# Making High Accuracy Temperature Measurements with the 3499A/B/C Switch and the 34401A Digital Multimeter

Application Note 1460

## Introduction

You can use an Agilent 3499A/B/C switch/control unit with a 34401A digital multimeter (DMM) and an external isothermal terminal panel, or "patch panel," such as the E1586A rack-mount terminal, available from VXI Technology (**www.vxitech.com**), to make thermocouple temperature measurements. Using the E1586A isothermal terminal panel, you can make measurements with less than ± 0.6°C error. Relative measurements are better than ± 0.4°C across 39 channels. For more information on using the 3499 switch with a 34401A DMM and software for temperature conversions, see Application Note 1459, *How to Program the 3499A/B/C Switch and the 34401A Digital Multimeter for Scanning Measurements*.
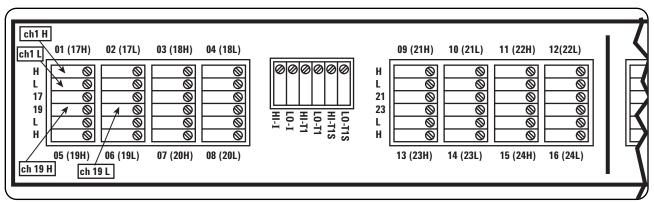
This application note explains how to wire the E1586A isothermal panel and use it to make high-accuracy temperature measurements with a 3499A/B/C switch and a 34401A DMM.

## Wiring the E1586A isothermal panel

The E1586A isothermal panel is designed for up to 32 channels with three wires each (Hi, Lo, Gnd), and it comes from the factory with the front-panel

markings for these three-wire channels. You can use the E1586A panel with the 3499A switch for up to 39 thermocouple channels, 2 wires each, with one N2260A 40-channel MUX. However, the connections to achieve the 39 channels do not follow the normal markings on the E1586's front panel. Panels manufactured after Jan. 1, 2003 also come with a silk-screened diagram on the rear of the panel for up to 48 two-wire channels. To use these two-wire markings with the N2260A, remove the two screws that hold the front panel in place, turn the panel over (left to right) and replace the screws. On this panel face (aluminum background), the channels are divided into two sections (left and right), with 24 channels each. One E1586A panel can accommodate one N2260A for a maximum of 39 channels of thermocouple measurements. Channel 00 is used as the reference temperature.

To wire the panel to a N2260A module, you need two SCSI cables: one cable for channels 00 to 20 and another cable for channels 21 to 39. One channel (for this example we chose channel 00 of the N2260A) is required for the thermistor reference on the E1586A, and therefore, each N2260A will provide 39 channels of temperature measurements.



Figure 1: Left side of the E1586A terminal panel, shown with two-wire markings

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| N2296A Pinout | N2260A Channel 00-20 | Left Panel E1586A Painted J19 | Left Panel E1586A Aluminum J19 | Twisted pair First color is solid color | N2296A Pinout | N2260A Channel 21-39 | Right panel E1586A Pinout J20 | Right panel E1586A Pinout J20 |
|---|---|---|---|---|---|---|---|---|
| 2A | Ch 00 H | I-Hi | I-Hi | Orange/Pink | | GND | Trig | Trig |
| 1A | Ch 00 L | I-Lo | I-Lo | Pink/Orange | | GND | Gnd | Gnd |
| 2B | Ch 01 H | 0 HI | Ch 01 H | Brown/White | 18B | Ch 21 H | 16 HI | Ch 01 H |
| 1B | Ch 01 L | 0 LO | Ch 01 L | White/Brown | 17B | Ch 21 L | 16 LO | Ch 01 L |
| 2C | Ch 02 H | 1 HI | Ch 02 H | Brown/Orange | 18C | Ch 22 H | 17 HI | Ch 02 H |
| 1C | Ch 02 L | 1 LO | Ch 02 L | Orange/Brown | 17C | Ch 22 L | 17 LO | Ch 02 L |
| 4A | Ch 03 H | 2 HI | Ch 03 H | Brown/Yellow | 20A | Ch 23 H | 18 HI | Ch 03 H |
| 3A | Ch 03 L | 2 LO | Ch 03 L | Yellow/Brown | 19A | Ch 23 L | 18 LO | Ch 03 L |
| 4B | Ch 04 H | 3 HI | Ch 04 H | Brown/Blue | 20B | Ch 24 H | 19 HI | Ch 04 H |
| 3B | Ch 04 L | 3 LO | Ch 04 L | Blue/Brown | 19B | Ch 24 L | 19 LO | Ch 04 L |
| 4C | Ch 05 H | 4 HI | Ch 05 H | Brown/Violet | 20C | Ch 25 H | 20 HI | Ch 05 H |
| 3C | Ch 05 L | 4 LO | Ch 05 L | Violet/Brown | 19C | Ch 25 L | 20 LO | Ch 05 L |
| 6A | Ch 06 H | 5 HI | Ch 06 H | Tan/Brown | 22A | Ch 26 H | 21 HI | Ch 06 H |
| 5A | Ch 06 L | 5 LO | Ch 06 L | Brown/Tan | 21A | Ch 26 L | 21 LO | Ch 06 L |
| 6B | Ch 07 H | 6 HI | Ch 07 H | Tan/White | 22B | Ch 27 H | 22 HI | Ch 07 H |
| 5B | Ch 07 L | 6 LO | Ch 07 L | White/Tan | 21B | Ch 27 L | 22 LO | Ch 07 L |
| 6C | Ch 08 H | 7 HI | Ch 08 H | Tan/Orange | 22C | Ch 28 H | 23 HI | Ch:08 H |
| 5C | Ch 08 L | 7 LO | Ch 08 L | Orange/Tan | 21C | Ch 28 L | 23 LO | Ch 08 L |
| 8A | Ch 09 H | 8 HI | Ch 09 H | Tan/Yellow | 24A | Ch 29 H | 24 HI | Ch 09 H |
| 7A | Ch 09 L | 8 LO | Ch 09 L | Yellow/Tan | 23A | Ch 29 L | 24 LO | Ch 09 L |
| 10A | Ch 10 H | 9 HI | Ch 10 H | Tan/Blue | 26A | Ch 30 H | 25 HI | Ch 10 H |
| 9A | Ch 10 L | 9 LO | Ch 10 L | Blue/Tan | 25A | Ch 30 L | 25 LO~ | Ch 10 L |
| 10B | Ch 11 H | 10 HI | Ch 11 H | Tan/Violet | 26B | Ch 31 H | 26 HI | Ch 11 H |
| 9B | Ch 11 L | 10 LO | Ch 11 L | Violet/Tan | 25B | Ch 31 L | 26 LO | Ch 11 L |
| 10C | Ch 12 H | 11 HI | Ch 12 H | White/Pink | 26C | Ch 32 H | 27 HI | Ch 12 H |
| 9C | Ch 12 L | 11 LO | Ch 12 L | Pink/White | 25C | Ch 32 L | 27 LO | Ch 12 L |
| 12A | Ch 13 H | 12 HI | Ch 13 H | White/Orange | 28A | Ch 33 H | 28 HI | Ch 13 H |
| 11A | Ch 12 L | 12 LO | Ch 13 L | Orange/White | 27A | Ch 33 L | 28 LO | Ch 13 L |
| 12B | Ch 14 H | 13 HI | Ch 14 H | White/Green | 28B | Ch 34 H | 29 HI | Ch 14 H |
| 11B | Ch 14 L | 13 LO | Ch 14 L | Green/White | 27B | Ch 34 L | 29 LO | Ch 14 L |
| 12C | Ch 15 H | 14 HI | Ch 15 H | White/Blue | 28C | Ch 35 H | 30 HI | Ch 15 H |
| 11C | Ch 15 L | 14 LO | Ch 15 L | Blue/White | 27C | Ch 35 L | 30 LO | Ch 15 L |
| 14A | Ch 16 H | 15 HI | Ch 16 H | White/Gray | 30A | Ch 36 H | 31 HI | Ch 16 H |
| 13A | Ch 16 L | 15 LO | Ch 16 L | Grey/White | 29A | Ch 36 L | 31 LO | Ch 16 L |
| 14B | Ch 17 H | 0 G | Ch 17 H | Brown/Pink | 30 B | Ch 37 H | 16 G | Ch 17 H |
| 13B | Ch 17 L | 1 G | Ch 17 L | Pink/Brown | 29B | Ch 37 L | 17 G | Ch 17 L |
| 14C | Ch 18 H | 2 G | Ch 18 H | Brown/Green | 30C | Ch 38 H | 18 G | Ch l8 H |
| 13C | Ch 18 L | 3 G | Ch 18 L | Green/Brown | 29C | Ch 38 L | 19 G | Ch 18 L |
| 16A | Ch 19 H | 4 G | Ch 19 H | Brown/Gray | 32A | Ch 39 H | 20 G | Ch 19 H |
| 15A | Ch 19 L | 5 G | Ch 19 L | Gray/Brown | 31A | Ch 39 L | 21 G | Ch 19 L |
| 18A | Ch 20 H | 6 G | Ch 20 H | Tan/Pink | | Not used | 22 G | Ch 20 H |
| 17A | Ch 20 L | 7 G | Ch 20 L | Pink/Tan | | | 23 G | Ch 20 L |
| | Not used | 8 G | Ch 21 H | Tan/Green | | Not used | 24 G | Ch 21 H |
| | | 9 G | Ch 21 L | Green/Tan | | | 25 G | Ch 21 L |
| | Not used | 10 G | Ch 22 H | Tan/Gray | | Not used | 26 G | Ch 22 H |
| | | 11 G | Ch 22 L | Gray/Tan | | | 27 G | Ch 22 L |
| | Ch00 H | 12 G | Ch 23 H | White/Yellow | | Not used | 28 G | Ch 23 H |
| | Ch00 L | 13 G | Ch 23 L | Yellow/White | | | 29 G | Ch 23 L |
| | Not used | 14 G | Ch 24 H | White/Violet | | Not used | 30 G | Ch 24 H |
| | | 15 G | Ch 24 L | Violet/White | | | 31 G | Ch 24 L |
| 8C | COM 0 H | Connect to **DMM Input** | | | 24C | COM 1 H | Connect to **DMM Sense** | |
| 7C | COM 0 L | | | | 23C | COM 1 L | | |

**Table 1: Wiring table**

**Caution:** Your cable may have different color codes for each wire. This is a Computer Cable Makers PN SCS2-1000-003 wiring table.

Each cable must have an HD-50 male metal connector on one end to connect to the E1586A. The cable selected here has 25 color-coded twisted pairs and bare wires on the other end. An 80 cm (2.5 ft) SCSI-2 to SCSI-1 cable is available for about $20 from Computer Cable Makers (**www.cablemakers.com**, PN SCS2-1000-003) and from Cables to Go (**www.cablestogo.com**).

Wiring is straightforward. Insert the cable into J19 on the left rear of the E1586A terminal panel and cut off the connector on the other end of the cable. Strip the outer insulation back about 10 cm (4 in). Strip the outer and inner shield back 9 cm (3.5 in). Fold the outer shield back on the insulation and cover it with heat shrink. Insert the cable in the N2290A terminal block. Wire the cable to the N2290A terminal block following the Table 1. Channel 00 is wired to the HI-I and LO-I for connecting to the thermistor of the E1586A, channel 01 is wired to channel 01 of the E1586A left side and so on through channel 20. Alternately, you can wire the cable directly to the connector of the terminal module N2296A. When using the N2296A, be sure to wire the connector for COM0 and COM1 connections to the DMM.

The second cable is wired for channel 21 of the N2260A to channel 01 on the right side of the E1586A and so on through channel 39 of the N2260A wired to channel 19 on the right half of the E1586A.

You can reduce the resistance of channel 00 to below 0.5 ohm by connecting the twisted pair in the cable for channel 23 to channel 00 of the N2260A terminal block. This will parallel two twisted wire pairs for channel 00. See wiring table.

To connect the center reference thermistor on the E1586A, connect channel HI-I and 23H to HI-T2S, and channel LO-I and 23L to LO-T2S.

To connect the shield and the ground on the E1586A, connect together GND, and TRIG. The wiring from the N2290A to the E1586A is now complete. See Table 1 for detailed connections.

Wire the thermocouple wires to the channels on the E1586A. Channels 01 to 20 correspond to channels 01 to 20 on the left side of the E1586A. Channels 21 to 39 on the N2260A correspond to channels 01 to 19 on the right side of the E1586A. See Table 1 for panel labeling.

## Making accurate measurements

You can mount the E1586A terminal panel in a standard-size instrument rack or place it on your bench. To minimize any variation between channels, the terminal panel must be kept away from heat sources and drafts. Do not place the terminal panel directly next to instruments, or directly on top of a powered instrument. To isolate the panel from any heat source beneath the panel on your bench, place a section of foam or Styrofoam under the full length of the terminal panel. To protect the terminal panel from drafts, cover or wrap it in a towel or cloth or surround it with Styrofoam.

When you mount the terminal panel in a rack, it should be mounted such that it is away from the heat sources. The bottom of the rack is usually the preferred location. Take particular care to minimize the temperature difference across the horizontal width of the terminal panel, since it is most susceptible to horizontal temperature gradients across its longest dimensions. Avoid mounting the terminal panel directly above or below instruments that have a hot air exit on the side.

Channels closest to the center near the reference thermistor will have the best accuracy. When relative measurements are important, put those channels

| Source of Error | Absolute accuracy J | Relative accuracy |
|---|---|---|
| Isothermal termination, E1586A | ± 0.2°C (± 10µV) | 0.2°C (± 10µV) difference between any two channels |
| Ref. Thermistor Measurement (DMM in 100k ohm range) | ± 0.03°C (± 6 ohms) | N/A |
| Ref. Thermocouple conversion | ± 0.02°C | N/A |
| Ref. Thermistor accuracy | ± 0.1°C | N/A |
| Ref. Thermistor lead + relay ohms | - 0.013°C < (0.5 + 2 ohms) | N/A |
| Ref. Thermocouple conversion | ± 0.05°C | ± 0.05°C |
| Voltmeter accuracy | ± 0.08°C (± 4uV @ 0.0mV), 25°C<br>± 0.1°C (± 5uV @ 26mV), 500°C | ± 0.08°C (± 4uV @ 0.0 mV), 25°C<br>± 0.1°C (± 5uV @ 26 mV), 500°C |
| Relay thermal offset, N2260A | ± 0.075°C (3uV) | ± 0.06°C (3uV) |
| **Total** | ± 0.6°C not including sensor | ± 0.4°C not including sensor |

**Table 2: Measurement uncertainty**

physically close together on the terminal panel. Channels closest together will have the best agreement among each other. There are three thermistors on the E1586A. If only one side (left or right) is used, use the thermistor closest to the terminal blocks in use. See the E1586A manual for thermistor locations.

Table 2 shows the measurement uncertainty for the individual error contributions when you use a J-type thermocouple. The errors for other thermocouples and temperature ranges will be different depending on the error of the voltmeter, the temperature measured, thermocouple type and voltage level of the thermocouple. The error due to the thermocouple is not included in the calculation.

## Summary

If you use the E1586A patch panel with the 3499A/B/C, 34401A and N2260A MUX module and appropriate software conversion, you will be able to measure thermocouple temperature to ±0.6°C.

## Glossary

*J-type thermocouple* – iron-constantan thermocouple with a temperature range of -210 to 1200°C

*Thermocouple* – a temperature sensor consisting of two dissimilar metals joined together. When a temperature gradient exists (one end is a different temperature from the other), a voltage is generated. Different types of thermocouples are constructed from different metals, with differing temperature ranges and accuracies.

*Thermistor* – a ceramic temperature sensor that exhibits a change in resistance as a function of temperature. With most thermistors, resistance decreases as the temperature increases.

## Related Agilent Literature

Agilent 3499 Switch/Control Unit:
**www.agilent.com/find/3499**

Agilent N2260A 2-Wire, 40-Channel Multiplexer Module: **www.agilent.com/find/3499**

Agilent 34401A Multimeter:
**www.agilent.com/find/34401a**

AN 290 – Practical Temperature Measurements **www.agilent.com**, search on 5965-7822E

AN 1459 – How to Program the 3499A/B/C Switch and the 34401A Digital Multimeter for Scanning Measurements: **www.agilent.com**, search on 5988-9549EN

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