HP E1413A/B/C, E1313A, and E1415A Recommended Wiring and Noise Reduction Techniques

Product Note

Introduction

Incorrect wiring, shielding, or grounding can result in noisy readings or DC offsets on readings with sampling analog-to-digital converters like the HP E1413A/B/C, E1313A, and E1415A. Correct wiring, though expensive, improves measurement accuracy.

This product note gives background information and suggestions for using the HP E1413A/B/C, E1313A, and E1415A (collectively referred to in this note as the HP E1413) to measure low level signals.

For a thorough discussion of measurement noise, shielding, and filtering, see Noise Reduction Techniques in Electronic Systems by Henry W. Ott of Bell Laboratories, published by Wiley & Sons, ISBN 0-471-657726-3.

Shielding

Unshielded signal wiring is very common in Data Acquisition applications. While this works well for low speed integrating A/D measurements and/or for measuring high level signals, it does not work well for high speed sampling A/Ds, particularly when measuring low level signals like thermocouples or strain gage bridge outputs. These measurements require the more expensive, shielded, twisted pair signal wiring, unless you use an even more expensive amplifier-at-the-signal-source or individual A/D at the source. Unshielded wiring will pick up environmental noise, causing measurement errors.

Professional sound re-enforcement installations show the potential of shielded twisted pair wiring. In an environment with 5-20 kW of SCR controlled lighting, noise levels of 200 to 500 nV are routinely achieved from low level, 600 W microphones, with no filtering below 20 kHz, using shielded twisted pair cables 100 to 300 feet long.

Shield performance depends on the noise coupling mechanism, which may be difficult to determine. The recommendations given here generally achieve the most accuracy, but if feasible, experiment with shield connections to see which provides the best performance for your installation and environment.

To avoid ground loops, connect the shield to ground (or a path to ground) at only one point, and as near to the noise source as possible. HP recommends that you connect the shield to ground at the DUT and leave it open at the HP E1413, unless the DUT or the transducers on the DUT are floating. For floating DUTs or transducers, connect the shield to the HP E1413 GND or GRD terminals (more likely), whichever gives the best performance. Always securely screw the cards into the card cage. This gives the best card to VXI power supply ground connection and thus minimizes ground noise.

The HP E1413 guard connection provides a 10 Kohm current limiting resistor between the guard terminals and HP E1413 chassis ground for each 8-channel SCP bank. This is a safety device in case the DUT isn't actually floating; the shield is connected to the DUT and also connected to the HP E1413 guard terminal. The 10 Kohm resistor limits the ground loop current, which has been known to burn out shields. The resistor also provides 20 Kohm isolation between shields between SCP banks which helps isolate the noise source.

HP E1413 Noise Rejection

This section describes normal mode noise, common mode noise, and high-performance common mode noise rejection. Based on your application, you need to choose appropriate options for the HP E1413.

Normal Mode Noise Rejection

Normal mode noise (Enm), is the differential noise (Hi to Lo) present at the signal source. Normal mode noise is filtered out by the buffered filters on all SCPs except the E1501A, straight-through SCP.

Common Mode Noise Rejection

Common mode noise (Ecm) is noise common to both the Hi and Lo differential signal inputs. A good differential instrumentation amplifier is effective at rejecting low frequency Ecm. The sampling AD input amplifier common mode rejection (CMR) is 120 dB to 300 Hz, then rolls off at 20 dB per octave. Most common mode noise is about 60 Hz (low frequency), so the differential amplifier rejection is very good.

High frequency Ecm, however, is rectified and generates an offset with the amplifier and filter SCPs, which have buffer-amplifiers on board. This is a characteristic of amplifiers, so the best way to avoid this problem is to keep high frequency Ecm from getting into the amplifier. This can’t be averaged out because it appears as a DC offset. This is not the case with the E1501A, straight through SCP. Since there is no offset generating amplifier on the E1501A, you can average out Ecm on signals coming through the E1501A.

The HP E1413 amplifiers are selected for low gain error, offset, temperature drift, and low power. These characteristics are generally incompatible with good high frequency CMR performance. More expensive, high performance amplifiers can solve this problem, but since they aren’t required for many systems, HP elected to handle this with the tri-filar transformer/filter option to the E1586A Remote Rack Panel as described in the “High Performance Common Mode Noise Rejection” section.

Shielded, twisted pair lead wire generally keeps high frequency common mode noise out of the amplifier if you connect the shield to the HP E1413 chassis ground through a low impedance. Connecting the shield to the chassis conflicts with the recommended good practice of single-point grounding the shield at the signal source (the DUT) to eliminate line frequency ground loops. We recommend that you ground only at the signal source, and if you see high frequency common mode noise (or suspect it), tie the shield to the HP E1413 ground through an 0.1 uF capacitor. At high frequencies, the capacitor shorts the shield to 0 V at the HP E1413 input. Due to inductive coupling to the signal leads, the Ecm voltage on the signal leads is also zero volts.

Do not connect the shield to the HP E1413 guard terminal because the 10 Kohm resistor to chassis ground blocks the discharge of the high frequency Ecm. Use the guard terminal only to limit the shield current and to allow the DUT to float up to some DC common mode voltage subject to the maximum +/- 16 V input specification limit, or +/- 60 V with the E1513A Attenuator SCP.

High Performance Common Mode Noise Rejection

Greater than 110 dB CMR to 10 MHz is sometimes needed to get good thermocouple (TC) measurements in a high common mode noise test environments. The E1586A remote Rack Terminal Panel option 001 RF filter provides this high performance noise filtering. The option 001 filter is a tri-filar transformer, and is schematically represented in Figure 1.

RF Filter (tri-filar transformer) Option 001 for the E1586A Rack Mount Terminal Panel (See page 11.04 of the 1996 HP VXI Catalog) 110 dB CMR to 10 MHz.

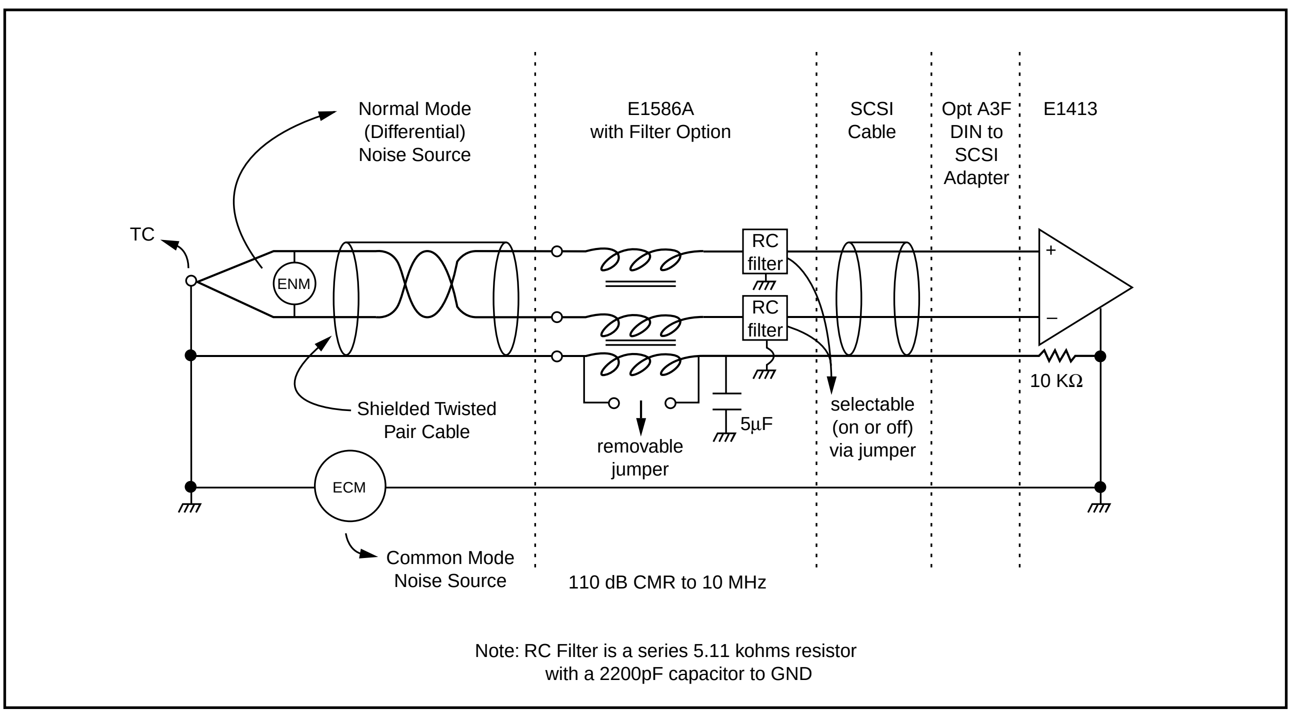
Tri-filar transformers work due to the inductance in the shield-connected winding, which presents a significant impedance to high frequency common mode noise and forces all the noise voltage to be dropped across the winding. The common mode noise on the input amplifier side of the winding is forced to 0 V by the low impedance connection to the HP E1413 ground via the selectable short or parallel combination of 1 Kohm and 0.1 µF. You can not use the short in situations where there is a very high common mode voltage (DC and/or AC) that could generate large shield currents.

The tight coupling of Hi and Low signal leads in the transformer forces the common mode noise to 0 V at the transformer output. This achieves the 110 dB to 10 MHz CMR, keeping the high frequency common mode noise out of the amplifier, thus preventing the amplifier from rectifying this into an offset error.

This performs the same noise rejection as shielded, twisted pair cable, only better. It is especially effective if the shield connection to the HP E1413 ground can't be a very low impedance due to large DC and/or low frequency common mode voltages.

The tri-filar transformers don't limit the differential signal bandwidth. Thus, the requirement for "slowly varying voltages" does not exist. The nature of the tri-filar transformer, or, more accurately, common-mode inductor, is that it provides a fairly high impedance to common mode signals, and a quite low impedance to differential mode signals. The ratio of common-mode impedance to differential-mode impedance for the transformer we use is approximately 3500:1. This means you incur no differential mode bandwidth penalty by using the tri-filar transformers.

Figure 1: E1586A Remote Rack Mount Isothermal Panel



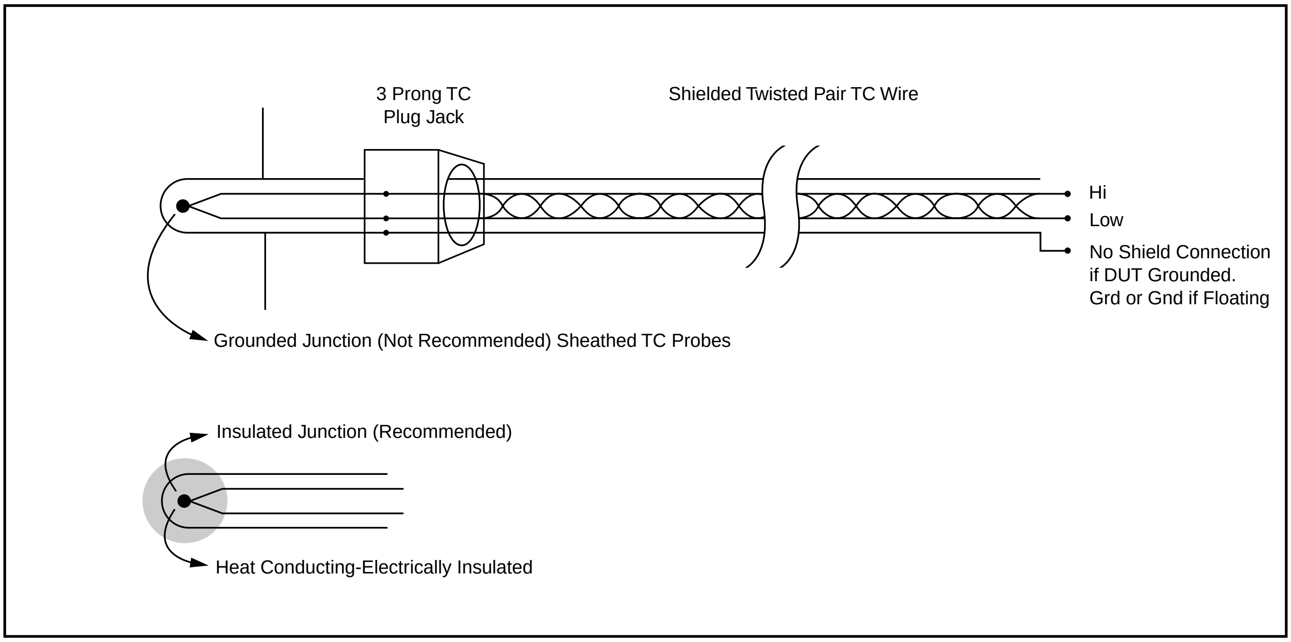


Figure 2: Insulated Junction 3-Prong TC Plug

Use the E1586A for Best Thermocouple Measurement Performance

The isothermal reference temperature accuracy specification for the HP E1413 terminal block is +/- 0.6 C, as long as the temperature difference between the air surrounding the terminal block and the inlet air temperature to the VXI mainframe is less than or equal to 1 C. If your application requires more accuracy, use the E1586A remote rack mount isothermal panel. The reference accuracy specification for this accessory is +/- 0.2 C.

You must minimize the temperature difference between the internal HP E1413 module and the terminal block. You must also ensure that the terminal block is in a stable temperature environment. The amplifier Signal Conditioning Plug-ons (SCPs) dissipate heat, which conducts through the DIN connector pins and interferes with the isothermal characteristics of the terminal block.

If you are not using the E1586A, use the following methods to improve TC readings on the instrument:

- Place the clear plastic cover on the terminal block.
- Insert the thin white plastic airflow barrier over the terminal block connector. This prevents airflow from the HP E1413 module into the terminal block.
- Use a well-ventilated rack, fully enclosing the HP E1413 and its terminal blocks, and close the front and back doors to keep the entire HP E1413 at a uniform temperature. If there is no front door, open the back door. Do not recirculate warm air inside a closed rack cabinet if the terminal block is suspended into ambient air, because this will create a significant temperature difference.
- Make sure the VXI cardcage cooling fan filters are clean. Clear as much space as possible in front of the fan intakes.
- Set the cooling fan switch on the back of the card cage to the “High” position. The normal position is a variable speed which can make the internal HP E1413 module temperature cycle up and down. This will affect the SCPs with mV level signals.

If there are unexplained offsets when measuring Tcs or a TC calibrator, then short the channels at the terminal block or the 1586A. Shorted channels should read the same as the reference. If they do not, try the following:

- Reseat the SCP or swap it with another SCP.
- Ensure that the SCP retaining screws are fully screwed in and firmly tightened.
- Execute the self-test (•TST command) and check for errors shown in the manual.

Thermocouple Probe Wiring

HP recommends you use an insulated junction TC probe with a three-prong plug (High, Low, and Shield) shown in Figure 2. Insulated junction TC probes are more expensive than grounded junction TC probes with two-prong plugs, but have much greater immunity to common mode noise problems. Insulated junction probes have slightly increased response times to rapid changes in the DUT temperature. You must carefully consider this for your application.

Insulated junction TC probes accomplish the following:

- Prevent DC common mode voltage from causing ground loop problems.
- Prevent DC common mode voltage from exceeding the HP E1413 common mode voltage limits.
- Reduce the AC common mode noise coupling.

For good performance, carry the shield through all junction boxes and cable panels, and ground it at only one point (the point nearest the noise source). Normally, connecting the shield to ground at the DUT works best if the DUT is well grounded. In many installations, a heavy ground bus bar connects the DUT ground to the instrumentation system ground, which minimizes or eliminates common mode voltage differences.

If you must use a two prong TC plug connector, use shielded, twisted-pair TC wire, and connect the shield to the DUT ground. If this is not possible, leave the shield open at the TC probe and connect the shield to the HP E1413 GRD or GND terminal, whichever appears to give the lowest noise readings.

If you use any buffered (filter SCP) or amplifier SCP, and then observe a DC offset, try connecting the shield to GND through a 0.1 uF capacitor at the HP E1413. The new E1413C terminal block provides this connection. If the problem persists, try putting 0.1 uF capacitors from High and Low to GND. If this still doesn't eliminate the offset, your application may require the E1586A option 001 RF filter described in “High Performance Common Mode Noise Rejection”.

Summary

To correctly measure readings on your DUT, you need to use correct wiring, shielding, and grounding. In addition, you need to carefully set up your instrumentation to prevent inaccurate readings.

Properly setting up and using the HP E1413A/B/C and HP E1415A, and correctly grounding your cables, will enable you to take accurate measurements for high speed sampling A/D converters and low level signals.

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