
Data Acquisition Tips

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A Guide To Signal Input Configuration

Does a thermocouple signal require isolation? Should the output of a strain gage amplifier be connected as a single-ended or differential input? Is a differential input always a better choice than a single-ended configuration? These fundamental instrumentation questions may not be easy to answer if you are new to the data acquisition arena. The issues of input configuration and isolation must be understood to optimize data acquisition system (DAS) performance and prevent equipment damage or possible operator injury. The goal of this article is to develop an understanding of correct input configuration practices and to serve as reference for several everyday data acquisition applications.

Table 1 contains 14 typical DAS applications and three input configuration options (single-ended, differential, and isolation) that must be resolved with any DAS measurement. An input configuration option is "checked" if it is required or sufficient for a measurement. In some cases, all three options apply. My goal is to impart a level of instrumentation expertise that will enable you to effectively size up any measurement application. A key to improving your instrumentation skills is to develop the ability to determine the minimum requirements of a measurement, and recognize if a specific measurement condition warrants more sophisticated techniques.

The reason for all this attention to input configuration is the existence of common mode voltage (CMV). CMV is an in-phase signal that appears simultaneously on both input terminals of a DAS channel. There are two levels of CMV that you need to be aware of. CMV can offset the signal you're trying to measure beyond the measurement range of the DAS, or CMV can exceed the maximum overvoltage rating of the DAS front end, possibly putting you and your hardware at risk.

The maximum CMV of a DAS input is the difference between the signal you are trying to measure and the full scale measurement of the input. In other words, if you have a 5 volt full scale input, and you are measuring a 1 volt signal, the input can tolerate any CMV less than 4 volts and still make the measurement. The presence of CMV and its magnitude will determine if a measurement is a single-ended or differential input application and if isolation is necessary.

Single-Ended Inputs

The single-ended (SE) input is the easiest to understand and connect. It consists of one signal lead and one common ground. This configuration is sufficient for making measurements where no CMV exists. You'll find such situations most commonly when you connect to the output of an amplifier. All amplifiers have single-ended outputs, and the only way a CMV can exist in this situation is if a difference in the grounds between the amplifier and the DAS exists - a rare

occurrence if both are powered locally. What happens if you connect a SE input to a signal with a CMV? There are two possibilities:

1. Assuming the CMV's magnitude was below the maximum input voltage spec of the DAS, you'd experience a noisy signal. The degree of noise is directly proportional to the magnitude of the CMV.
2. If the CMV's magnitude exceeds the maximum overvoltage spec of the DAS-look out! The best you can expect is to lose the front end of your DAS. The worst case is usually accompanied with electrical fireworks that take out the entire DAS, the computer, and maybe even you. To summarize, SE configurations in Table 1 are acceptable only in cases where no CMV exists.

Differential Inputs

The differential input (DI) is required when making balanced signal source measurements, or in the presence of a CMV.

An example of a balanced signal source is a Wheatstone bridge which is the basis for strain gage and pressure transducer measurements. The bridge output is the differential voltage present on the two non-excitation corners of the bridge (see Table 1). This measurement requires a DI if the grounds between the excitation supply and the instrument are the same. In contrast, a SE input would short one element of the bridge, making the measurement impossible. Another example that requires a DI is a grounded thermocouple. The thermocouple junction itself is grounded and the use of a SE would short the thermocouple to ground and destroy the measurement.

The DI measures the magnitude of an input signal as the difference between two inputs. Since one input carries the CMV plus the signal of interest, and the other carries just CMV, the difference between the two yields only the signal of interest. This fact can be leveraged in applications where the signal of interest is riding on a CMV as in a shunt measurement that is off ground (see Table 1).

So, you should use a DI configuration whenever a CMV or a balanced signal source exists. However, make sure you know the magnitude of the CMV:

- If the CMV plus the signal of interest is less than the full scale range (FSR) of the DAS, you will be able to make the measurement.
- If the CMV plus the signal of interest is greater than the FSR of the DAS but less than its maximum overvoltage spec, you can't make the measurement, but you won't damage the DAS.

DI inputs will suffer the same fate as their SE counterparts if the CMV exceeds the maximum overvoltage spec of the DAS-electrical fireworks with the potential for significant damage.

The advantages of the DI over the SE input are its ability to measure balanced inputs and reject CMVs. One DI consumes two SE channels (one for the positive and one for the negative input) but SE inputs are easier to connect. Further it is not uncommon to find a mix of SE and DI signals that need to be measured. DATAQ instruments' [data acquisition hardware](#) adapts to such situations by allowing each input channel to be programmed as either differential or single-ended. This approach conserves channel count by ensuring that only measurements requiring a DI are allocated the extra channel. [DI-720 Series instruments](#) for example (32SE/16DI channels); allow for any combination of differential and single ended inputs.

Isolation

So far, we've been able to handle any type of signal with a DI or SE input configuration except those with CMVs that exceed the full scale resolution of the DAS input. Handling this signal type is the domain of isolation. Isolation is an option for any instrumentation application but it's an absolute necessity under these conditions.

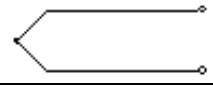
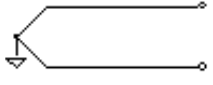
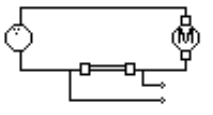
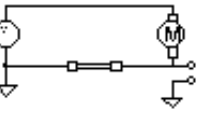
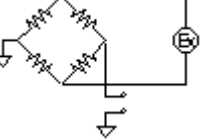
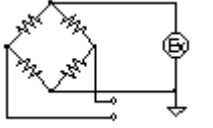
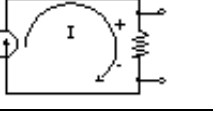
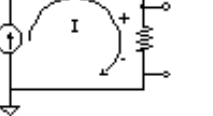
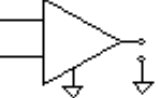


The presence of isolation ensures that absolutely no connection exists between the ground of the computer and that of the signal. As such, the CMV of the signal may float to a level defined by the isolation barrier (typically 1000 V). As shown in Table 1, instruments supporting isolation may be applied to virtually any measurement situation without damage to the DAS, the computer, or you.

If your instrumentation applications frequently require isolation, the ideal solution is a data acquisition system with built in isolation. DATAQ instruments' [DI-718B](#), [DI-718Bx](#) and [DI-788](#) data acquisition systems combine data acquisition with 1000-volt input-to-output isolated signal conditioning. Even though these products connect to any industrial signal (e.g. thermocouple, RTD, strain, RPM, etc.), this flexibility would be compromised without isolation. Isolation ensures a noise-free and safe environment for industrial data acquisition.

A final note regarding the need for isolation revolves around patient-connected measurements in life sciences applications. Any measurement involving the connection of an instrument to a human body requires medical-grade isolation to ensure the safety of the subject. DATAQ instrument supplies a line of specially designed biomedical amplifiers that provide isolation with less than 10 μ A of leakage current which is a requirement for this type of measurement.

I hope the concepts presented in this article have enhanced your understanding of how a DAS can be applied in a variety of instrumentation settings. Perhaps I've even given you some ideas on how to attack a particularly nagging problem. Far too often, little details like input configuration are overlooked, resulting in frustrating or even disastrous results.

TABLE 1

Input Signal Configuration Guide					
Application		Single-Ended	Differential	Isolation	
Thermocouple		Floating			<u>X</u>
		Grounded	(CMV+signal) \leq FSR		<u>X</u>
			(CMV+signal) $>$ FSR		<u>X</u>
Current Shunt		Floating	(CMV+signal) \leq FSR		<u>X</u>
			(CMV+signal) $>$ FSR		<u>X</u>
		Grounded		<u>X</u>	X
Bridge Strain		Floating Excitation		<u>X</u>	<u>X</u>
		Grounded Excitation			<u>X</u>
Process Current (4-20mA typical)		Floating	(CMV+signal) \leq FSR		<u>X</u>
			(CMV+signal) $>$ FSR		<u>X</u>
	Grounded		<u>X</u>	<u>X</u>	<u>X</u>
High Level Amplifier Outputs			<u>X</u>	X	<u>X</u>
Bio Potential		Patient Connected			<u>X</u>
		Non-Patient Connected			X

An "X" indicates the input configuration option is required or sufficient for that type of measurement.