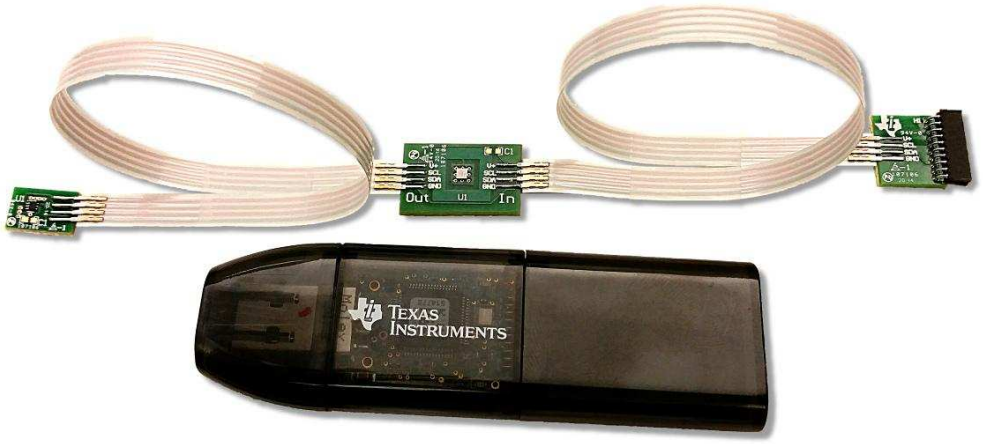
User's Guide
SBOU149–December 2014

TMP007EasyCal User's Guide



This user's guide describes the characteristics, operation, and use of the TMP007EasyCal software and hardware. This user's guide discusses how to set up and configure the software and hardware, and reviews various aspects of the program operation. Throughout this document, the term *EVM* is synonymous with *TMP007EasyCal.*

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1 Introduction to the TMP007EasyCal

The TMP007 is an infrared thermopile sensor that measures the temperature of an object without directly contacting the object. The integrated thermopile absorbs the infrared energy emitted from the object that appears in the sensor field of view. The thermopile voltage is digitized and input to the integrated math processor, along with the local die temperature. The integrated math processor then computes the corresponding object temperature.

Default Seebeck coefficients and thermal transient coefficients are encoded into the processor. The default coefficients work well for many systems where:

1. emissivity of the object is greater than 0.95,
2. the object fills the field of view of the TMP007,
3. and there are no disturbances from other sources of heat via conduction through the PCB or convection through the surrounding air.

For systems where custom calibration coefficients are required, the TMP007EasyCal tool can be used to collect data, analyze the data, and provide unique calibration coefficients. For improved system-level accuracy, these calibration coefficient values are programmed as user inputs and stored in the built-in, nonvolatile memory of the TMP007.

The TMP007EasyCal kit consists of four printed circuit boards (PCBs): the SM-USB-DIG, the SM-USB-DIG 10-pin header to four-wire adaptor board, the TMP007 board, and a TMP112 board. The SM-USB-DIG attaches to the four-wire adaptor board through a 10-pin header. The TMP007 board attaches to the four-wire adaptor board through a four-wire ribbon cable. The TMP112 board attaches to the TMP007 board through another four-wire ribbon cable. The SM-USB-DIG communicates with the computer, provides power, and sends and receives appropriate digital signals. The TMP007 board contains the TMP007 and support circuitry, and the TMP112 board contains the TMP112 and support circuitry. The three connected PCBs are referred to as the *TMP007EasyCal three-PCB-assembly*.

1.1 TMP007EasyCal Kit Contents

Table 1 summarizes the contents of the EVM kit. Contact the Texas Instruments Product Information Center nearest you if any component is missing. Verify you have the latest versions of the released software by checking the TMP007 product folder on the TI web site at www.ti.com.

Table 1. TMP007EasyCal Kit Contents

Item	Quantity
TMP007EasyCal Three-PCB-Assembly	1
SM-USB-DIG Board	1

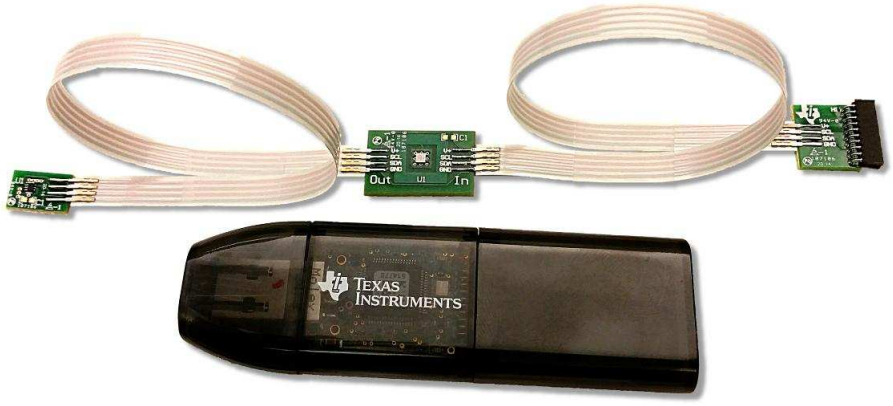

Figure 1. TMP007EasyCal Kit Contents

1.2 Related Documentation from Texas Instruments

The following documents provide information regarding Texas Instruments' integrated circuits used in the assembly of the TMP007EasyCal. The TMP007EasyCal User's Guide is available from the TI web site under literature number SBOU149. Any letter appended to the literature number corresponds to the document revision that is current at the time of the writing of this document. Newer revisions may be available from the TI web site, or call the Texas Instruments' Literature Response Center at (800) 477-8924 or the Product Information Center at (972) 644-5580. When ordering, identify the document by both title and literature number.

Table 2. Related Documentation

Document	Literature Number
TMP007 Product Data Sheet	SBOS685
SM-USB-DIG Platform User's Guide	SBOU098
TMP112 Product Data Sheet	SBOS473
TMP007 Calibration Guide	SBOU142
TMP007 User's Guide	SBOU137
TMP007 Layout and Assembly User Guide	SBOU143

2 TMP007EasyCal Hardware

Figure 2 shows the system setup for the TMP007EasyCal hardware. The computer runs the graphical user interface (GUI) software that communicates with the SM-USB-DIG over a USB connection. The SM-USB-DIG translates USB commands from the computer into power, I^2C, SPI™, and general-purpose input/output (GPIO) commands for the TMP007EasyCal test boards. Note that the TMP007EasyCal does not require any additional components to operate.

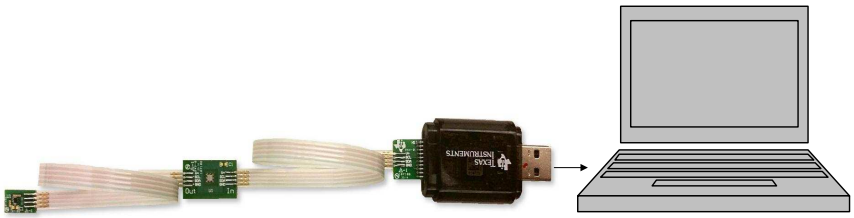

Figure 2. TMP007EasyCal Hardware Setup

2.1 Theory of Operation for the TMP007EasyCal

A block diagram of the TMP007EasyCal hardware is shown in Figure 3. The TMP007 and TMP112 test boards contain connections for the power and I^2C signals. The four-pin ribbon cables can be desoldered and replaced with other cables if needed.

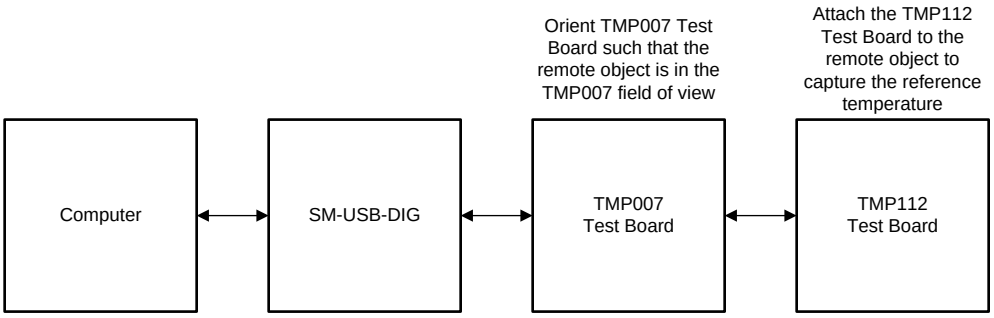

Figure 3. TMP007EasyCal Hardware Block Diagram

2.2 TMP007EasyCal Hardware Overview

If not already assembled, the basic hardware setup of the TMP007EasyCal involves connecting the TMP007EasyCal three-PCB-assembly to the SM-USB-DIG platform. The SM-USB-DIG is then connected to a computer through the USB port for use with the GUI software. This section presents the details of this procedure.

CAUTION

Many of the components on the TMP007EasyCal are susceptible to damage by electrostatic discharge (ESD). Users are advised to observe proper ESD handling precautions when unpacking and handling the EVM, including the use of a grounded wrist strap at an approved ESD workstation.

2.2.1 Typical TMP007EasyCal Hardware Setup

Connect the right-angle female socket on the four-pin to 10-pin adaptor board to the right-angle male header on the SM-USB-DIG Platform as shown in Figure 4. Take special care to make sure that the two 10-pin sockets directly align with each other. Plug the USB-A adaptor on the SM-USB-DIG into the male USB-A port on the computer.

NOTE: *Always* connect the two boards together before connecting the SM-USB-DIG with the computer to avoid any issues if the connectors are misaligned.

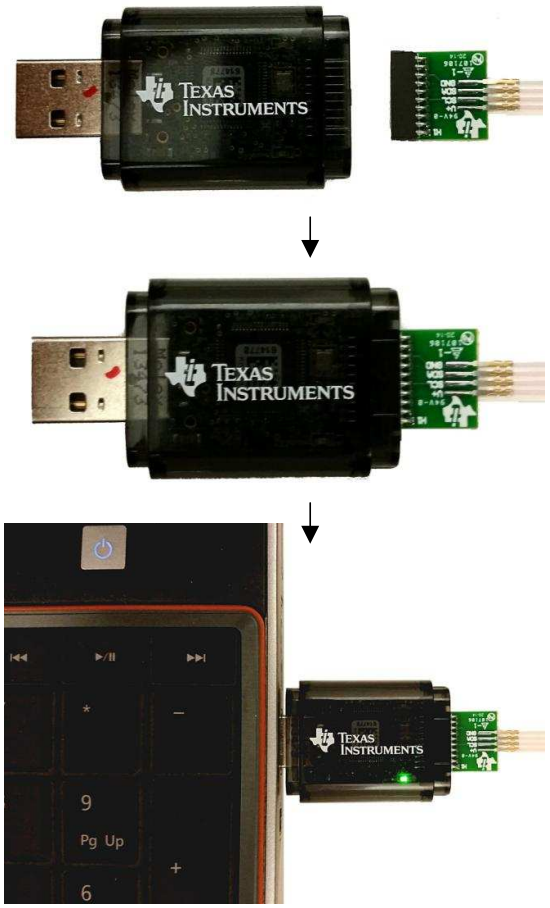

Figure 4. Typical Hardware Connection

Figure 5 shows the typical response when the SM-USB-DIG is plugged into the USB port of the computer for the first time. Typically, the computer responds with a *Found New Hardware, USB Device* pop-up dialog window. The pop-up window then typically changes to *Found New Hardware, USB Human Interface Device*. This pop-up indicates that the device is ready to be used. The SM-USB-DIG Platform uses the human interface device drivers that are part of the Windows® operating system.

Figure 5. Typical Response After Connecting TMP007EasyCal to the Computer

In some cases, the *Add Hardware Wizard* appears. If this installation prompt occurs, allow the device manager to install the human interface device drivers by clicking *Yes* at each request to install the drivers.

2.2.2 Placement of the TMP007 and TMP112 Test Boards

The TMP007 test board and the TMP112 test board must be mounted in the system to be calibrated. A detailed explanation of the calibration process is available in user guide SBOU142, *TMP007 Calibration Guide*, available for download from www.ti.com. Fundamentally, the process is described in two steps.

First, attach the TMP112 test board to the object whose temperature is to be measured. The TMP112 provides the reference temperature for TMP007 calibration. Therefore, attach the TMP112 test board to the object making sure to maintain a good thermal connection. To facilitate a good thermal connection, the TMP112 test board is designed with a large exposed copper surface that can be attached to the object using a thermally conductive adhesive, such as double-sided, 0.005" thermal tape from Bergquist, part number BP100-0.005-00-1112.

Second, attach the TMP007 test board to the PCB or fixture so that the object is within the field of view of the TMP007, while making sure that the TMP007 test board is oriented so that the top of the TMP007 device is exposed to, but not in contact with, the surface of the object whose temperature is to be measured.

3 TMP007EasyCal Software

This section describes the installation and operation of the TMP007EasyCal software.

3.1 Hardware Requirements

The TMP007EasyCal software has been tested on the Windows 7® operating system (OS) with United States regional settings. The software should function correctly on other Windows operating systems.

3.2 Software Installation

The TMP007EasyCal software is available from the TMP007 Product Folder on the TI web site (www.ti.com). To install the software to your computer, download it from the ti.com web page, navigate to the TMP007EasyCal software folder, and open the installer directory, as shown in Figure 6. Launch the TMP007EasyCal installation file, *setup.exe*.

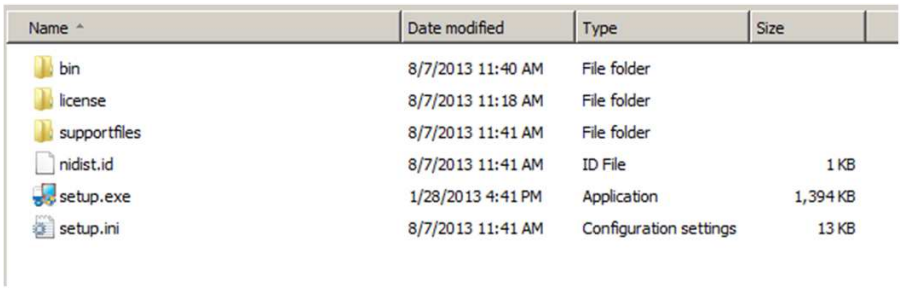

Figure 6. TMP007EasyCal Software-Installation Files

The TMP007EasyCal software then begins the installation setup process, as shown in Figure 7

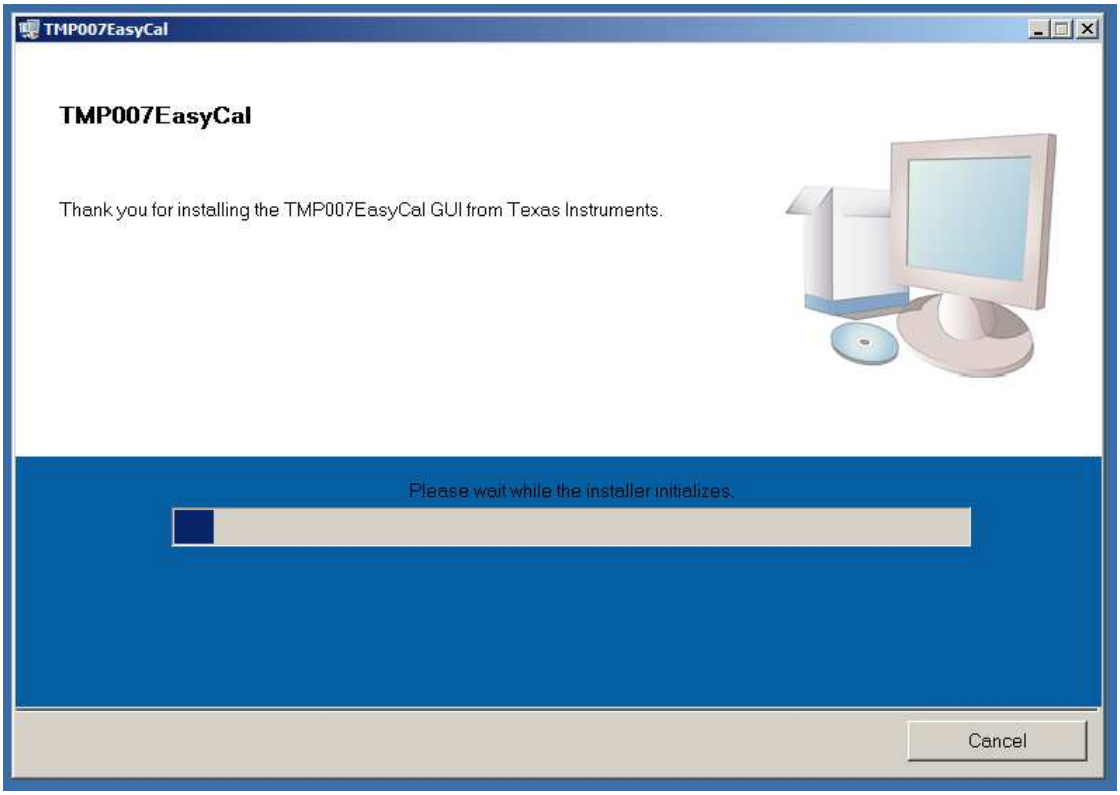

Figure 7. TMP007EasyCal Software-Installation Launch

Follow the prompts as shown in Figure 8 to choose the directories for the TMP007EasyCal software. The default directories are recommended.

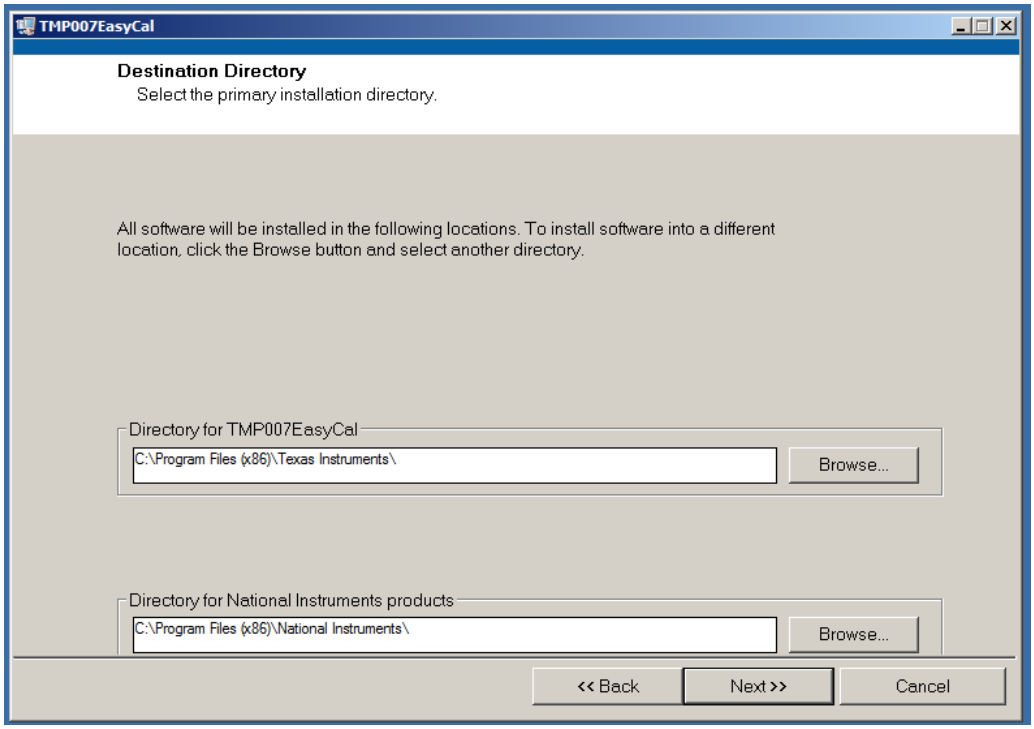

Figure 8. TMP007EasyCal Software-Installation Destination Directory

Read and accept the license agreements as shown in Figure 9 to continue the software installation setup.

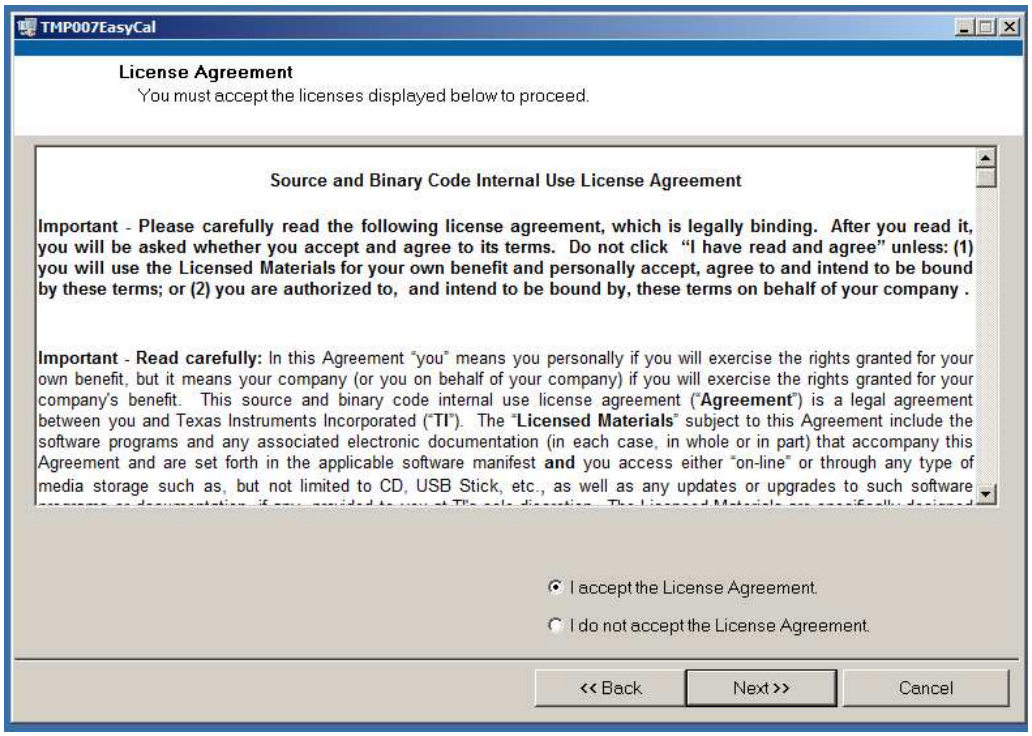

Figure 9. TMP007EasyCal Software-Installation License Agreements

Review the items to be added and changed and click *Next* to start the automated software installer, as shown in Figure 10.

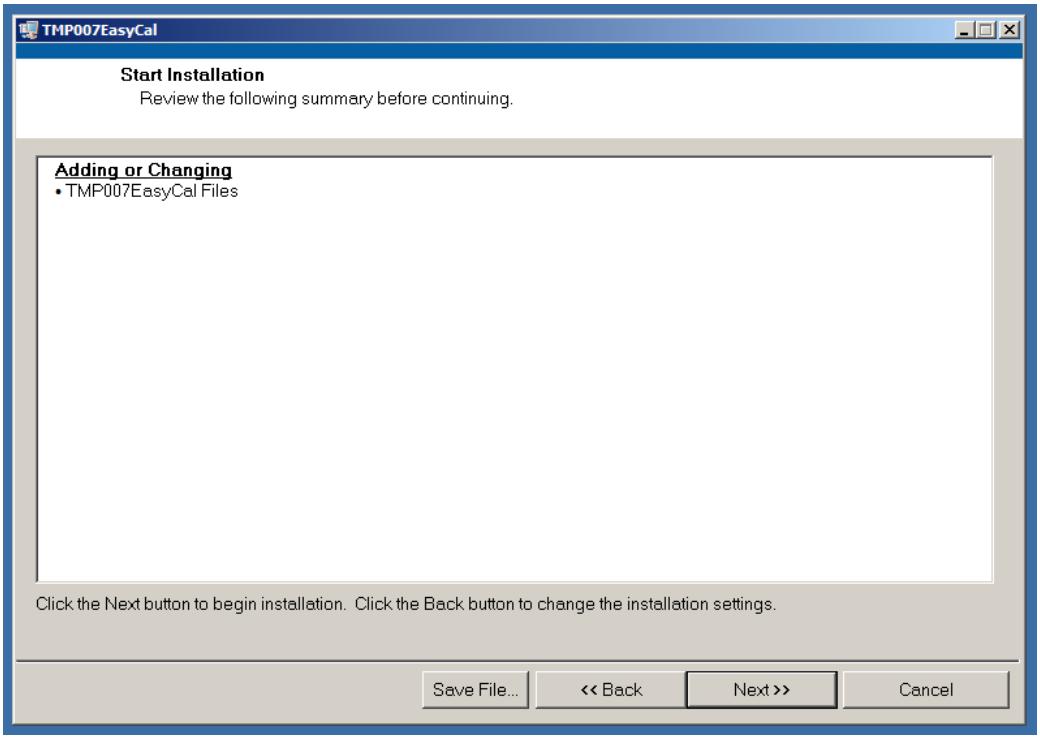

Figure 10. TMP007EasyCal Software-Start Installation

Figure 11 shows the progress bars and status text that display the current activity and overall progress of the installation.

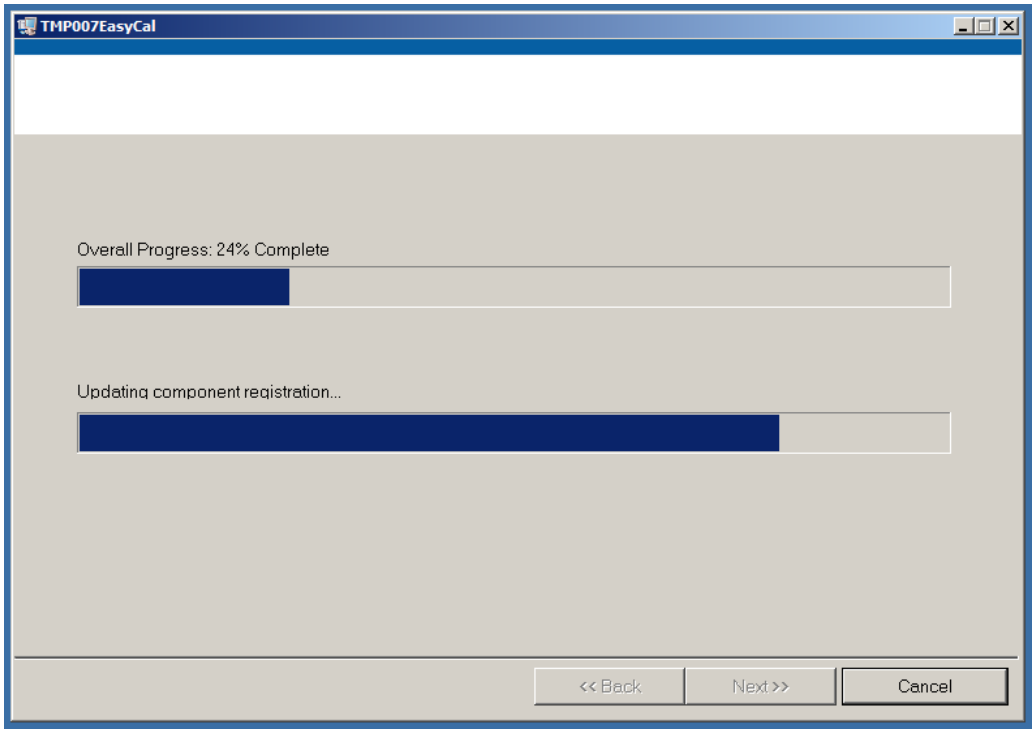

Figure 11. TMP007EasyCal Software-Installation Progress

When the automated installer completes, the message shown in Figure 12 displays. Click *Finish* to close the window.

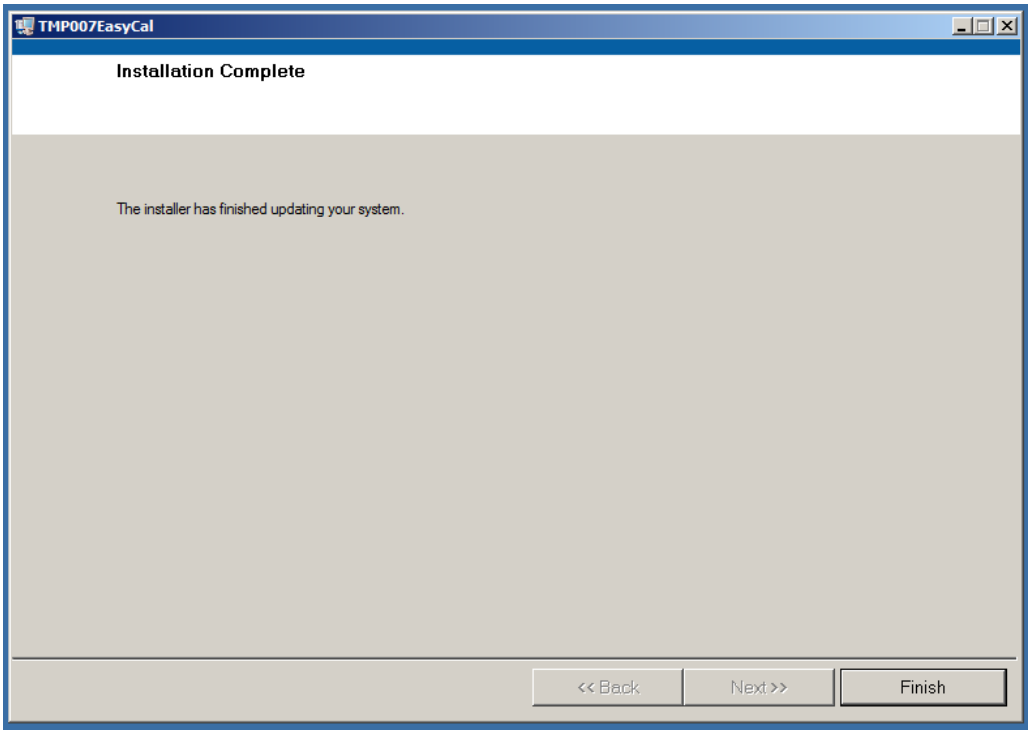

Figure 12. TMP007EasyCal Software-Installation Complete

The TMP007EasyCal GUI software is now installed.

3.3 Launching the TMP007EasyCal Software

With the TMP007EasyCal hardware properly connected (see Section 2.2.1 and Figure 4), launch the TMP007EasyCal GUI software from the Windows *Start* menu. The program is located in a folder titled *Texas Instruments*, as shown in Figure 13.

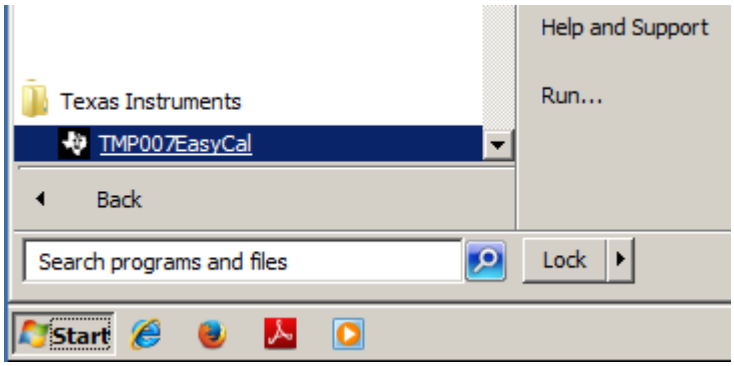

Figure 13. Starting the TMP007EasyCal Software

While loading, the TMP007EasyCal GUI splash screen is displayed, as shown in Figure 14.

Figure 14. TMP007EasyCal Splash Screen

If the hardware is connected, the software launches to the window shown in Figure 15.

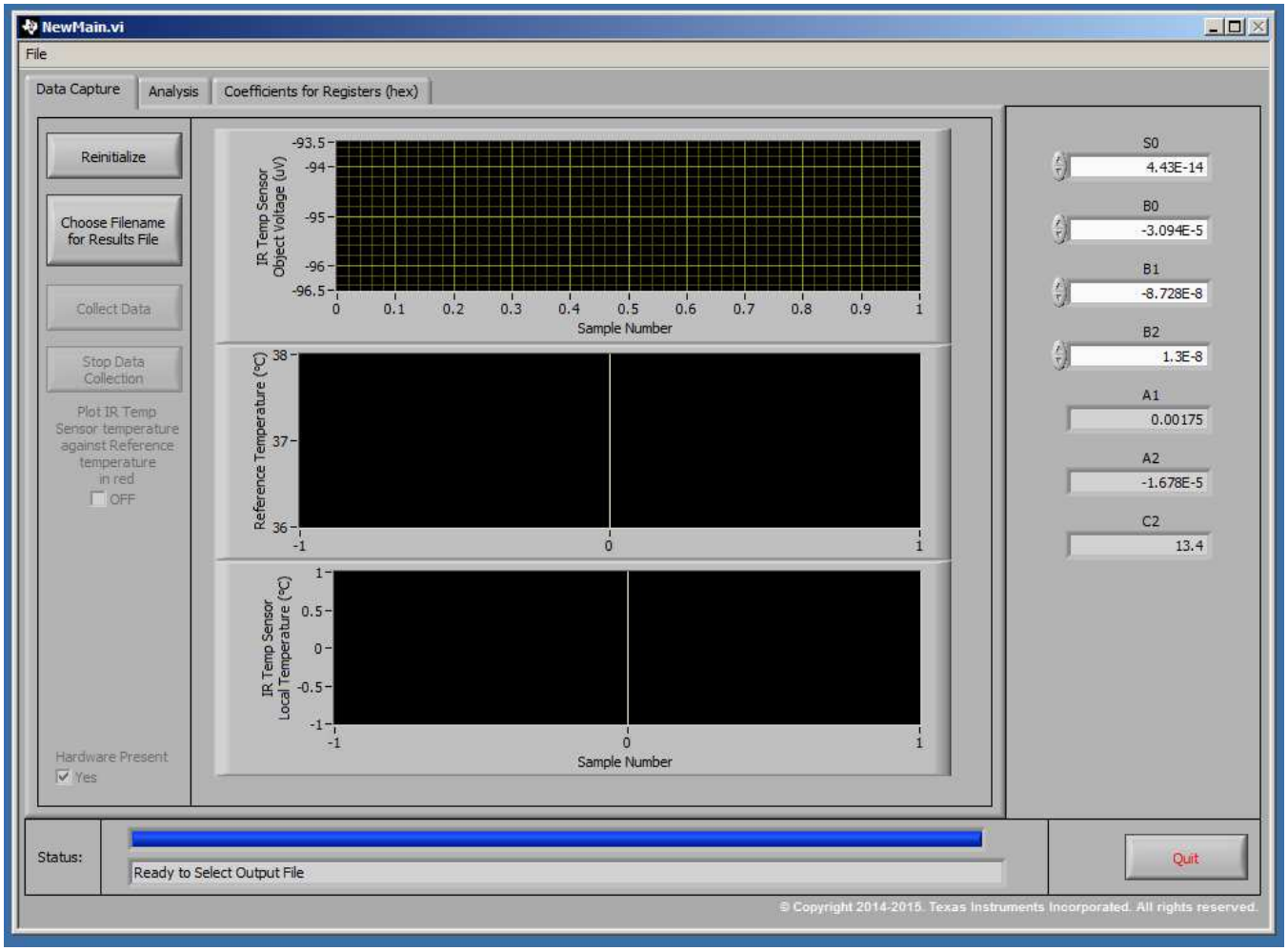

Figure 15. TMP007EasyCal Main Operation Screen with Hardware Connected

The TMP007EasyCal collects temperature data, and then processes the collected data to determine the best set of TMP007 calibration coefficients. Use these calibration coefficients in the desired system implementation.

The TMP007EasyCal software analyzes data collected by the TMP007EasyCal hardware. The TMP007EasyCal software can also analyze data collected using user-provided hardware. This scenario is common when a thermocouple, thermistor, or other calibrated temperature sensor is used to provide the reference temperature of the object (instead of a TMP112), provided that the collected data is formatted for use with the TMP007EasyCal software. For more information regarding data-file formatting requirements, see Section 3.4.2.

To use only the analysis tool without the hardware connected, uncheck the *Hardware Present* box to halt the hardware search and proceed to the *Analysis* tab, as shown in Figure 16. If the TMP007EasyCal hardware is not connected, the status bar and field indicate that the software is searching for connected hardware.

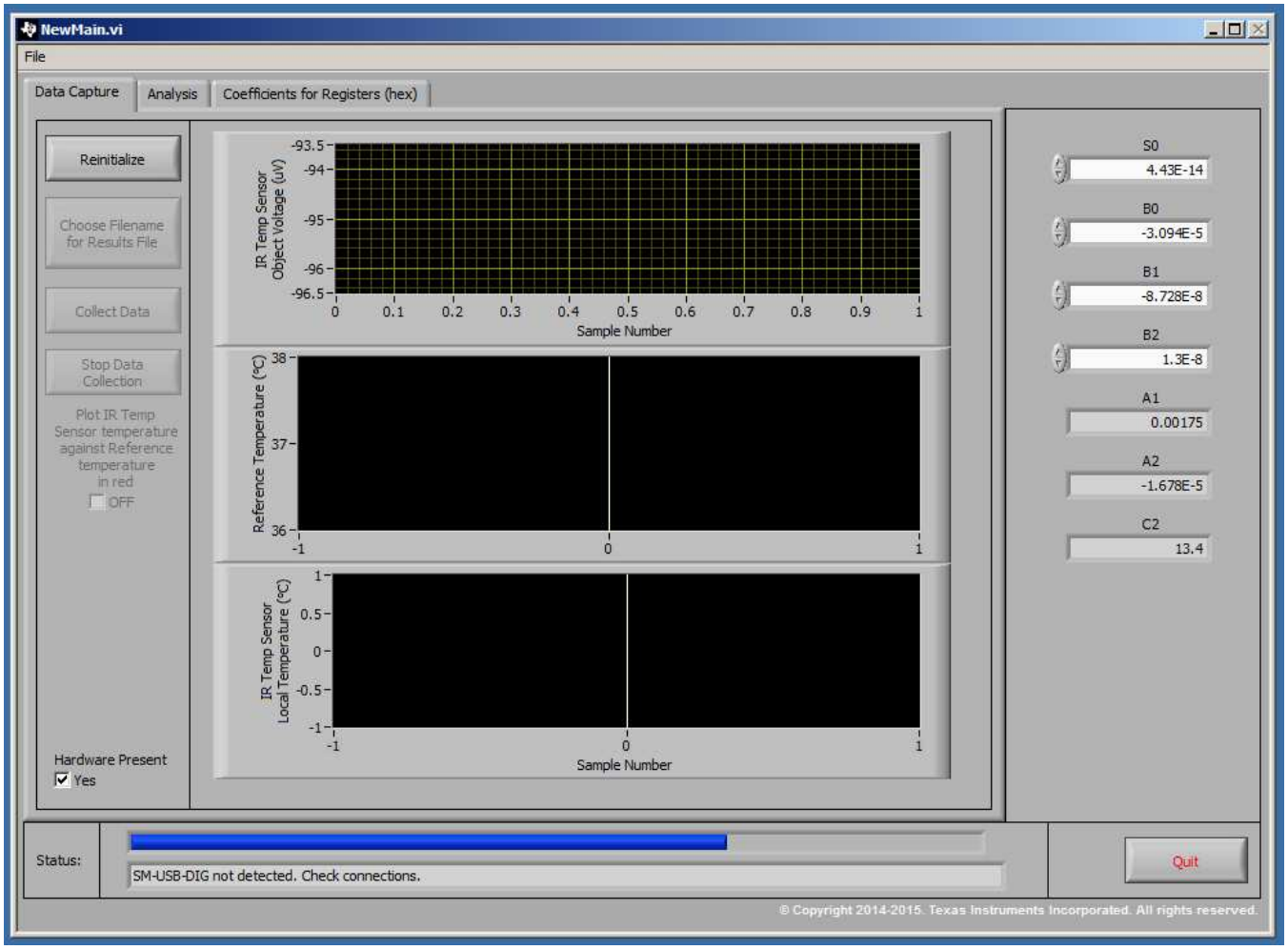

Figure 16. TMP007EasyCal Main Operation Screen with No Hardware Connected

3.4 TMP007EasyCal Software Operation

This section describes how to operate the TMP007EasyCal GUI. The GUI has a primary window with tabs that allow access to various features of the GUI. Basic functionality and a description of the tabs are also presented in this section.

3.4.1 Capturing Data

With the hardware connected, click the *Data Capture* tab at the top of the GUI to get to the screen shown in Figure 15. The only active buttons are *Reinitialize* and *Choose Filename for Results File*. *Reinitialize* resets the hardware and software, and readies the GUI for use. To prepare the results file for data capture, click *Choose Filename for Results File* to open a directory navigation window, as shown in Figure 17. Choose a unique file name and press *OK*.

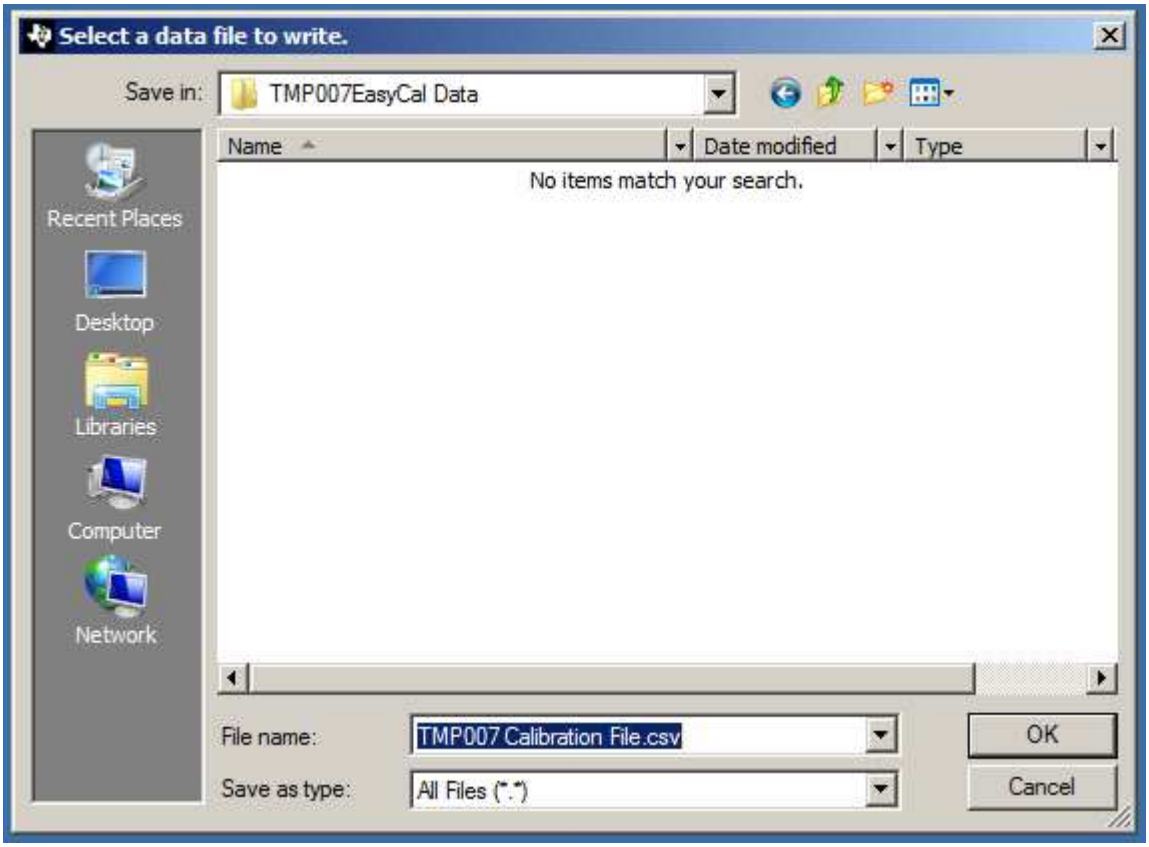

Figure 17. TMP007EasyCal Data Output File Selection

With the data output file created, the *Collect Data* button and a checkbox titled *Plot IR Temp Sensor temperature against Reference temperature in red* become available, as shown in Figure 18. Turning on the additional red line in the reference temperature plot is a good way to check the performance of coefficients in real time as data are captured. The S0, B0, B1, and B2 coefficients on the right-hand side of the window are used to calculate the object temperature based on the data reported in the plot *IR Temp Sensor Object Voltage (uV)*. Before any coefficients have been calculated, default coefficients are used and may or may not be suitable for the custom calibration. Following the analysis performed by the TMP007EasyCal software, the calibration coefficients are updated, and the updated results are displayed. Click the *Collect Data* button to begin the data capture process.

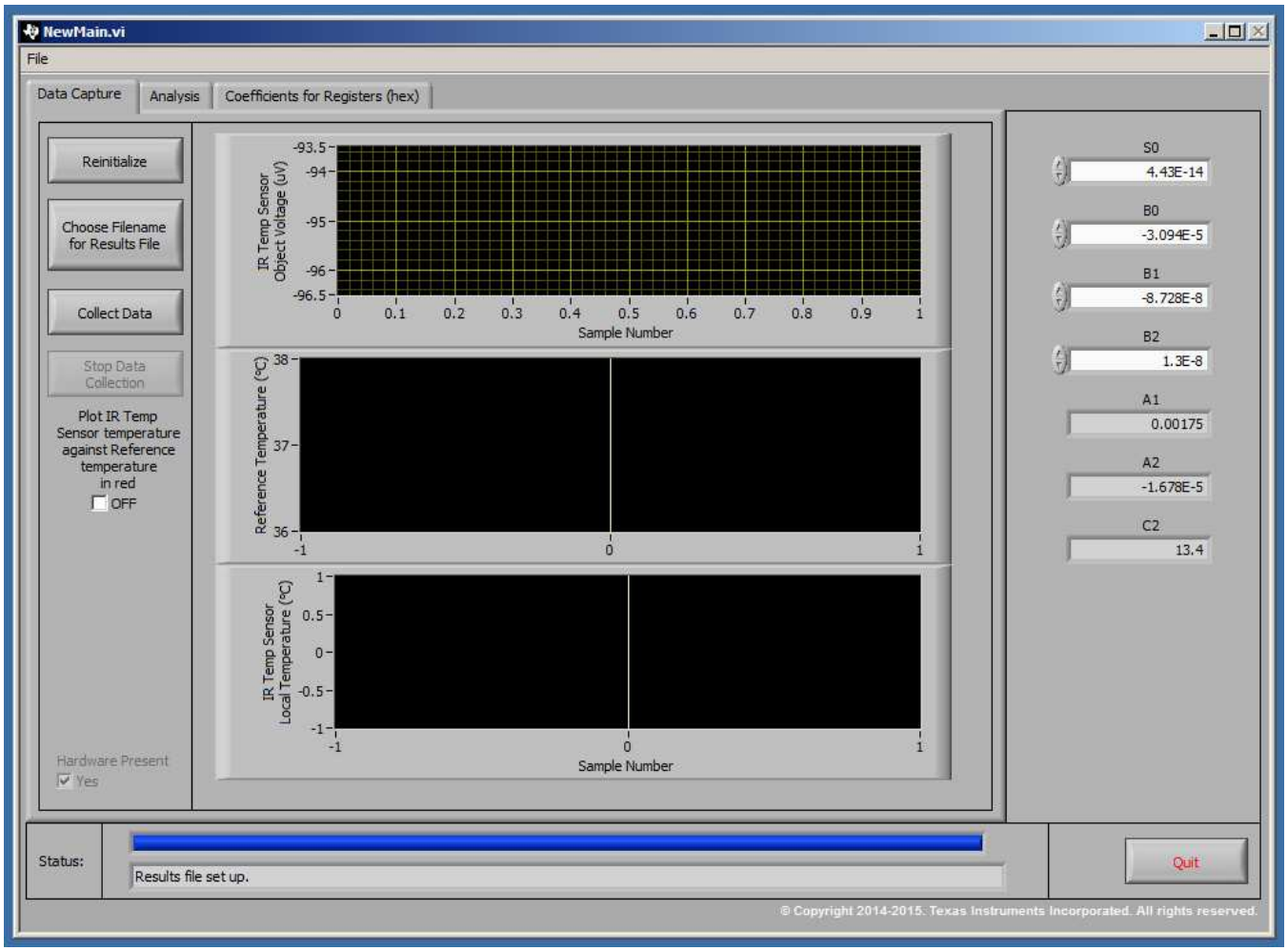

Figure 18. TMP007EasyCal set up for Data Capture

Data are captured from the TMP007 and the TMP112 at one-second intervals. Three plots are populated with this data, shown in Figure 19. The *IR Temp Sensor Object Voltage (uV)* plot shows the reported measurement of the object voltage (TMP007 thermopile voltage) from the TMP007 in µV. A red @ symbol indicates a potentially noisy spot in the data, where a gap between data points of over 5 µV was recorded. The presence of the red @ symbol in the data display does not indicate invalid data, but should serve as an indicator that something may be happening in the system that requires additional investigation by the user. For example, the @ symbol may mean that there is noise in the system (if the temperature is not changing abruptly at the time of measurement), or that either the temperature of the object or the ambient temperature (TMP007 die temperature) has changed rapidly, or that air is flowing across the sensor.

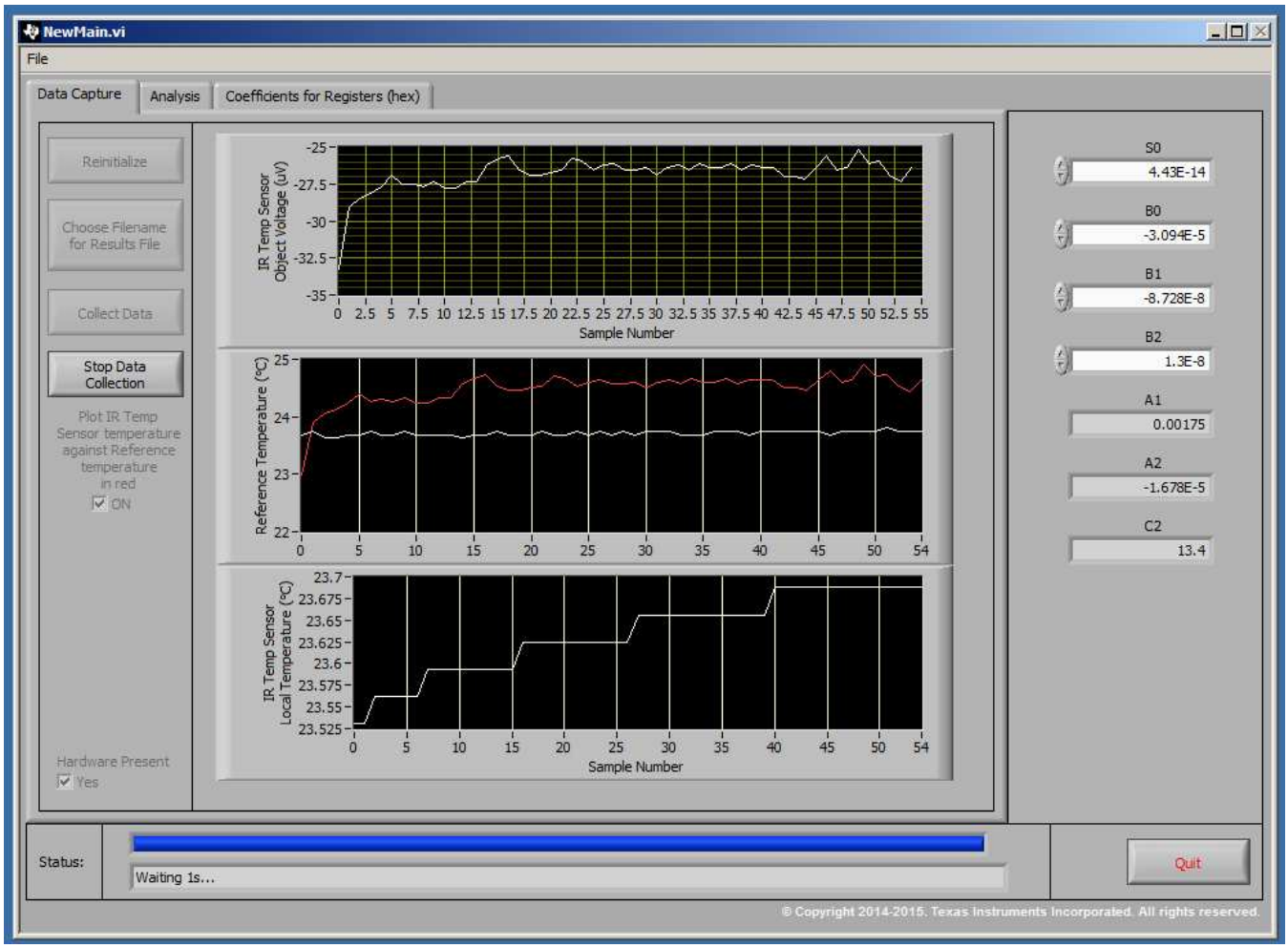

Figure 19. TMP007EasyCal Data Capture in Progress

The *Reference Temperature (°C)* plot shows the measurement of the TMP112 on the remote object as a white line. This is essentially the target temperature that the calibration attempts to match. If the additional red line in this plot is on, the calculated object temperature is displayed as well. The S0, B0, B1, and B2 numerical control fields displayed on the right-hand side remain active for real-time adjustment of the coefficients, if desired. Adjust the coefficients manually either during real-time data collection, or after the data collection process is complete. Manual adjustment of the coefficients is not required, but serves as a useful feature of the TMP007EasyCal software that allows the relationship between the coefficient values and the object temperature result to be observed. When adjusting the coefficients during real-time data capture, only the data captured after the coefficient adjustment has been made will use the new coefficients. Previously displayed data use the coefficients that were used previously at the time the data was displayed.

The final plot, *IR Temp Sensor Local Temperature (°C)*, shows the reported die temperature of the TMP007 used in the calculations of the object temperature.

During data collection, all buttons are unavailable, except for the *Stop Data Collection* button that ends the data capture run and makes the data ready for analysis.

Press the *Stop Data Collection* button to stop the data capture. The data file is stored on the disk so the data remains available for immediate analysis, or can be reloaded at a later time as well.

3.4.2 Analyzing Data

Select the *Analysis* tab at the top of the GUI. If data were just captured, the data are available for analysis, as indicated by the green light labeled *Data Available*, shown in Figure 20.

If the data capture was not previously run and a previous data set is ready for analysis, click *Load Data File...* and navigate to the directory and file for analysis. Appropriately formatted data files are in comma-separated variable (CSV) format, with a header row and three columns. The first column is the sensor voltage in µV. The second column is the local (TMP007 die) temperature in °C. The third column is the object reference temperature in °C. Each row represents data taken at one-second intervals. Additional following columns are ignored and can be used for time-stamps, notes, and other data. Additional rows are not allowed. For quick reference, the description of the data file format for import is directly beneath the analysis buttons and indicators.

Click *Run Calibration* to analyze the data set. Depending on the size of the data set, the *Running* light remains lit as the calculations are performed. When the algorithm is complete, the *Running* light turns off and the *Calibrated* light turns on, indicating a set of coefficients has been calculated. The new coefficients are displayed on the right-hand side of the window.

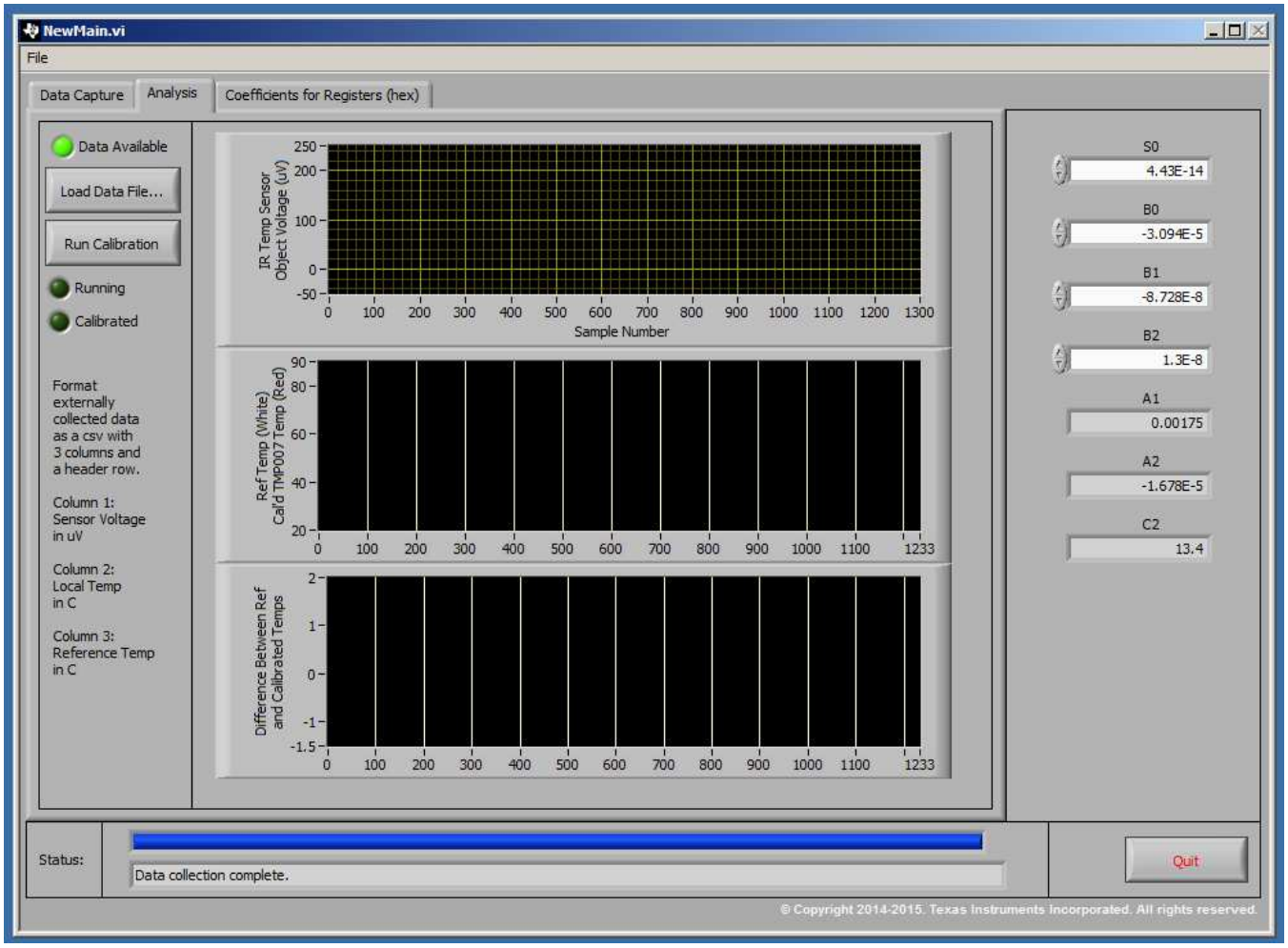

Figure 20. TMP007EasyCal Data Analysis Tab

The three plots on the *Analysis* tab are used in evaluating and manual adjustment of coefficients. After the calibration is performed or an adjustment to a coefficient is made, the plots are refreshed with the captured and calculated data, as shown in Figure 21.

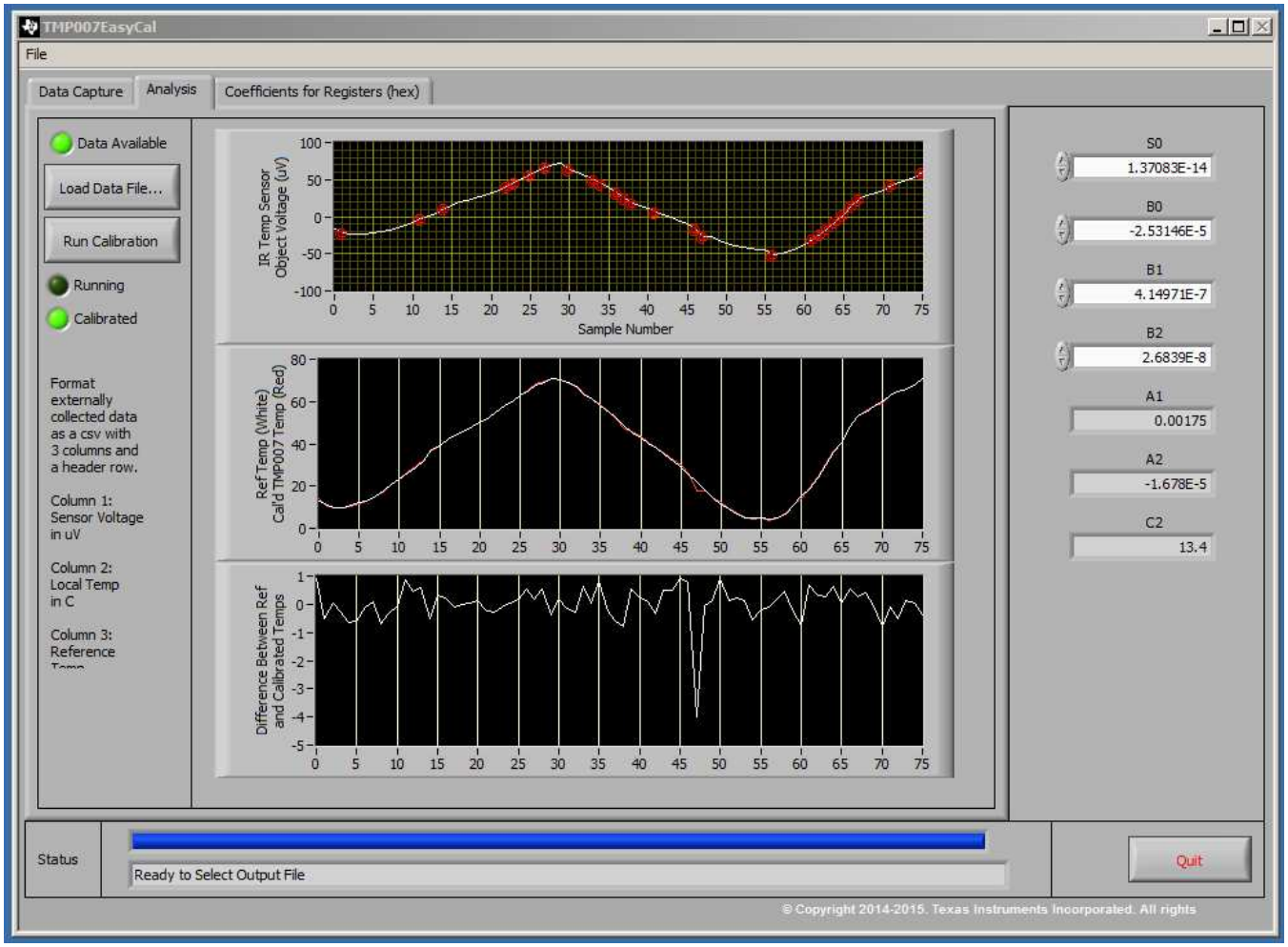

Figure 21. TMP007EasyCal with Calibrated Data

The first plot is the *IR Temp Sensor Object Voltage (uV)* and displays that data in white, again with red @ symbols denoting points of potential noise in the data.

The second plot displays the *Ref Temp (White)* and *Cal'd TMP007 Object Temp (Red)* lines. In an ideal example, the calibrated object temperature (red) is identical to the reference temperature (white).

The final plot is the *Difference between Reference and Calibrated Temps*. This plot shows the distance, in °C, between the red and white lines in the second plot; essentially, this plot gives the error of the calibrated object temperature.

3.4.3 Evaluating the Calculated Coefficients

The algorithm that calculates the coefficients for a given data set is a looping polynomial fit of the data. The algorithm expects the data to be sampled at one-second intervals; do not use discrete measurements at different times and temperatures. The one-second intervals between samples is not a strict requirement, but it is highly recommended to maintain a minimal time delay between reading the reference temperature result and the TMP007 object voltage result. in the case of the TMP007EasyCal, both the TMP007 and TMP112 are read at one-second intervals with less than 100 ms between reading each device. Using the TMP007EasyCal ensures that the reference temperature and object voltage readings are correlated in time and result in the most accurate results. If custom hardware is used to collect data, where a different sensor is used as the reference temperature sensor, make sure to maintain time correlation between readings for best results. Analyzing noisy or erratic data, or data that are not well correlated in time, may result in coefficients that are outside the bounds of the TMP007 math engine. The best course of action is to simply set up the TMP007EasyCal hardware as described in Section 2.2.2, and then capture data continuously at one-second intervals as the temperature increases and decreases.

On the *Coefficients for Registers (hex)* tab, the formatted hexadecimal equivalents of the calculated decimal coefficients are available. The fields are surrounded by either white or red borders. The white border indicates that the value for the corresponding coefficient is within the range of the TMP007 math engine register bounds, as shown in Figure 22. A red border indicates that the coefficient value is outside the allowed bounds of the register; the data set must be recollected or manually adjusted until a set of coefficients that work in the TMP007 math engine are found (see Figure 23).

After acceptable and usable coefficients are found, they can be programmed into the TMP007 and the integrated math engine computes the object-voltage to object-temperature conversion internally.

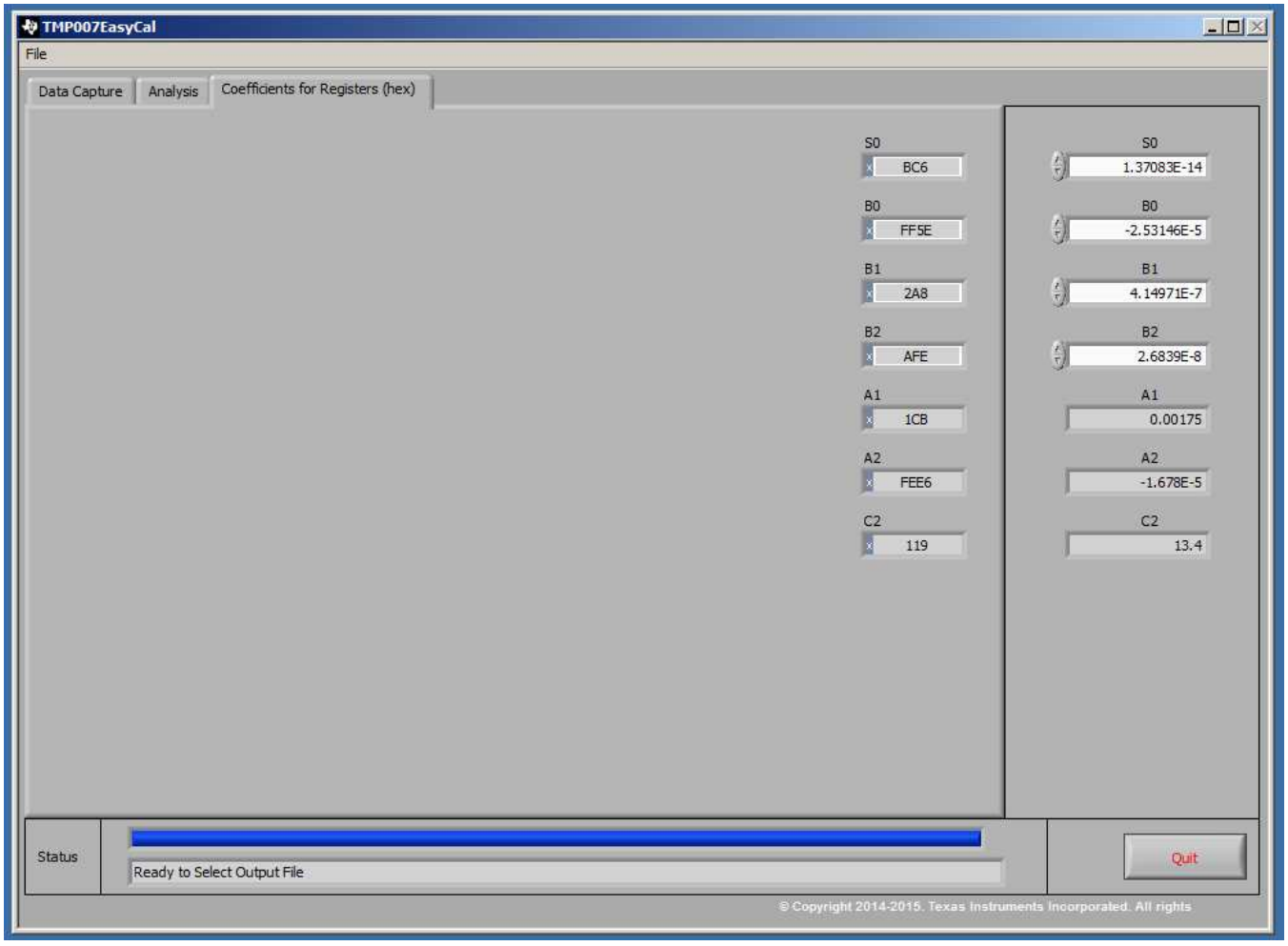

Figure 22. TMP007EasyCal Example of Usable Coefficients

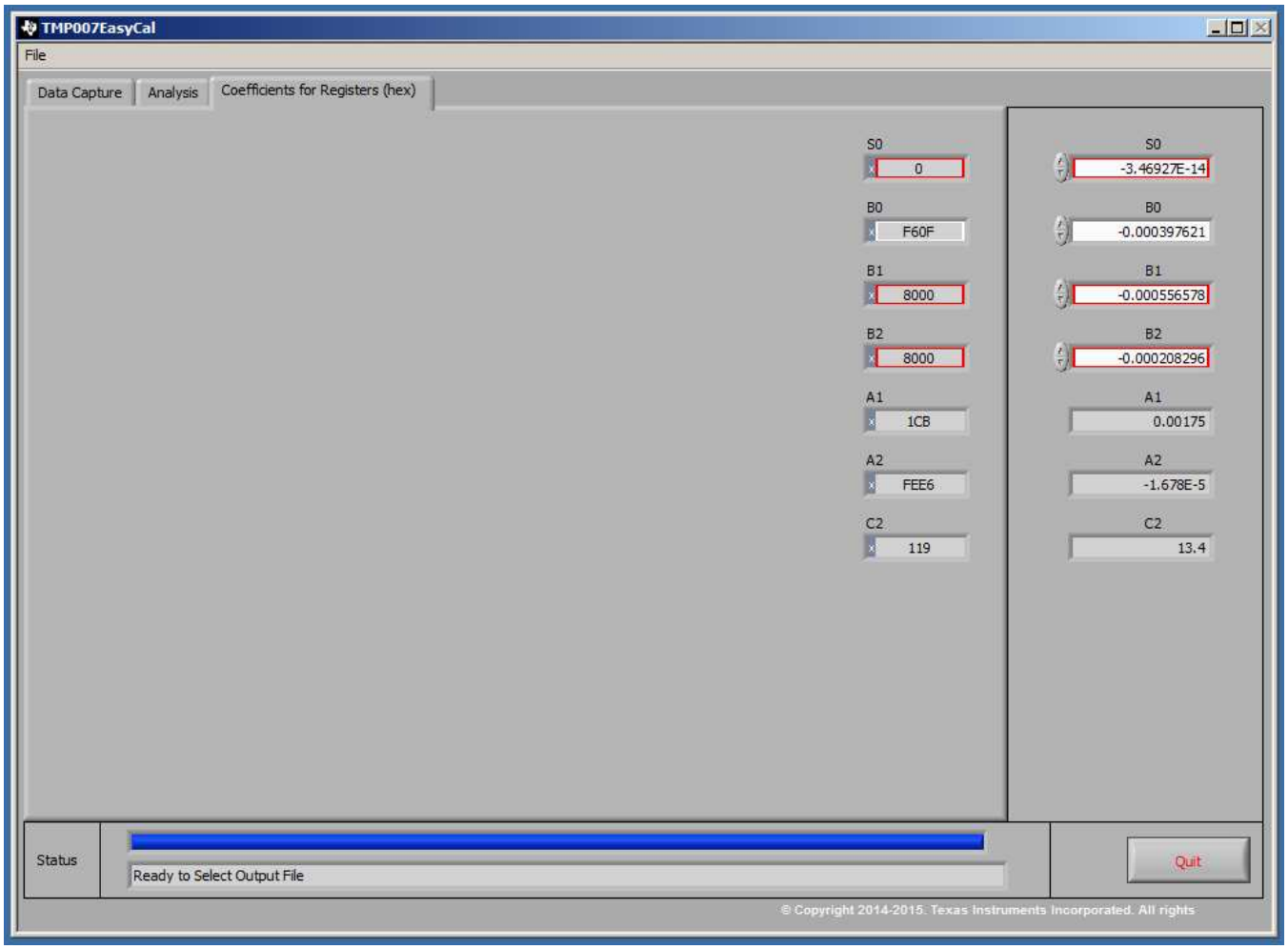

Figure 23. TMP007EasyCal Example of Unusable Coefficients

4 Schematic, PCB Layout, and Bill of Materials

4.1 Schematics

4.1.1 Adaptor Board Schematic

Figure 24 shows a schematic of the adaptor board. The V+, SCL, SDA, and GND pins of the 10-pin header are routed to pads to attach a surface-mount ribbon cable. No other components are included on this board.

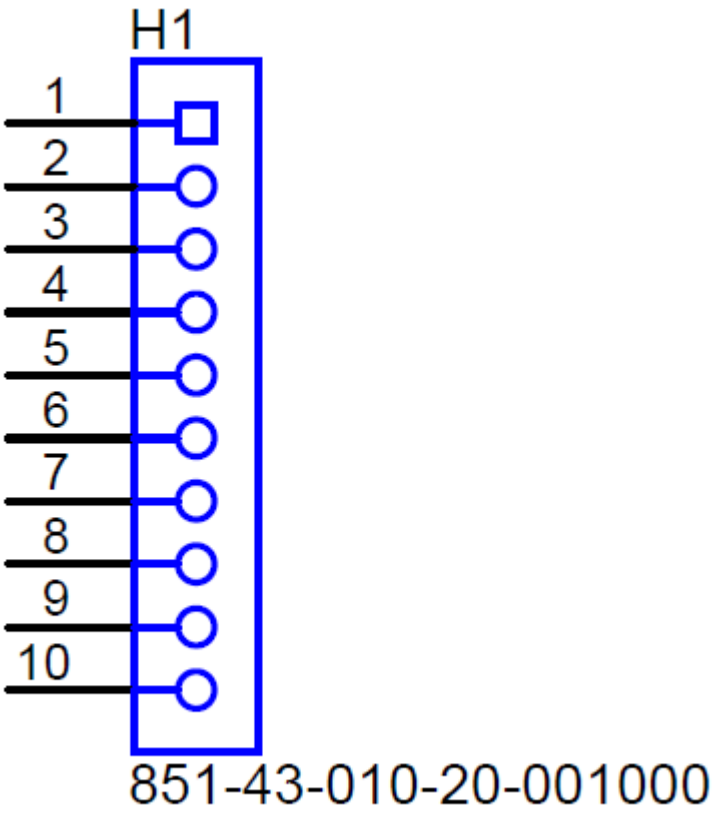

Figure 24. Adaptor Board Schematic

4.1.2 TMP007 Test Board Schematic

Figure 25 shows a schematic of the TMP007 test board. On one side of the board, V+, SCL, SDA, and GND pads are attached to the surface mount ribbon cable from the adaptor board. On the other side of the board, the same V+, SCL, SDA, and GND lines are routed to pads to attach another surface-mount ribbon cable to the TMP112 test board. The TMP007 device is soldered to the center of the board, and C1 is used for a bypass capacitor. No other components are included on this board.

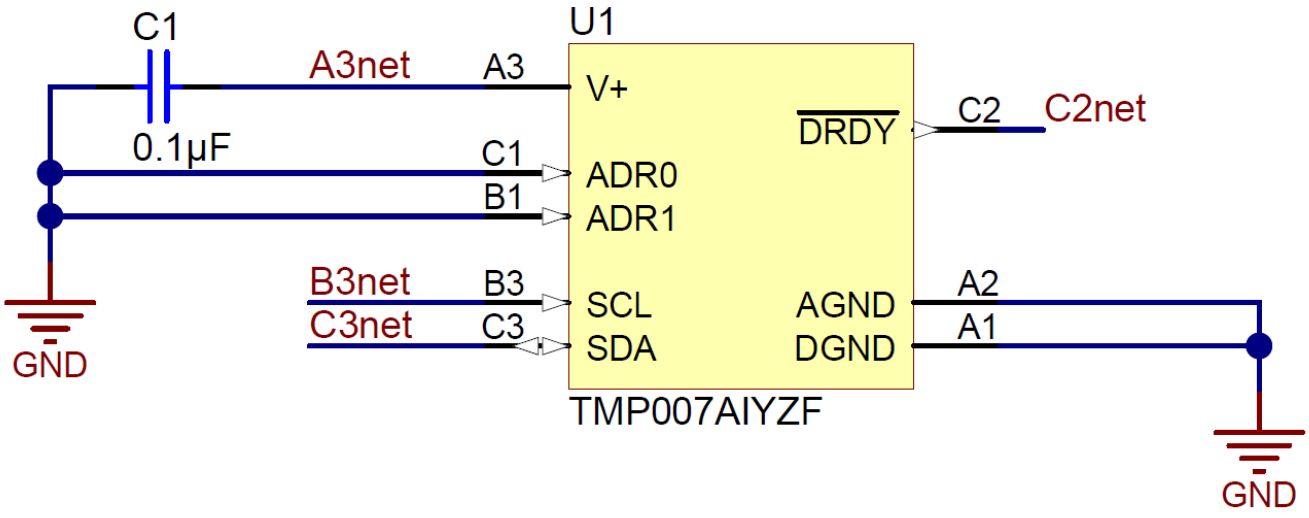

Figure 25. TMP007 Test Board Schematic

4.1.3 TMP112 Test Board Schematic

Figure 26 shows a schematic of the TMP112 test board. On one side of the board, V+, SCL, SDA, and GND pads are attached to the surface-mount ribbon cable from the TMP007 test board. The TMP112 device is soldered to the center of the board, and C1 is used for a bypass capacitor. No other components are included on this board

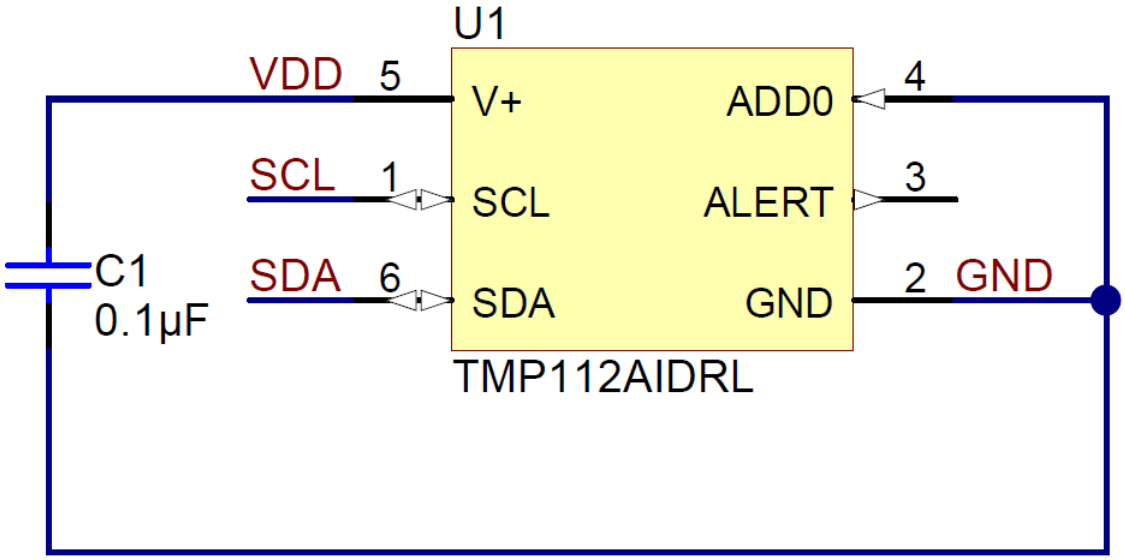

Figure 26. TMP112 Test Board Schematic

4.2 PCB Layouts

4.2.1 Adaptor Board Layout

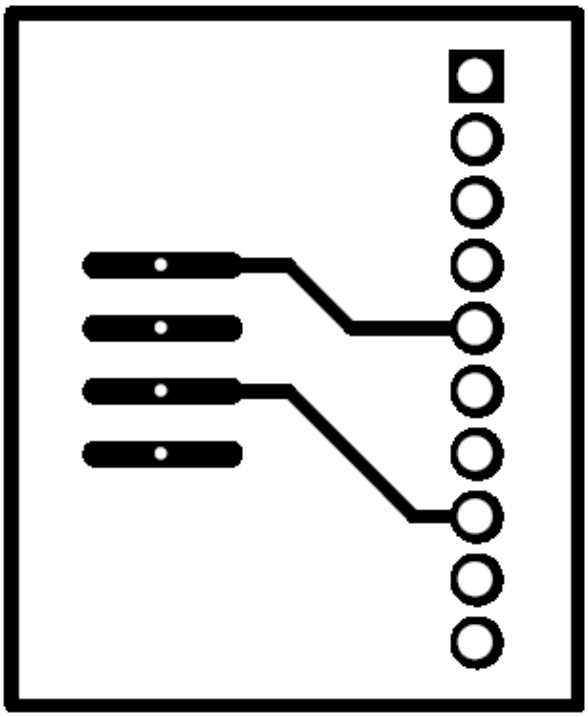

Figure 27. Adaptor Board PCB Top Layer

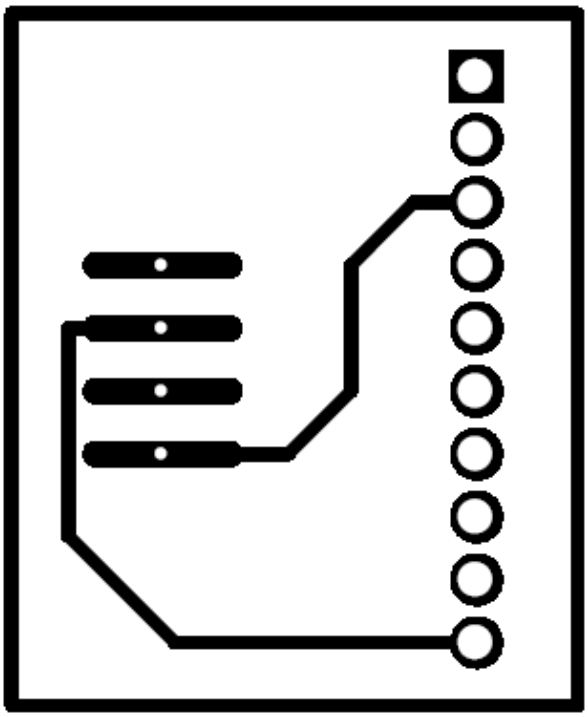

Figure 28. Adaptor Board PCB Bottom Layer

4.2.2 TMP007 Test Board Layout

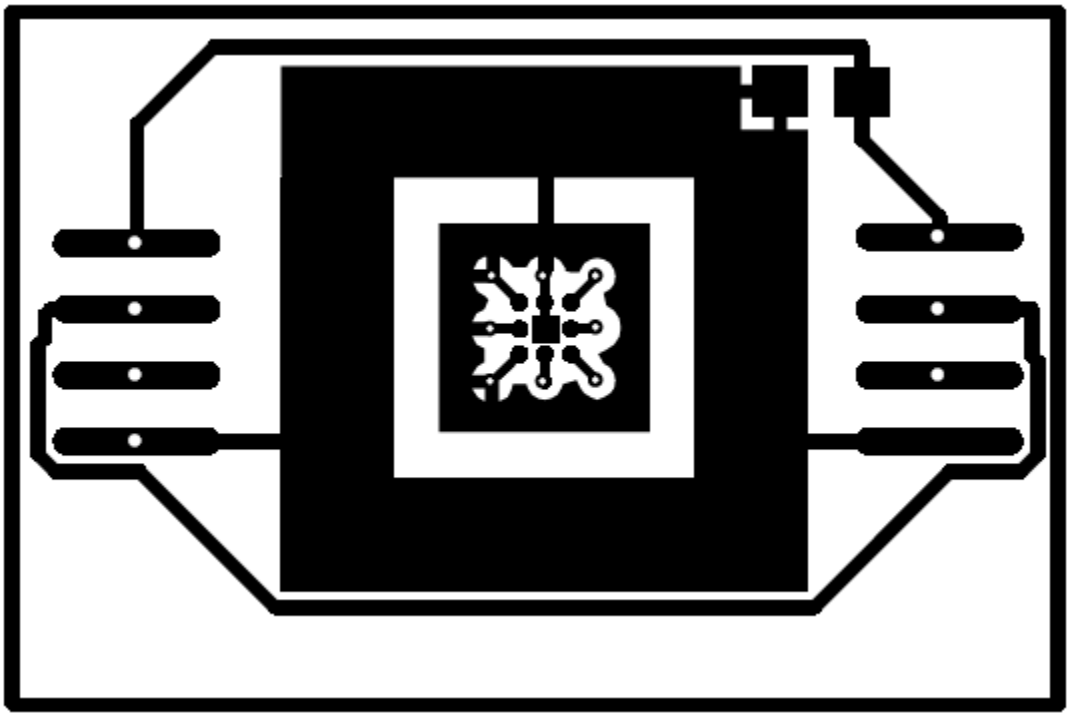

Figure 29. TMP007 Test Board PCB Top Layer

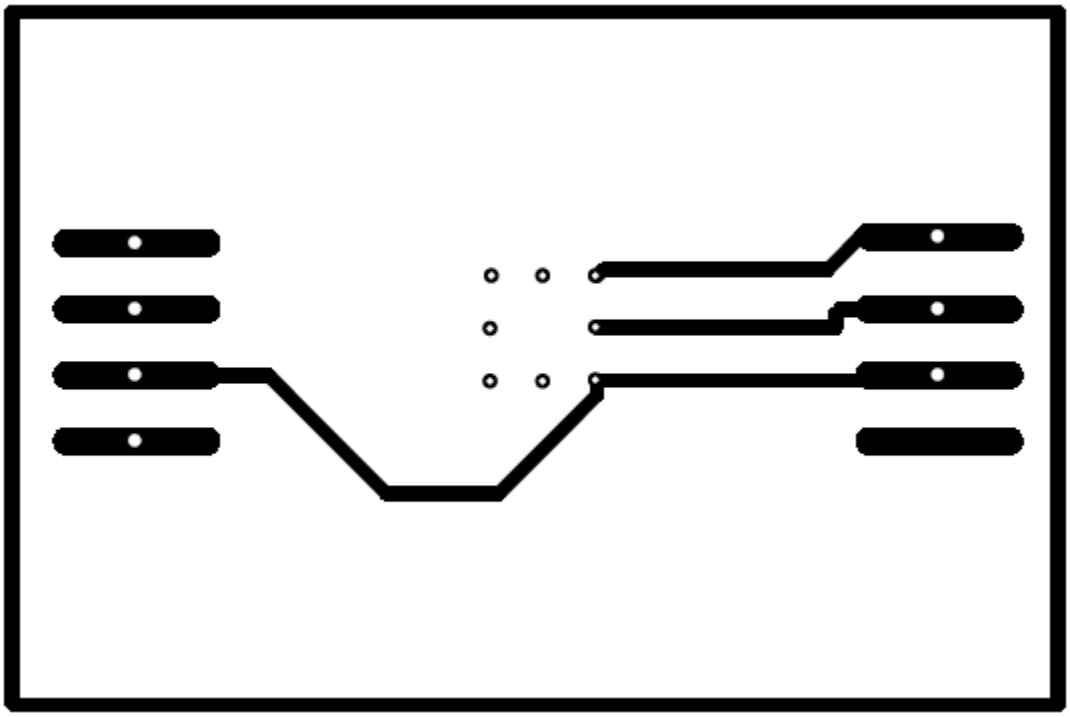

Figure 30. TMP007 Test Board PCB Bottom Layer

4.2.3 TMP112 Test Board Layout

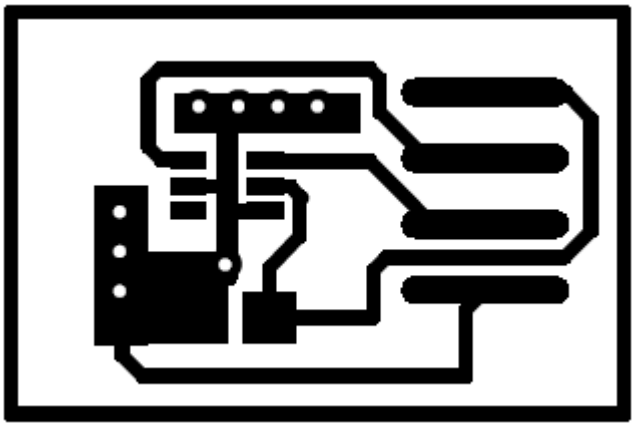

Figure 31. TMP112 Test Board PCB Top Layer

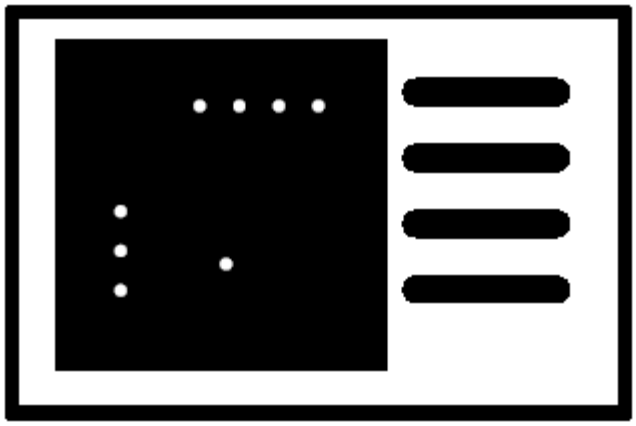

Figure 32. TMP112 Test Board PCB Bottom Layer

4.3 Bill of Materials

Table 3. Bill of Materials

Qty	RefDes	Description	Part Number	MFR
2	C1 (TMP007), C1 (TMP112)	0.1uF capacitor	CAP, CERM, 0.1uF, 16V, +/-5%, X7R, 0603	AVX
1	H1 (Adaptor)	10x1, 50 mil, right-angle, through-hole female header	851-43-010-20-001000	Mill-Max
1	U1 (TMP007)	Infrared Thermopile Sensor in Chip-Scale Package	TMP007AIYZF	Texas Instruments
1	U1 (TMP112)	High-Accuracy, Low-Power, Digital Temperature Sensor With SMBus(TM)/Two-Wire Serial Interface	TMP112AIDRL	Texas Instruments

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      3.1.1 *Notice applicable to EVMs not FCC-Approved:*

      This kit is designed to allow product developers to evaluate electronic components, circuitry, or software associated with the kit to determine whether to incorporate such items in a finished product and software developers to write software applications for use with the end product. This kit is not a finished product and when assembled may not be resold or otherwise marketed unless all required FCC equipment authorizations are first obtained. Operation is subject to the condition that this product not cause harmful interference to licensed radio stations and that this product accept harmful interference. Unless the assembled kit is designed to operate under part 15, part 18 or part 95 of this chapter, the operator of the kit must operate under the authority of an FCC license holder or must secure an experimental authorization under part 5 of this chapter.

      3.1.2 *For EVMs annotated as FCC – FEDERAL COMMUNICATIONS COMMISSION Part 15 Compliant:*

      CAUTION

      This device complies with part 15 of the FCC Rules. Operation is subject to the following two conditions: (1) This device may not cause harmful interference, and (2) this device must accept any interference received, including interference that may cause undesired operation.

      Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

      FCC Interference Statement for Class A EVM devices

      NOTE: This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

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- *Reorient or relocate the receiving antenna.*
- *Increase the separation between the equipment and receiver.*
- *Connect the equipment into an outlet on a circuit different from that to which the receiver is connected.*
- *Consult the dealer or an experienced radio/TV technician for help.*

3.2 *Canada*

3.2.1 *For EVMs issued with an Industry Canada Certificate of Conformance to RSS-210*

Concerning EVMs Including Radio Transmitters:

This device complies with Industry Canada license-exempt RSS standard(s). Operation is subject to the following two conditions: (1) this device may not cause interference, and (2) this device must accept any interference, including interference that may cause undesired operation of the device.

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Concernant les EVMs avec antennes détachables

Conformément à la réglementation d'Industrie Canada, le présent émetteur radio peut fonctionner avec une antenne d'un type et d'un gain maximal (ou inférieur) approuvé pour l'émetteur par Industrie Canada. Dans le but de réduire les risques de brouillage radioélectrique à l'intention des autres utilisateurs, il faut choisir le type d'antenne et son gain de sorte que la puissance isotrope rayonnée équivalente (p.i.r.e.) ne dépasse pas l'intensité nécessaire à l'établissement d'une communication satisfaisante. Le présent émetteur radio a été approuvé par Industrie Canada pour fonctionner avec les types d'antenne énumérés dans le manuel d'usage et ayant un gain admissible maximal et l'impédance requise pour chaque type d'antenne. Les types d'antenne non inclus dans cette liste, ou dont le gain est supérieur au gain maximal indiqué, sont strictement interdits pour l'exploitation de l'émetteur

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2. Use EVMs only after User obtains the license of Test Radio Station as provided in Radio Law of Japan with respect to EVMs, or
3. Use of EVMs only after User obtains the Technical Regulations Conformity Certification as provided in Radio Law of Japan with respect to EVMs. Also, do not transfer EVMs, unless User gives the same notice above to the transferee. Please note that if User does not follow the instructions above, User will be subject to penalties of Radio Law of Japan.

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