

Keysight Technologies

Essential Components of Data Acquisition Systems

Application Note



Unlocking Measurement Insights



Introduction

The purpose of any data acquisition system is to gather useful measurement data for characterization, monitoring, or control. The specific parameters of your application will dictate the resolution, accuracy, channel count, and speed requirements for a data acquisition system. There is a wide assortment of data acquisition components and solutions on the market, ranging from low cost USB modules to bench top data loggers to large channel systems. Before you start your search for a data acquisition solution, carefully analyze your application requirements, so you have a good understanding of how much capability and performance you need to purchase.

To help you choose a system that meets your needs, this article gives an overview of the components that make up a typical data acquisition system and examines some of the advantages and disadvantages of the different component types and configurations.

Data Acquisition System Overview

Data acquisition is a term that encompasses a wide range of measurement applications, all of which require some form of characterization, monitoring, or control. No matter what the specific application, all data acquisition systems either measure a physical parameter (temperature, pressure, flow, etc.) or take a specific action (sound an alarm, turn on a light, etc.) based on the data received. A simplified block diagram of a typical data acquisition system is shown in Figure 1.

Measurement hardware

A/D converter

The A/D converter, a key element in any data acquisition system, is used to convert dc voltages acquired from the transducers into digital data. The measured voltages may correspond to a specific temperature, pressure, flow, or speed. While there are several types of A/D conversion techniques, they can generally be divided into two types: integrating and non-integrating. The integrating techniques measure the average input value over a defined time interval, thereby rejecting many noise sources. The non-integrating techniques sample the instantaneous value of the input (plus noise) during a very short time interval.

Digital input

Some data acquisition systems contain a digital input card that senses a digital bit pattern to determine whether an external device is on or off. Digital input cards typically contain 8, 16, or 32 channels that can be used to monitor a number of external devices. For example, a digital input card can be connected to an operator panel to determine the position of various switches on the panel.

Counter

Some data acquisition systems contain a counter card that can be used to count events coming from an external device. For example, a counter card can be used to count the number of digital pulses (totalize), the duration of a digital pulse (pulse width), or the rate of digital pulses (frequency).

Control hardware

Analog output

Some data acquisition systems contain a D/A converter that performs the opposite function of an A/D converter. A D/A converter interprets commands from the control hardware and outputs a corresponding dc voltage or current. The output remains at this level until the control hardware instructs the D/A converter to output a new value. The voltage or current from the D/A converter can be used to control the speed of a fan, the position of a valve, or the flow rate of a pump. D/A converters are typically used in applications that require precise control of external devices.

Digital output

Some data acquisition systems contain a digital output card that interprets commands from the control hardware and outputs a corresponding digital bit pattern. A digital output card is typically used to control lights, or send digital control signal to external devices.

Control switching

For control applications, a switching card can be used to supply power to external fans, pumps, or valves by completing an electrical circuit. The switch card (often referred to as an actuator) operates much like a light switch to provide power to the external device. A switch card is typically used instead of a digital output card in those applications that require switching of high voltage and power. There are three common types of switches used in control applications. (See Figure 2).

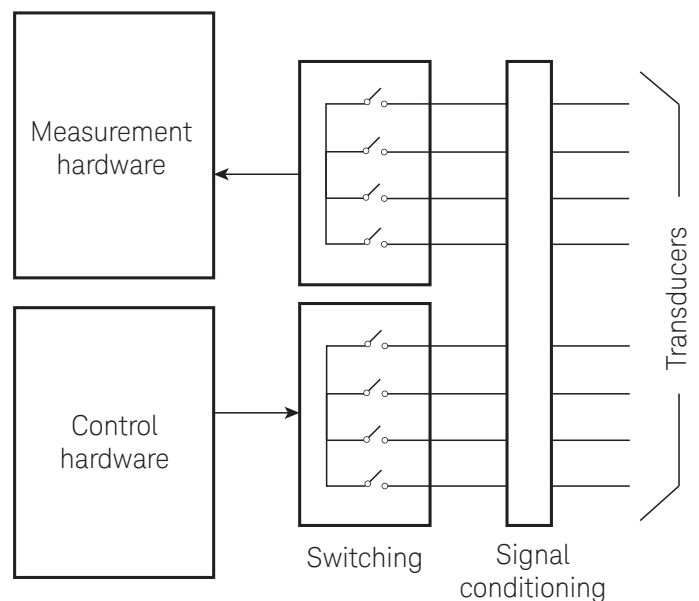


Figure 1. Typical Data Acquisition System

Switching

Electromechanical switches, such as reed and armature relays, are common in low-speed applications. A key benefit is their ability to switch high voltage and current levels, but they are limited to switching rates of several hundred channels per second. Also, because they are mechanical devices, they will eventually wear out. Electronic switches, such as field-effect transistors (FETs) and solid-state relays, are typically used in high-speed applications. In addition to providing fast switching, they contain no moving parts and therefore do not wear out. The disadvantage of electronic switches is that they typically cannot handle high voltage or current, and must have high impedance to protect them from input spikes and transients.

Multiplexer configuration

A multiplexer configuration is most commonly used for signal switching to a single measuring instrument. Generally, in the multiplexer configuration, only one signal is connected at a time to the measuring device, and the switching is break-before-make (i.e., the input is disconnected before a new input is connected). Multiplexers are available in one-, two-, three-, and four-wire configurations as shown in Figure 3.

One-wire (or single-ended) multiplexers are used in applications where a common ground is practical. Two-wire (or differential) multiplexers are used in applications that have a differential (high and low) input. Three-wire (or guarded) multiplexers are designed for use with guarded multimeters to give the best accuracy for analog measurements. Four-wire multiplexers are used for four-wire measurements of transducers such as resistive temperature detectors (RTDs) that require a current source.

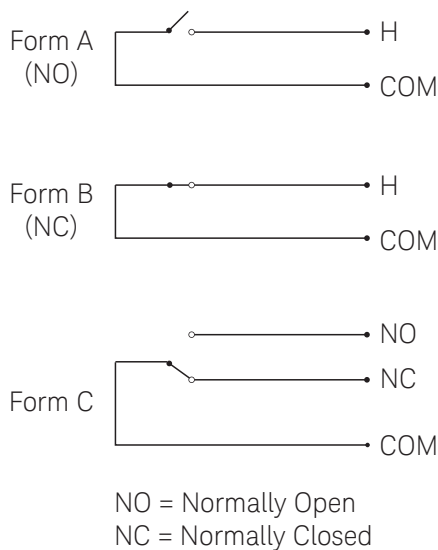


Figure 2. Simple Control Switch Configurations

Matrix configuration

A matrix configuration connects multiple inputs to multiple outputs, and therefore offers more switching flexibility than a multiplexer. A matrix configuration is typically used for switching low-frequency signals (less than 10 MHz). A matrix is arranged in rows and columns as shown in Figure 4. With a matrix configuration, any one of the signal sources can be connected to any one of the test inputs. Be aware that with a matrix, it is possible to connect more than one source at the same time. Therefore, it is important for you to make sure you are not creating dangerous or unwanted conditions by these connections.

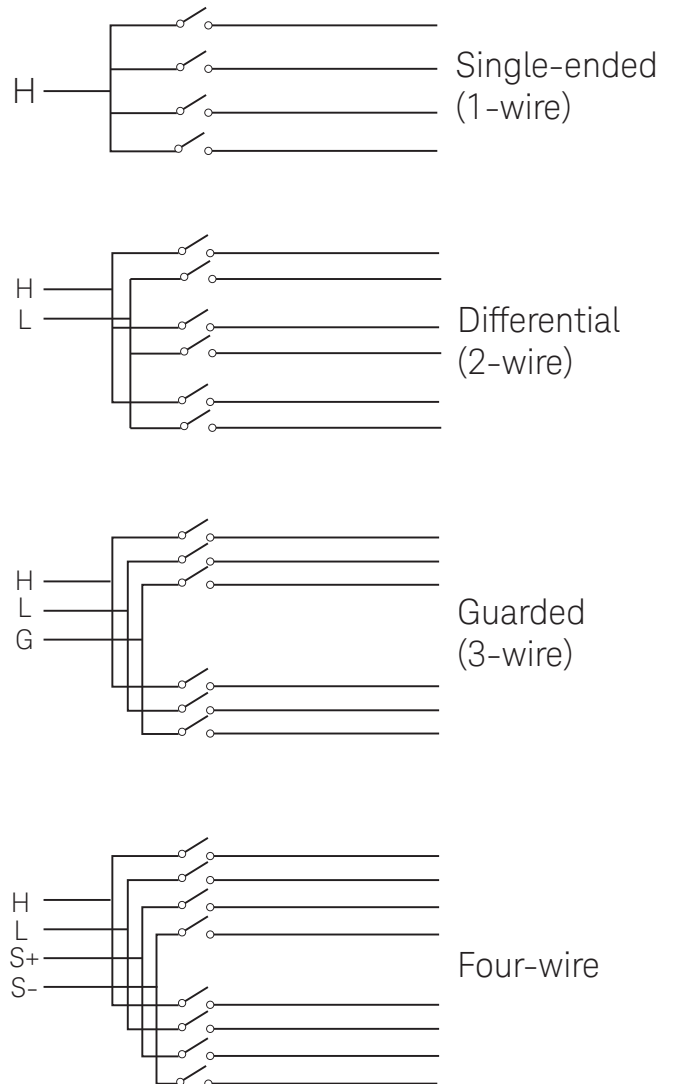


Figure 3. Multiplexer Configurations

Signal conditioning

Signal conditioning is used to amplify, attenuate, shape, or isolate signals from transducers before they are sent to the measurement hardware. Signal conditioning converts the signal to a form that is better measured by the system, or in some cases, makes it possible to measure the signal at all. Examples of signal conditioning include:

- Amplification of small signals
- Attenuation of large signals
- Thermocouple compensation for temperature measurements
- Current sourcing for 2-wire and 4-wire resistance measurements
- Filtering to remove system noise
- Shunt resistors for current measurements

In some data acquisition systems, the signal conditioning components are incorporated internally within the system. These systems can measure dc voltage, ac voltage, resistance, frequency, current, and temperature on any input channel without the need for external signal-conditioning components.

Transducers

Transducers are devices that transform physical parameters (such as temperature, pressure, flow, and strain) into electrical parameters (such as voltage, current, and resistance). The electrical parameter is measured by measurement hardware and the result is converted to engineering units. For example, when measuring a thermocouple, the measurement hardware actually reads a dc voltage, which it then converts to a corresponding temperature using a mathematical algorithm. Table 1 shows several types of transducers with their corresponding output.

Analyzing and control

When monitoring a small number of channels a bench top data logger can be configured directly from its front panel. Measurements can be stored; alarms can be configured and individual channels can be monitored from the front panel. Larger systems will need to be controlled from a PC. Application specific software for data acquisition will make it easier to configure channels, visualize data, document and share results. Using software will provide consistent configurations and repeatable results.

Conclusion

By understanding the functions of the various components of a data acquisition system, you will be better able to evaluate the available options and choose the best system to meet your needs.

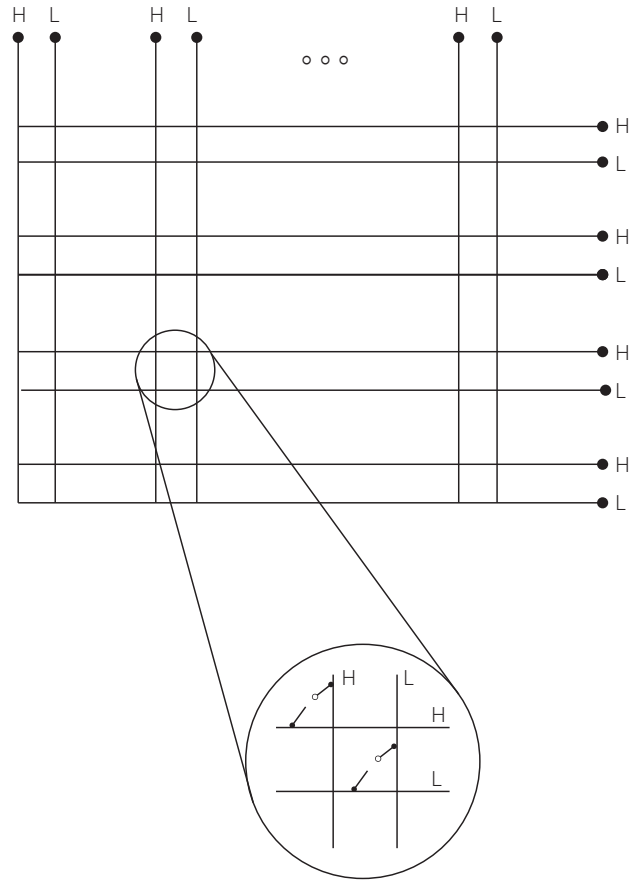


Figure 4. Matrix configuration

Table 1.

Measurement	Typical transducer types	Typical transducer output
Temperature	Thermocouple	0 mV to 80 mV
	RTD	2-wire or 4-wire resistance from 5 Ω to 500 Ω
	Thermistor	2-wire resistance from 10 Ω to 1 MΩ
Pressure	Solid state	±10 Vdc
Flow	Rotary type Thermal type	4 mA to 20 mA
Strain	Resistive elements	4-wire resistance from 10 Ω to 10 kΩ
Events	Limit switches	0 V or 5 V Pulse train
	Optical counters	
	Rotary encoders	
Digital	System status	TTL Levels

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