

Connecting Signals to Differential Inputs

Bustec Productions Ltd.

Contents

1	Introduction	1
2	Differential Input	1
3	Twisted Shielded Pair Wiring	2
4	Connecting to Single-Ended Instrumentation	3
5	Grounding	3
5.1	Ideal Connection	4
5.2	Ground Referenced Sensor or Signal Source	4
6	Other Effects and Considerations	5
7	Check List for Differential Inputs	5

1. Introduction

When connecting signals to data acquisition equipment a number of considerations can be quite important to achieve quality data. The signals of interest are frequently low-level milli-volt signals generated by such sensors as thermocouples, strain gages, etc. Furthermore the sensors are frequently remote to the data acquisition equipment requiring long cable runs and in some cases in areas where high levels of electromagnetic interference (EMI) is encountered. To further complicate accurate measurements, less than ideal grounding situations frequently exist.

Proper design and installation of wiring between sensors and the data acquisition equipment can be an important factor in obtaining quality data.

2. Differential Input

For signals with frequencies below approximately 1 MHz the use of differential signaling techniques, also known as balanced input, has distinct advantages in providing immunity to noise pickup and crosstalk between channels. This technique depends on the fact that the signal of interest generates equal but opposite currents

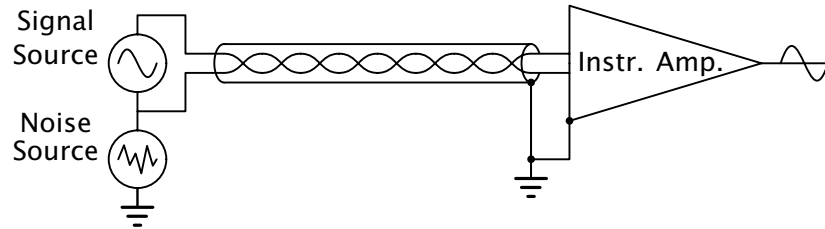


Figure 1: Illustration of Differential Signal with Common Mode Noise.

on a balanced pair of wires while noise that is picked up is typically induced equally in both signal lines. The use of *shielded twisted pair cable* is key to insuring that the noise and cross coupling is induced equally in both signal lines of a cable pair.

The input amplifier (instrumentation amplifier) is designed to amplify the differential (*normal mode*) signals and attenuate the signals common to both signal lines (*common mode*), refer to Figure 1. One measure of the quality of the instrumentation amplifier front-end is the *common mode rejection ratio (CMRR)*. Good instrumentation amplifiers today have typical CMRR ratings of 100dB or more up to 100 KHz or more.

To put this in perspective, a good instrumentation amplifier with an input of an equal amount of *normal mode signal* and *common mode noise* would attenuate the noise below one least significant bit (lsb) when the signal was digitized by a 16-bit ADC and thus would not affect the accuracy of the measurement. Bustec analog input modules for signal bandwidths below 1 MHz exclusively use differential inputs to achieve optimum noise immunity.

3. Twisted Shielded Pair Wiring

For the instrumentation amplifiers to achieve the best noise rejection it is essential that any noise induced in the wiring be common mode. This is best achieved by the use of *shielded twisted pair wiring* between the sensor or signal source and the instrumentation front-end. It is important to note that not all “shielded pair” cable are in fact twisted. Cables where the wire pairs simply run parallel to each other are significantly more susceptible to induced normal mode noise caused by fluctuating fields as well as cross coupling between adjacent pairs. The use of *shielded twisted pair cable* is strongly encouraged.

The telephone industry is a testament to the noise immunity that can be achieved through the use of twisted pair cable and differential signaling. They run twisted

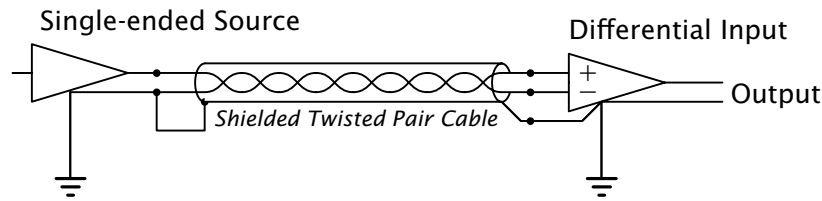


Figure 2: Driving a differential input channel from an unbalanced source

pair cable for miles along power lines and open country with thunder storms and achieve amazingly low crosstalk and noise pickup ...remember the human ear is a marvelous device with a logarithmic response so even the smallest amount of noise or crosstalk can be objectionable.

4. Connecting to Single-Ended Instrumentation

While many instruments such as amplifiers and filters may receive differential signals, it is generally the case that they only provide single-ended output. In some cases it may be necessary to acquire signals from a single-ended device. Driving the differential input from a single-ended output must be done correctly to avoid noise pickup.

Figure 2 illustrates the proper connections. Note that both the shield and the negative lead of the differential pair are tied to the ground at the single-ended driving source. When connecting to a device with a coaxial connector, then the shield and negative lead are tied to the shield of the coaxial connector. If the driving source is some distance away and particularly if it is powered from a power source that is derived from a different power distribution center, then it may be necessary to provide a heavy ground strap between the single-ended analog source and the differential input instrumentation to minimize currents flowing through the shield of the twisted pair cable. Refer to the section on grounding.

5. Grounding

Proper equipment grounding is essential to acquiring quality data. Electrical engineers are taught at an early age to avoid ground loops and to ground equipment. This can all sound easy, but in the real world it is not always possible to avoid grounding problems.

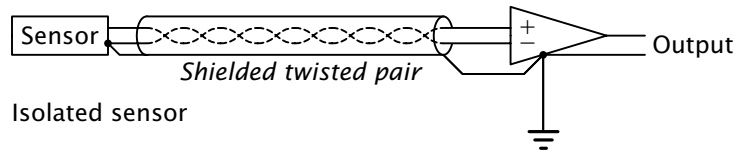


Figure 3: Connecting to an isolated sensor.

5.1. Ideal Connection

The ideal situation is where the sensor is not referenced to ground. The connections should be made as illustrated in Figure 3. In this case the differential pair are connected to the respective sensor leads with one side (typically the - lead) tied to the shield of the shielded twisted pair cable.

It is critical that one lead be tied to the shield and that the shield be tied to analog ground at the instrumentation amplifier as illustrated in Figure 3. If the signal pair are left to float (i.e. not ground referenced), then the signal pair can float up near the supply voltage rails on the instrumentation amplifier (typically ± 15 Volts) where the instrumentation amplifier becomes non-linear and sensitive to common mode noise. Modern instrumentation amplifiers have extremely high input impedances which makes it easy for any small current to cause the signal pair to float up near the supply rails.

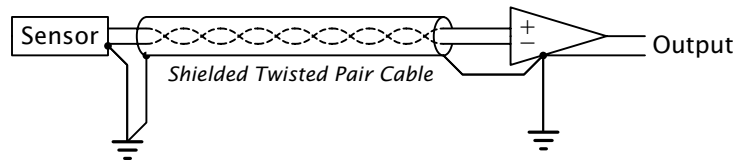
It is very important that a ground reference be provided for the signal lines to an instrumentation amplifier to prevent the signal lines from floating up near the power supply rails. An impedance of even several megohms to ground will suffice in most cases.

5.2. Ground Referenced Sensor or Signal Source

In real life it is not always possible to have an isolated sensor or signal source. Engineers are taught to avoid ground loops so one is very tempted to tie the shield of a shielded twisted pair to ground at only one end or the other to avoid a ground loop. Unfortunately this frequently leads to much higher noise levels from the instrumentation amplifier and corresponding loss of accuracy in the measured quantity.

Tests by instrumentation manufacturers and others have shown that in many cases significantly improved noise levels can be achieved by grounding the shield at both ends as illustrated in Figure 4.

In some situations it can also help if a heavy ground strap is run with the signal cabling between the signal source and the instrumentation front-ends.



A grounded sensor with a shield connection at both ends.

Figure 4: Connecting to a ground referenced sensor or signal source.

6. Other Effects and Considerations

As mentioned earlier instrumentation amplifiers typically have good common mode rejection for signal frequencies up to about 100 KHz. At higher frequencies the common mode rejection of the instrumentation amplifier slowly rolls off. In environments with high EMI and requirements for high accuracy it may be necessary to take steps to limit high frequencies reaching the instrumentation amplifier.

7. Check List for Differential Inputs

- Is the cabling shielded twisted pair cable?
- Is shield tied to instrumentation or analog ground at the instrumentation amplifier?
- Are the signal lines properly referenced to ground i.e. not left floating?
- If the signal source is grounded is the shield of the shielded twisted pair tied to ground at the signal source as well as at the instrumentation amplifier?

Corporate Headquarters:

Bustec Production Ltd.
 World Aviation Park
 Shannon, Co. Clare
 Ireland
 Tel: +353 61 707 100
 Fax: +353 61 707 106

Bustec, Inc.
 17820 Englewood Dr. #14
 Middleburg Hts. OH 44130
 Tel: (440) 826 4156
 Fax: (440) 826 4184
