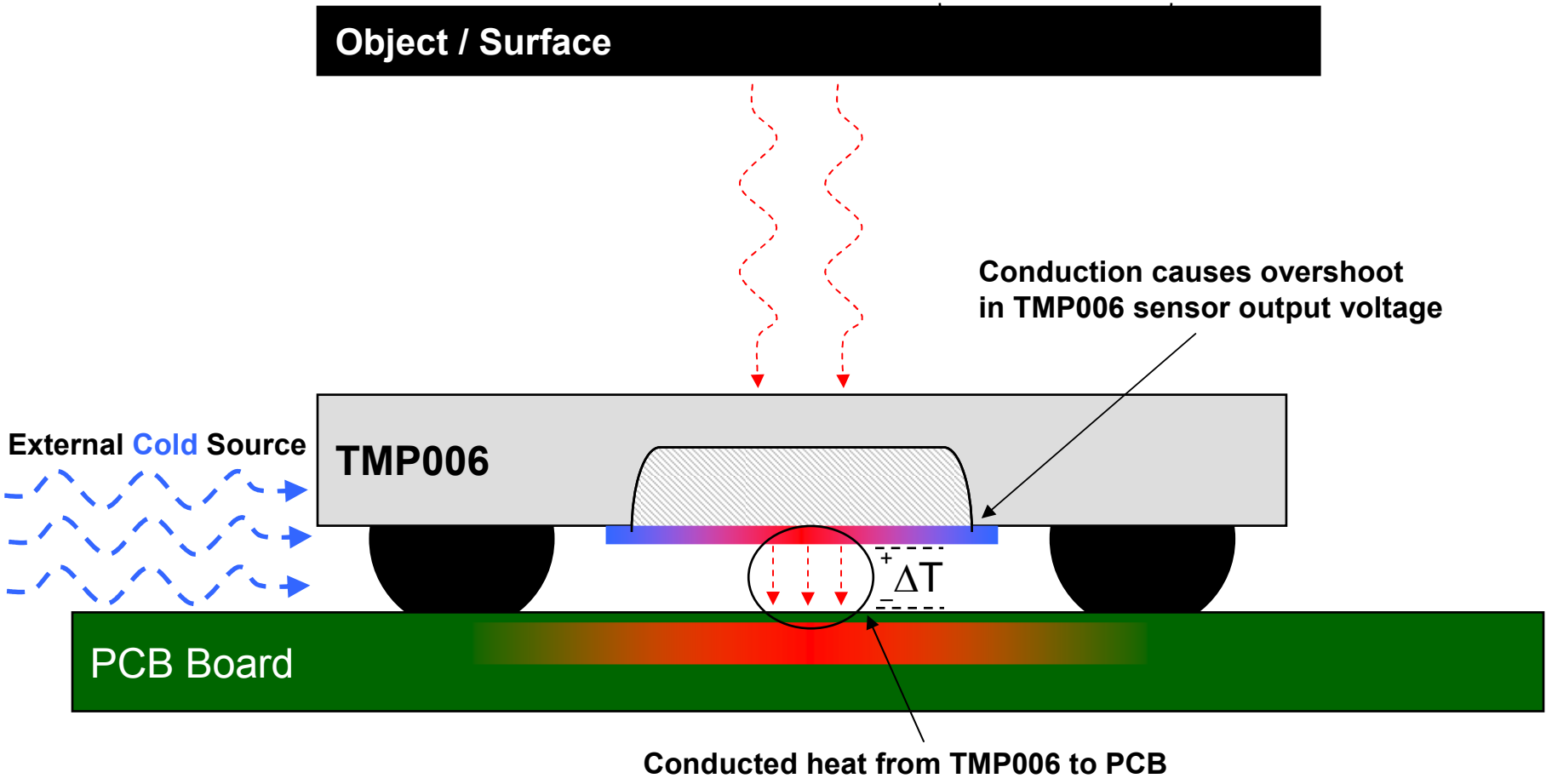
Background

- Accuracy of the TMP006 is highly dependent on stable local temperature
- The IR (infrared) thermopile sensor in the TMP006 has a thermal RC response
  - Responds to thermal transients more slowly than a PCB board, causing temperature gradients to develop
  - Temperature gradients cause heat transfer by conduction between TMP006 and PCB, resulting in offsets in sensor voltage and unwanted error

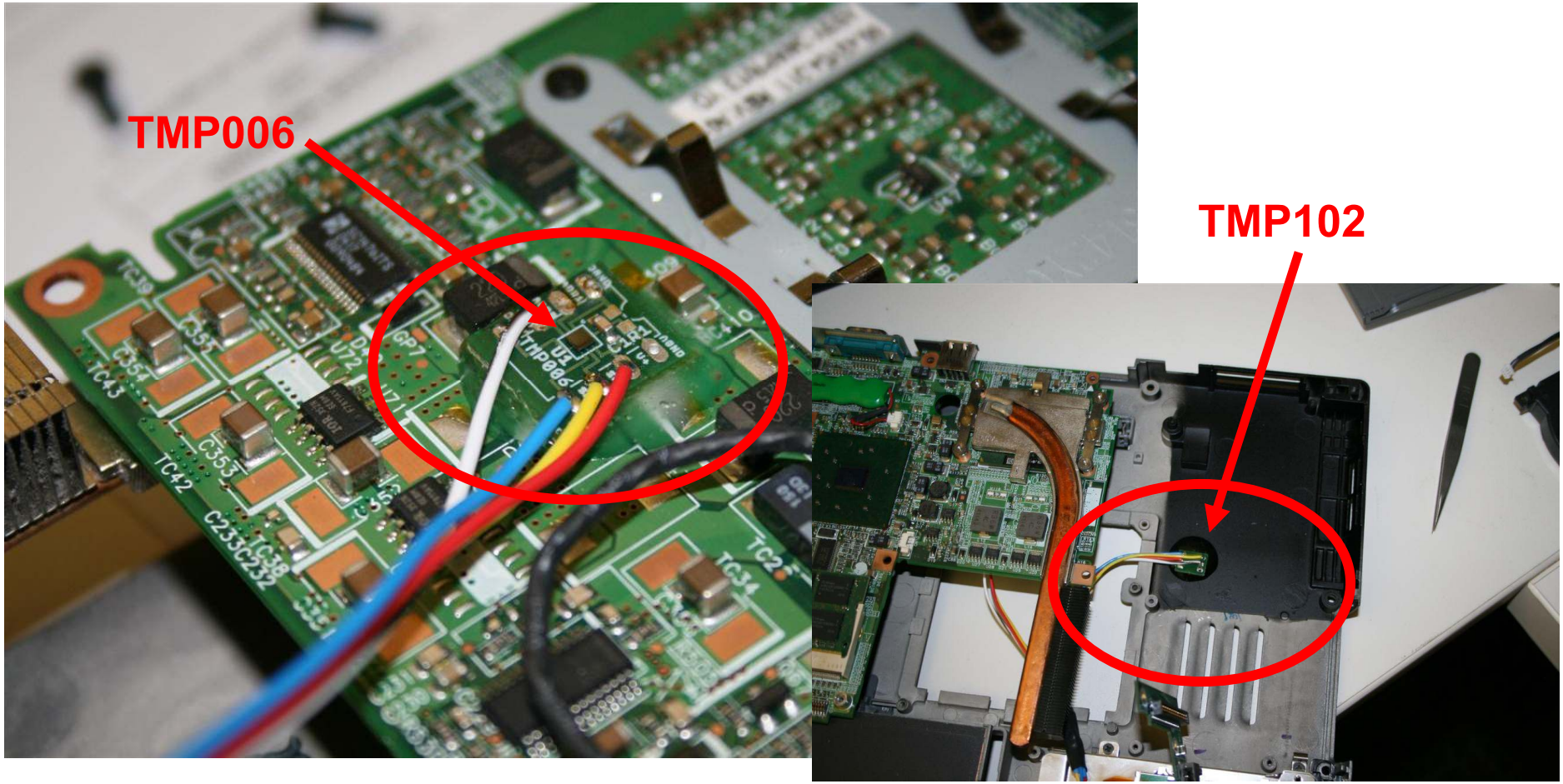
Response to Hot Transient Event



Response to Cold Transient Event

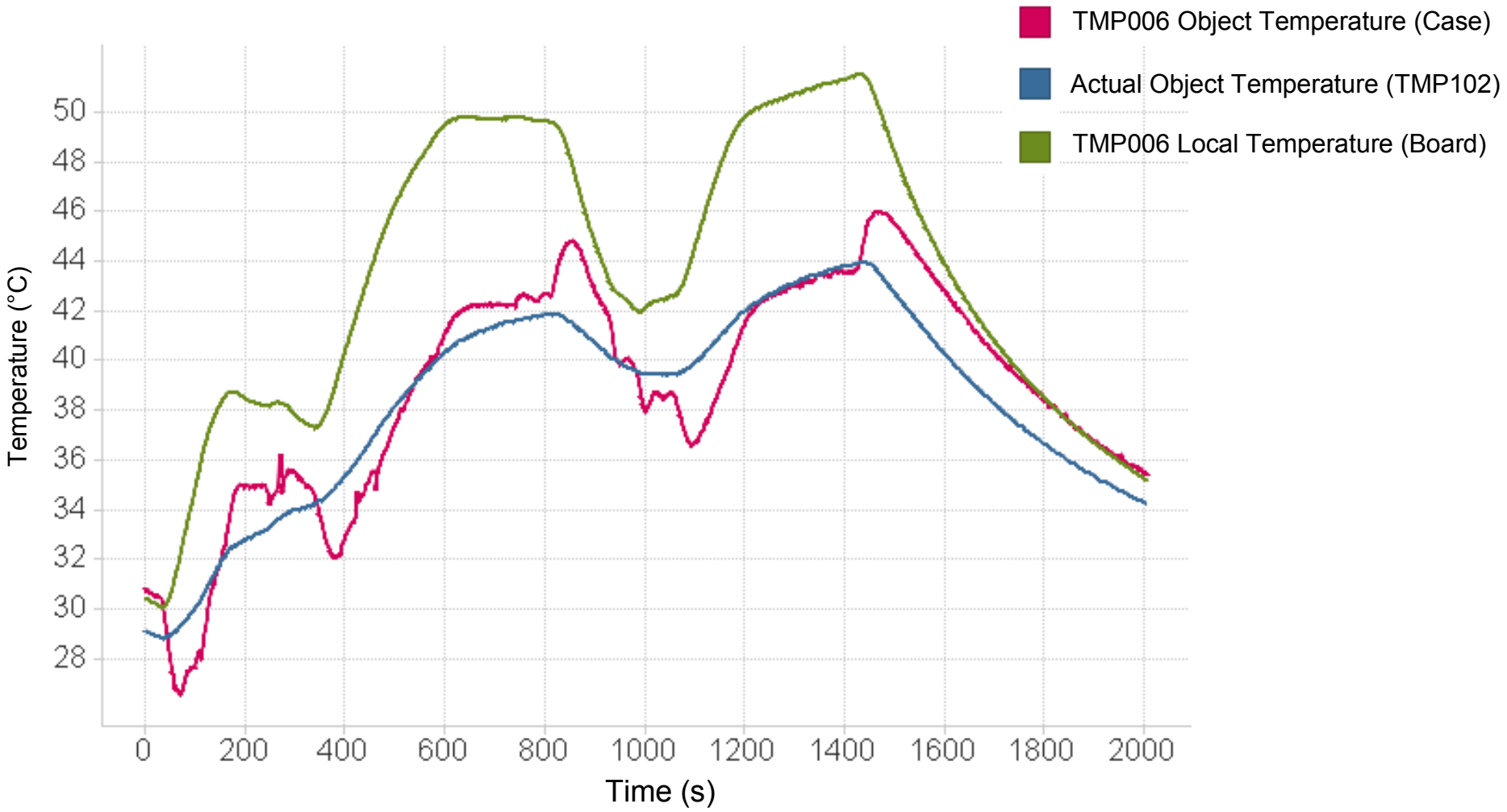


Laptop Experiment Setup

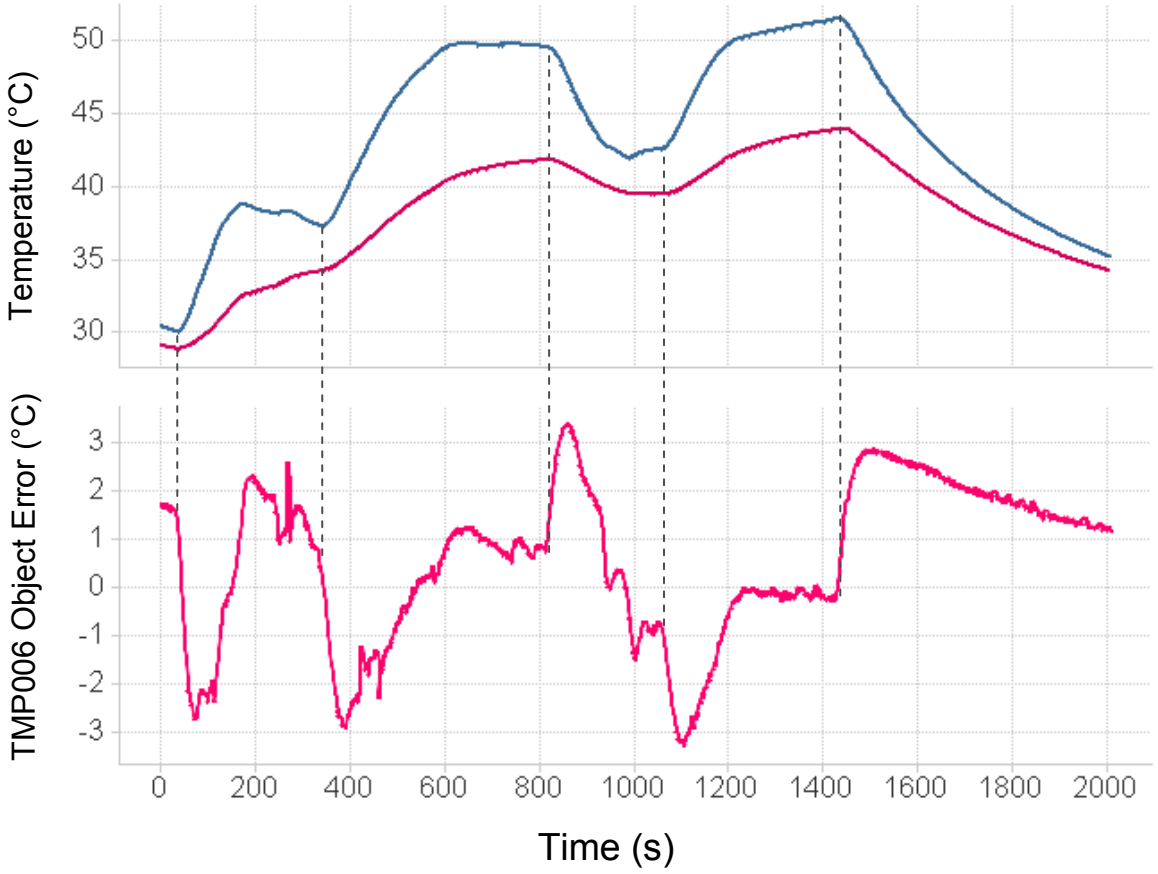


- Laptop was powered for 30 min and several applications were run to stress the processor

Laptop Experiment Results



Laptop Experiment Results



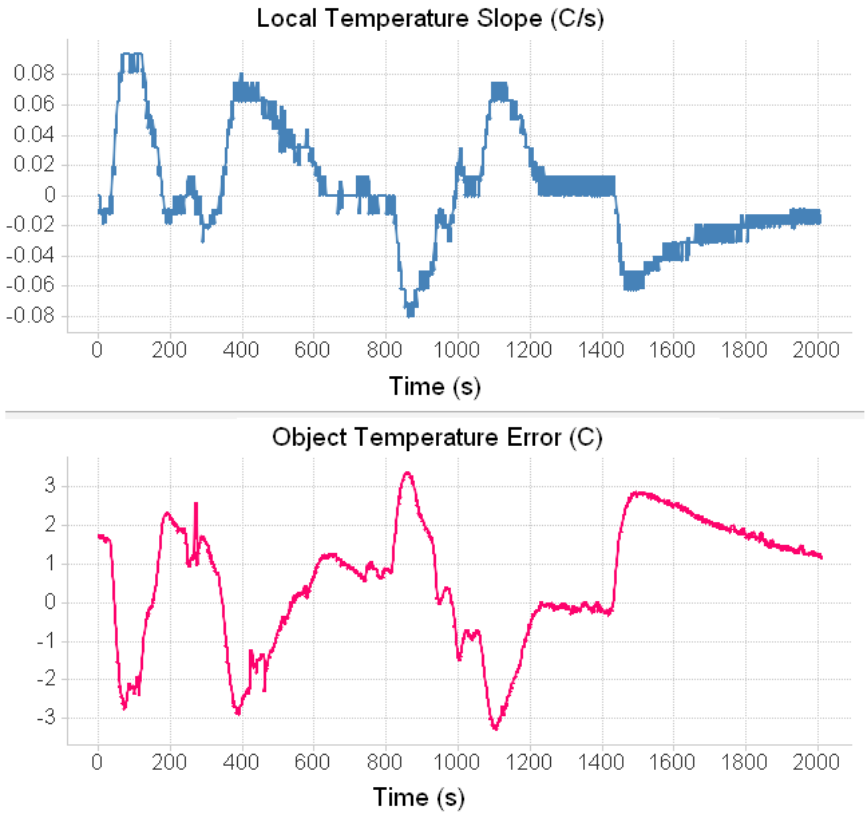
TMP006 Local Temperature (Board)

Actual Object Temperature (TMP102)

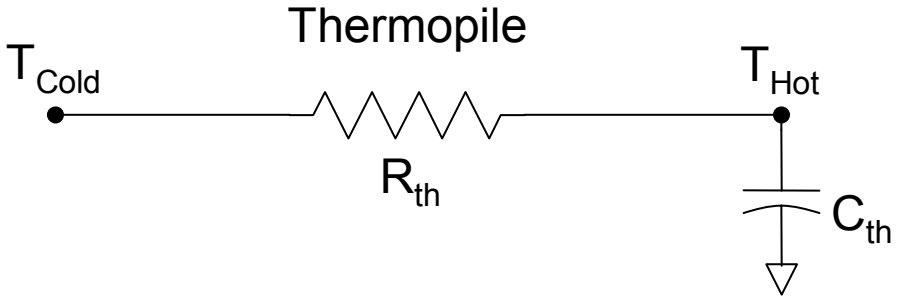
- The temperature error will over/undershoot during large PCB board temperature transients until the system settles
- The overshoot errors can be minimized by using the transient correction algorithm

Object Temperature Error Due to Transients

- The TMP006 transient error is proportional to the slope of the local temperature: $V_{obj}\ Error = \boldsymbol{\alpha}(dT_{die} / dt)$



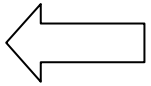
Theory: Sensor Time Constant Effect on Transients



- R_{th} Thermal resistance of thermopile
- C_{th} Thermal capacitance of thermopile
- $\frac{\partial T_{Hot}}{\partial t} = \frac{\partial T_{Cold}}{\partial t}$ (Delayed by $R_{th}C_{th}$)
- $T_{Hot} - T_{Cold} = -\frac{\partial T_{Cold}}{\partial t} \times R_{th} C_{th}$ ⟸ The difference in temperature created by a drift in the die temperature

Theory: Sensor Time Constant Effect on Transients

$$T_{Hot} - T_{Die} = -\frac{\partial T_{Cold}}{\partial t} \times R_{th}C_{th}$$



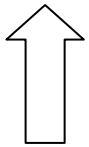
The difference in temperature results in a voltage error on the thermopile

$$V_{Error} = Seebeck \times (T_{Hot} - T_{Die})$$

$$V_{Error} = Seebeck \times -\frac{\partial T_{Cold}}{\partial t} \times R_{th}C_{th}$$

$$V_{Error} = -\frac{\partial T_{Cold}}{\partial t} \times (Seebeck \times R_{th}C_{th})$$

$$\alpha = (Seebeck \times R_{th}C_{th}) = 2.96 \times 10^{-4}\ (V \times sec / C)$$



The alpha mentioned before is a constant which corresponds to the multiplication of the Seebeck coefficient and slope of the die temperature (cold junction)

Calculating the Slope of Die Temperature

The slope of the best straight line fit for any set of points (x_i, y_i) can be calculated using the equation given below.

$$S_0 = \frac{\left(n\sum_{i=1}^{n} x_i y_i\right) - \left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} y_i\right)}{\left(n\sum_{i=1}^{n} x_i x_i\right) - \left(\sum_{i=1}^{n} x_i\right)\left(\sum_{i=1}^{n} x_i\right)}$$

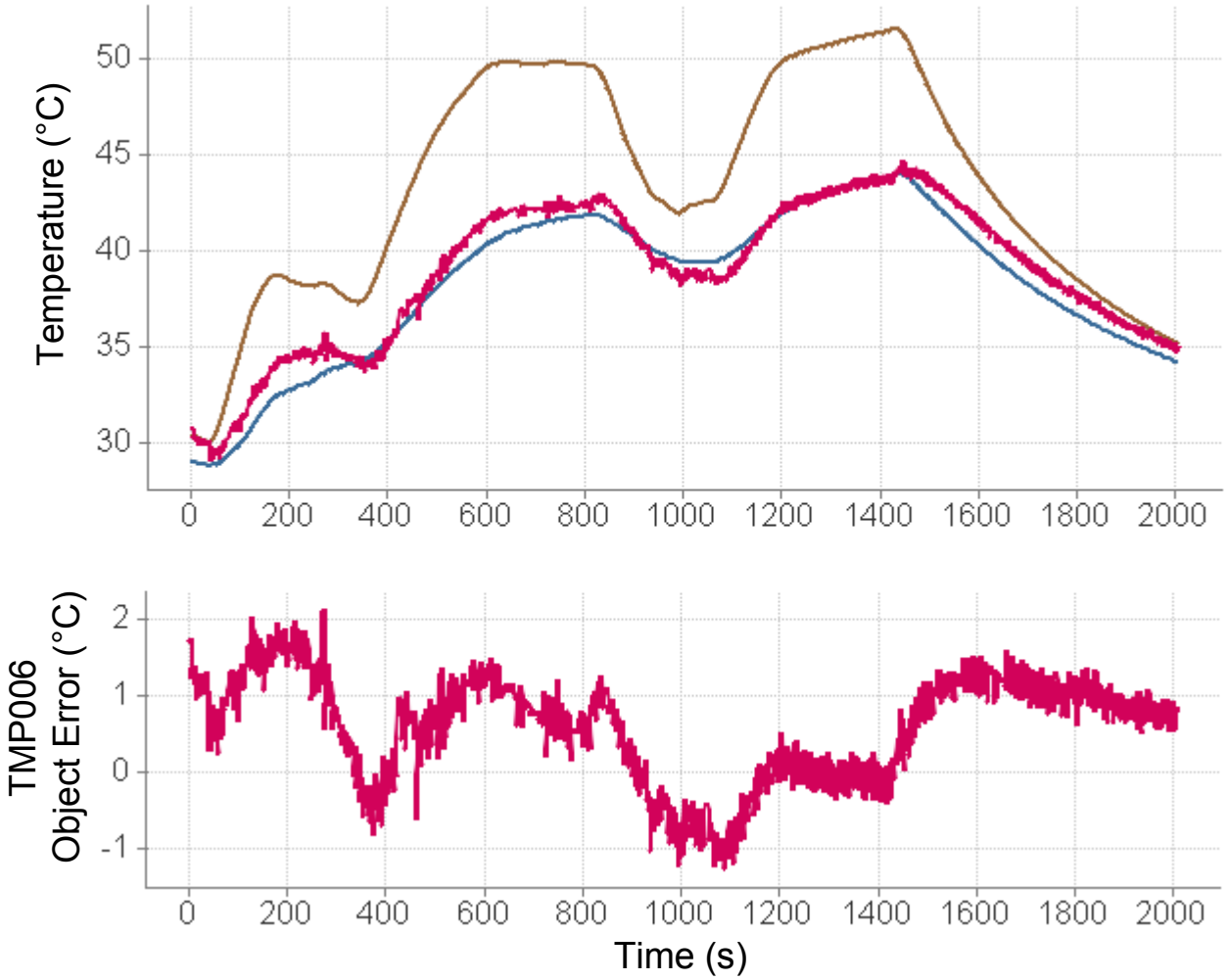
If we use four temperature points that are spaced 1 second apart; $(1, T_{die1})$ $(2, T_{die2})$ $(3, T_{die3})$ $(4, T_{die4})$ where T_{die4} is the latest measurement and T_{die1} is the first measurement, the above equation simplifies to:

$$T_{Slope} = -(0.3 \times T_{die1}) - (0.1 \times T_{die2}) + (0.1 \times T_{die3}) + (0.3 \times T_{die4})$$

Correcting Object Voltage Error

- Measure the slope of the local temperature versus time (recommend using 4 measurements)
  - For four, one second spaced readings:
    - $T_{Slope} = -(0.3 \times T_{die1}) - (0.1 \times T_{die2}) + (0.1 \times T_{die3}) + (0.3 \times T_{die4})$
- Correct the sensor object voltage using:
    - $V_{obj\_corrected} = V_{obj} + T_{Slope} \times 2.96 \times 10^{-4}$
- Apply $V_{obj\_corrected}$ to the standard 3D equation to correct the transients

Laptop Experiment Post Transient Correction



Object Temperature (TMP102)

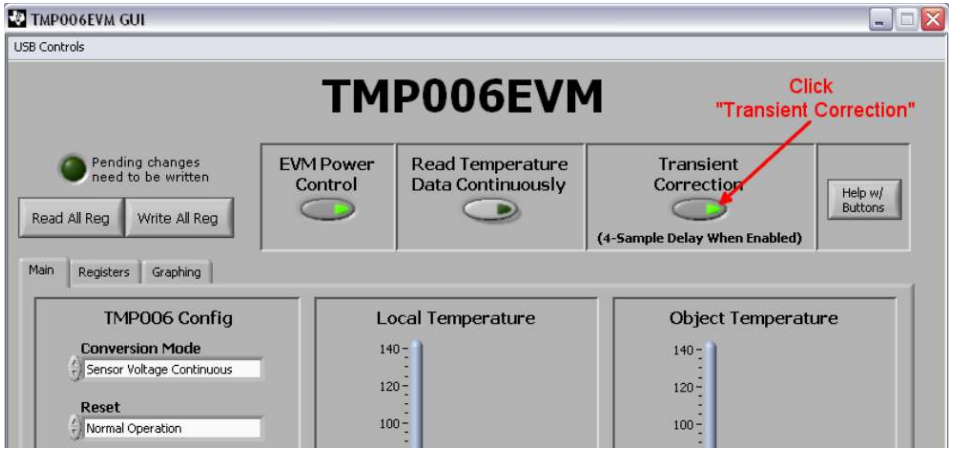
TMP006 Local

TMP006 Object (Corrected)

- To calculate the local temperature slope this example uses **4 consecutive** temperature readings
- The error post correction is within ±2°C
- No overshoots are observed

TMP006EVM Software

- New revision (Rev. A) of TMP006EVM software includes transient correction functionality
- To enable, click **Transient Correction** at top-right of GUI
  - 4-sample delay will be observed when enabled while software calculates slope of local temperature



Questions?

- Contact information
  - Temperature Sensor area of E2E forums (preferred): http://e2e.ti.com/support/other_analog/temperature_sensors/default.aspx
  - E-mail: ian@ti.com