Getting Started with Data Acquisition Systems

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 of a data acquisition system. A wide assortment of data acquisition components and solutions is available on the market, including low-cost USB modules, benchtop data loggers, and large channel systems. Before you start your search for a data acquisition solution, carefully analyze your application requirements to understand how much capability and performance you need to purchase.

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

> Most data acquisition applications use data logging to manage the measurement of temperature, voltage, current signals, frequency, or resistance regularly.
>
> Modern data acquisition systems are configurable to measure dynamic signals such as vibration, shock, and noise.

KEYSIGHT TECHNOLOGIES

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 application, all data acquisition systems either measure a physical parameter (such as temperature, pressure, or flow) or take a specific action (such as sound an alarm or turn on a light) based on the data received. Figure 1 shows a simplified block diagram of a typical data acquisition system.

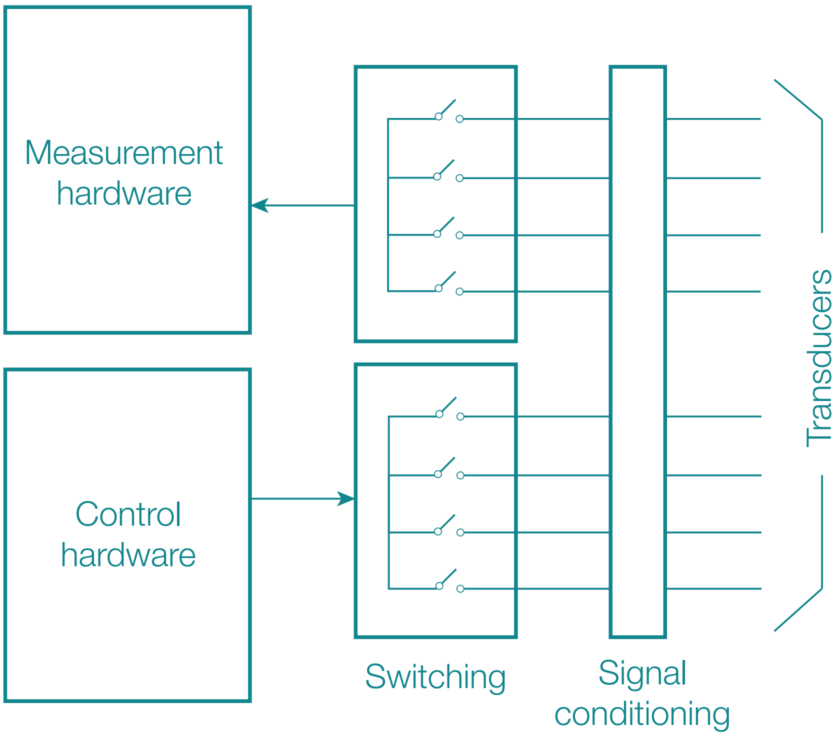
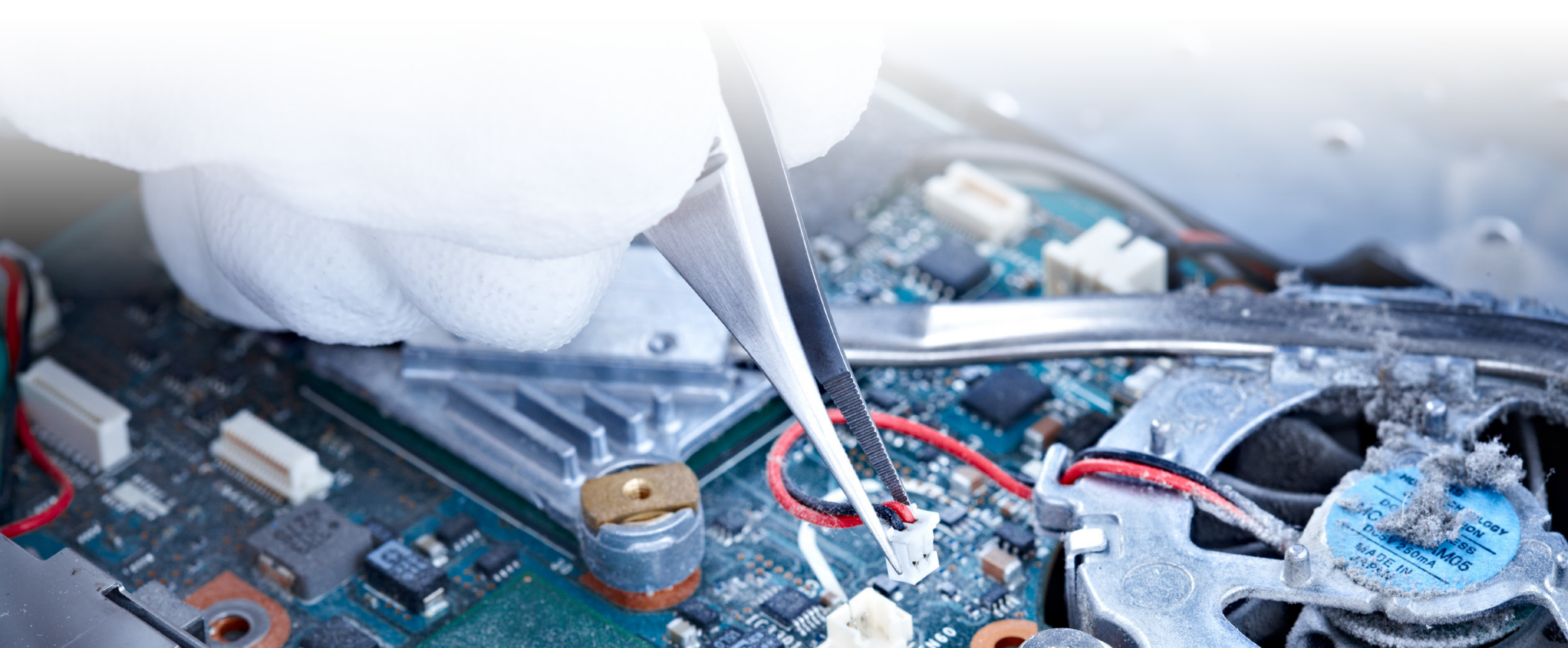


Figure 1. Data acquisition system functional block diagram

Keysight's DAQ970A / DAQ973A data acquisition system and Keysight's PathWave BenchVue DAQ application software enable you to

- measure multiple types of input signals with confidence
- wire any signal to any channel with universal inputs and integrated signal conditioning
- easily configure measurements and create test automation using a front panel, without programming



Measurement hardware

Understand how and when to use analog-to-digital (A/D) converters, digital input cards, and counter cards.

A/D converter

The A/D converter, a key element in any data acquisition system, converts 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 generally fall into one of two types: integrating and nonintegrating. Integrating techniques measure the average input value over a defined time interval, thereby rejecting many noise sources. Nonintegrating techniques sample the instantaneous value of the input (plus noise) during a brief time interval.

If you are performing data-logging measurements, the A/D integrating method is the better choice because it gives you averaged input values. If you are performing dynamic data acquisition, such as measuring vibration, shock, noise, or transient signals, it is better to use a nonintegrating A/D converter that can measure at high sampling rates.

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 monitor a few external devices. For example, you can connect a digital input card to an operator panel to determine the position of various switches on the panel.

Counter

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

Control hardware

This section describes digital-to-analog (D/A) converters, digital output cards, and switching cards.

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 control the speed of a fan, the position of a valve, or the flow rate of a pump. Applications that require precise control of external devices typically use D/A converters.

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. Applications that require switching of high voltage and power typically use a switch card instead of a digital output card. Control applications use three common types of switches (see Figure 2).

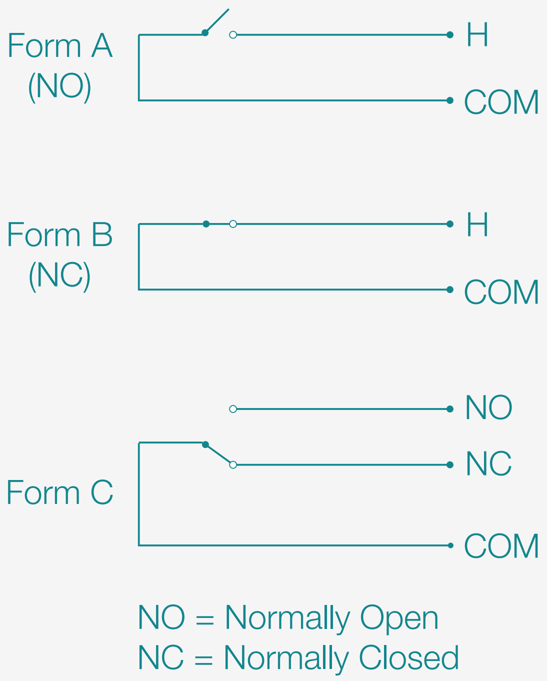


Figure 2. Simple control switch configurations

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. High-speed applications typically use electronic switches, such as field-effect transistors and solid-state relays. 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 from input spikes and transients.

Multiplexer configuration

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

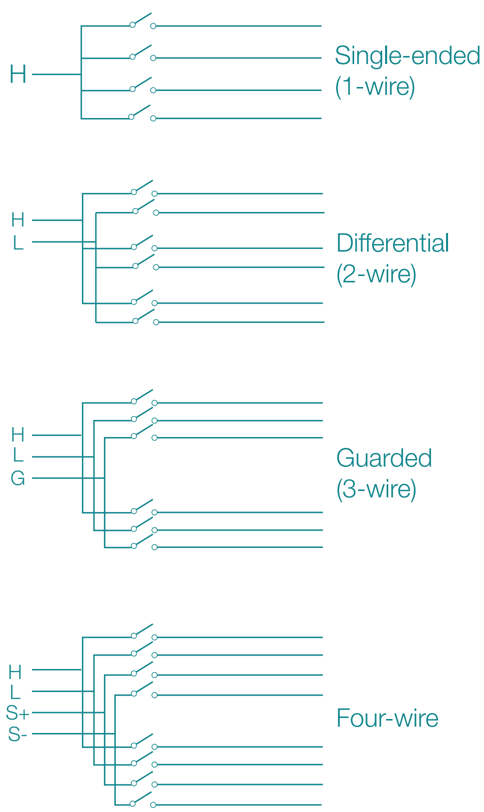
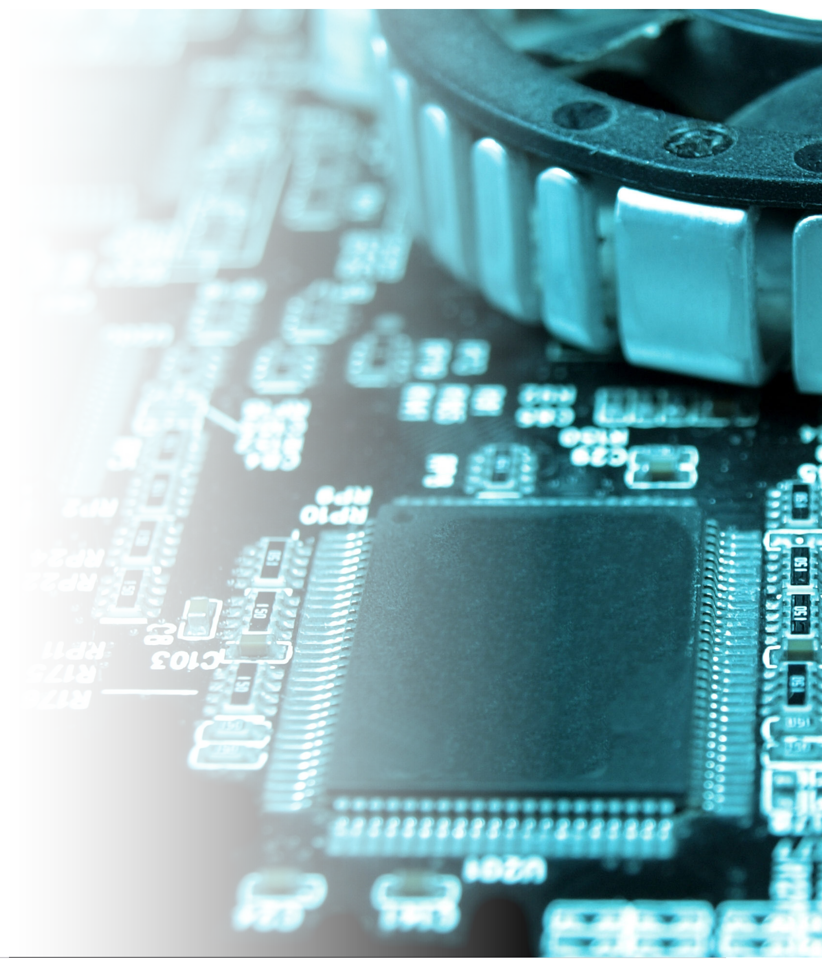


Figure 3. Multiplexer configurations



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

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 arrangement uses rows and columns, as shown in Figure 4. With a matrix configuration, any one of the signal sources can connect 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 to make sure you are not creating dangerous or unwanted conditions by making these connections.

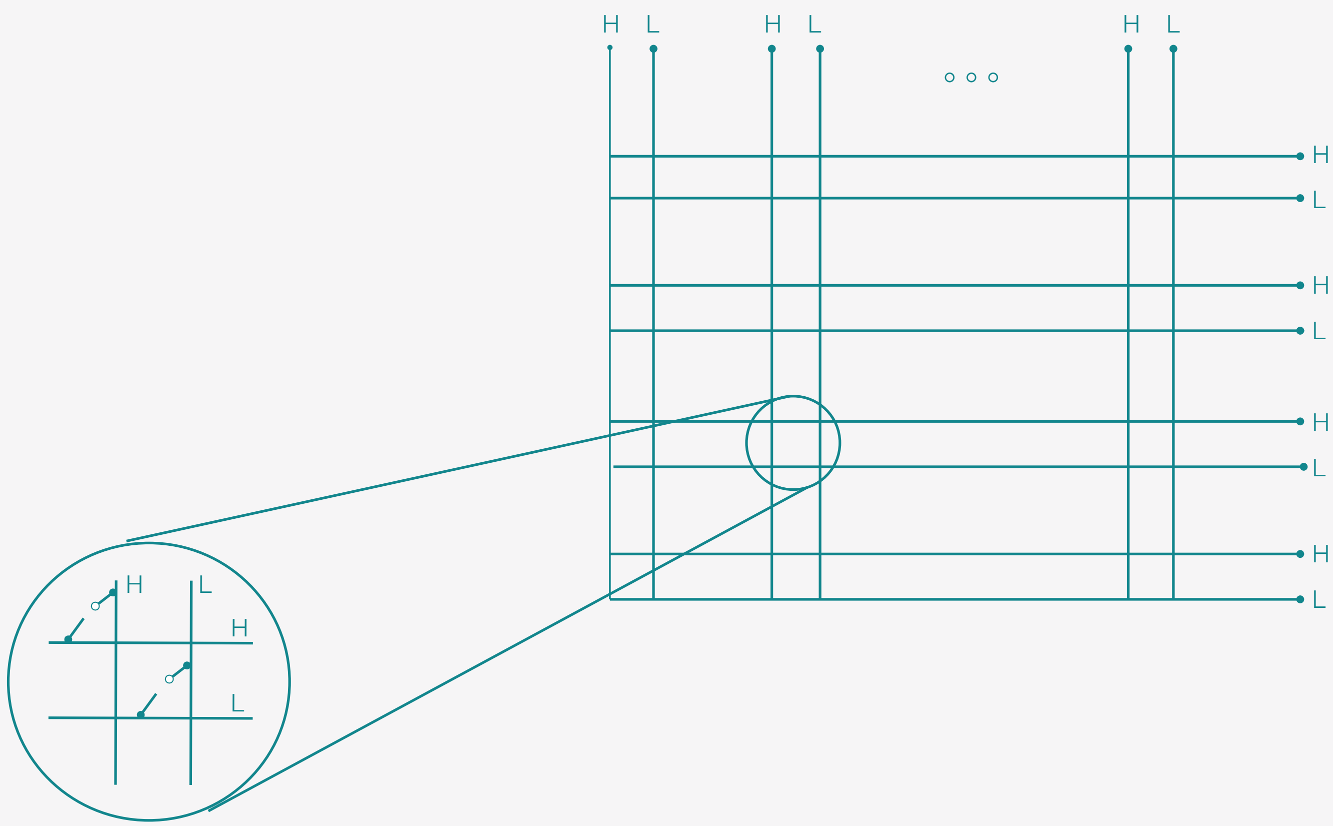


Figure 4. Matrix configuration

Signal conditioning

Signal conditioning amplifies, attenuates, shapes, or isolates signals from transducers before they move on to the measurement hardware. Signal conditioning converts the signal to a form that the system can more easily measure or, in some cases, makes it possible to measure the signal at all. Examples of signal conditioning include the following:

- amplification of small signals
- attenuation of large signals
- thermocouple compensation for temperature measurements
- current sourcing for two-wire and four-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 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 outputs.

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

Table 1. Types of transducers

Analyzing and control

When monitoring a small number of channels, you can configure a benchtop data logger directly from its front panel. During scanning, you can monitor the measurement data on a specified channel. You can select to view the monitor measurements in number, bar meter, trend chart, and histogram format. Figure 5 shows an example of monitoring displays in various formats.

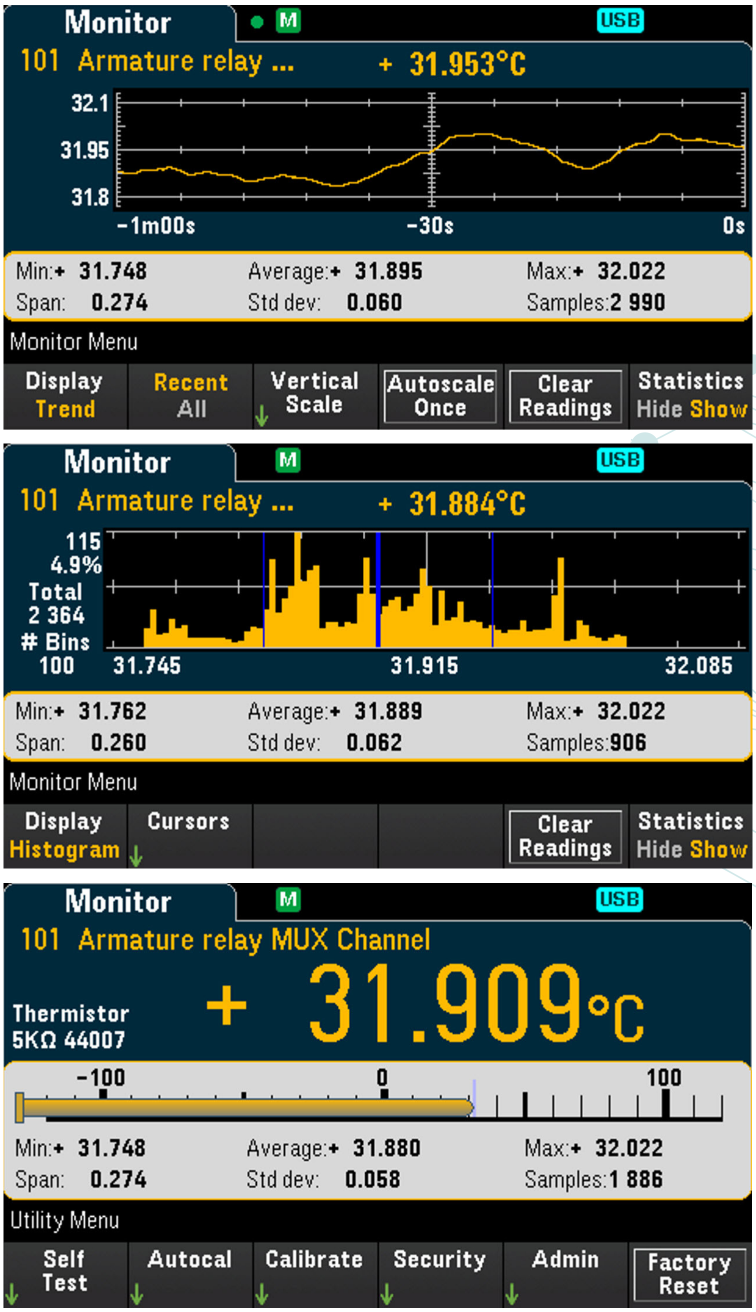


Figure 5. From top to bottom, trend, histogram, and bar charts from a Keysight DAQ970A / DAQ973A

You can store measurements, configure alarms, and monitor individual channels from the front panel. Alarm settings allow you to set the TTL alarm outputs to trigger external alarm lights or sirens or to set a control system to take corrective actions.

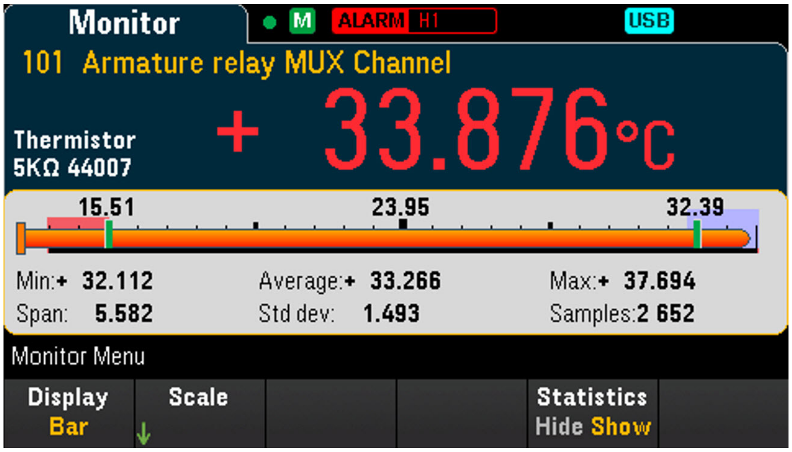


Figure 6. Example of an alarm-triggered display on a Keysight DAQ970A / DAQ973A

You can control larger systems from a PC. Application-specific software for data acquisition makes it easier to configure channels, visualize data, and document and share results. Using software will provide consistent configurations and repeatable results.

Figure 7. Example of Keysight's PathWave BenchVue data acquisition application software, which runs from a PC to configure and visualize data and export 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 for your needs.

Resources

Learn more about Keysight's general-purpose data acquisition and data logger solutions:

- www.keysight.com/find/DAQ970A
- www.keysight.com/find/DAQ973A
- Keysight PathWave BenchVue software

Read the white paper Dynamic Data Acquisition System.

Learn more at: www.keysight.com

For more information on Keysight Technologies' products, applications or services, please contact your local Keysight office. The complete list is available at: www.keysight.com/find/contactus