MEASUREMENT TIPS
Volume 9, Number 2

Selecting Modern Sensors for Today's Data Acquisition Systems

Modern sensors detect a multitude of real-world attributes, such as temperature, force, pressure, humidity, flow, power and much more. In turn, they typically output a useful voltage, current or resistive analog signal, or a digital signal, in proportion to their respective environmental stimulus. Depending on the type of sensor, it may operate autonomously or it may need power supplied. Many times unique signal conditioning is incorporated to provide a useful electrical output. Modern sensors' outputs are in turn easily measured by today's data acquisition equipment such as the Agilent 34972A data acquisition switch unit, bridging the divide between the real world and digital data.

Snapshot: Environmental Test Chamber Automation

An environmental testing lab had several issues with its aging environmental test chambers; they were inaccurate and required ongoing monitoring and adjustment to bring the temperature, humidity and barometric pressure within acceptable levels while running environmental cycling profiles. Taking action to address these issues was long overdue.

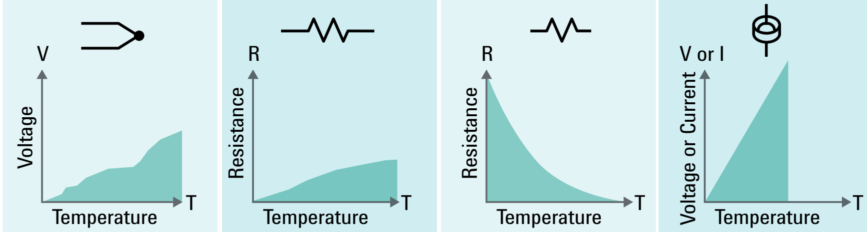
As they were otherwise quite serviceable, the lab decided to update the monitoring and control equipment using modern sensors and PC-controlled data acquisition equipment. After some investigation, the lab engineers determined a resistance temperature detector (RTD), a capacitive relative humidity (RH) sensor, and a barometric pressure sensor for altitude simulation would best provide the appropriate conversion of environmental elements to electrical signals that can be easily measured by the data acquisition equipment. The lab engineers selected the Agilent 34972A data acquisition switch unit because it had the ideal combination of size, I/O module selection, features and flexibility for their needs.

Agilent Technologies

Common modern temperature sensors

Common modern temperature sensors include thermocouples, resistance temperature detectors (RTDs), thermistors and IC sensors. Each has its own particular advantages for different applications. For example, thermocouples are well suited for temperature profiling many points in electronic products because of their form factor, simplicity and low cost. In contrast, a 100-ohm RTD is well suited for use in an environmental chamber because of its relatively high linearity, long-term stability and measurement repeatability. Four-wire ohms measurement capability in data acquisition equipment is well suited for accurately measuring RTDs. Of these sensors, only the IC sensor requires power and incorporates signal conditioning in order to output an easily measured electrical signal.

The Agilent 34972A data acquisition switch unit is equipped to directly measure a wide variety of industry-standard temperature sensors, apply appropriate linearization, and provide an accurate readout in temperature.

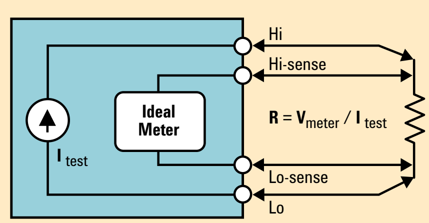


	Thermocouple	RTD	Thermistor	IC Sensor
Advantages	• Self-powered • Simple • Rugged • Inexpensive • Wide variety of physical forms • Wide temp range	• Most stable • Most accurate • More linear than thermocouple	• High output • Fast • Two-wire ohms measurement	• Most linear • Highest output • Inexpensive
Disadvantages	• Non linear • Low voltage • Reference required • Least stable • Least expensive	• Expensive • Slow • Current source required • Small resistance change • Four-wire measurement	• Non- linear • Limited temp range • Fragile • Current source required • Self-heating	• T<250 °C • Power supply required • Slow • Self-heating • Limited configurations

MEASUREMENT TIP

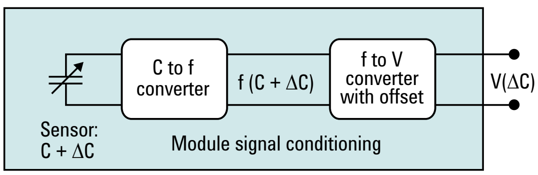
Use a four-wire ohms connection for high-accuracy resistance measurements

The accuracy of a two-wire ohms connection is limited, as the measurement includes lead and contact resistance, so this is best suited for applications where the resistances you are measuring are large. A four-wire ohms connection cancels out lead and contact resistance, providing high measurement accuracy and resolution when you are measuring very small resistance values. Four-wire ohms measurements are ideal for measuring small incremental resistance changes in resistance-output sensors like RTDs



Common modern humidity sensors

Common modern humidity sensors include capacitive, resistive and thermal conductivity types. Each has certain advantages for different applications. Typical of many kinds of sensors, the sensor elements for these three types of humidity sensors have unique needs that dictate incorporating circuitry for signal conversion, linearization, and buffering to make it a practical device having an easily measured output signal. A separate bias supply is needed for power. A capacitive sensor is well suited for measuring an environmental chamber's humidity. Its DC voltage output signal is in turn easily measured by the data acquisition equipment's DMM.



Capacitive humidity sensor module

MEASUREMENT TIP

Select the correct type of humidity sensor for your application

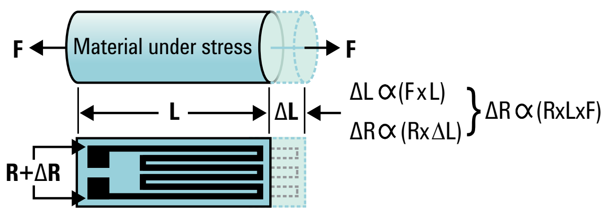
ABSOLUTE HUMIDITY (AH) is a measure of the mass of moisture in a unit volume of air. Choose a thermal conductivity humidity sensor when you need to measure absolute humidity.

RELATIVE HUMIDITY (RH) is the ratio of moisture content in the air to the saturated moisture content of the air for the same pressure and temperature. Capacitive and resistive humidity sensors both respond proportionally to relative humidity. Capacitive sensors are better suited for applications having greater temperature fluctuation. Choose a capacitive or resistive humidity sensor when you need to measure relative humidity.

Modern sensors for force measurements

STRAIN GAUGES are the basis for many types of sensors for making force measurements, including compression, tension and shear, pressure and vacuum, and more. Strain gauges are bonded to a structure, to measure the structure's strain in response to an applied force.

Strain (ϵ) is a non-dimensional value expressed as the ratio of the change in length to the overall length of a piece of material, due to an applied stress or force. Because strain is extremely small for most materials, it is usually expressed in terms of micro-strain (10^{-6}) units. Resistive strain gauges are designed to create a very linear change in resistance in proportion to the applied strain, although over a very small range of typically just a few thousand micro-strain units. While the resistance of a strain gauge can be measured directly, more often the data acquisition equipment is instead used to measure a voltage signal from a Wheatstone bridge that is incorporating the strain gauge.

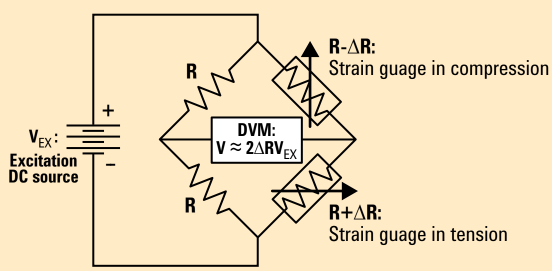


Stress (F), strain (ΔL) and strain gauge response (ΔR)

MEASUREMENT TIP

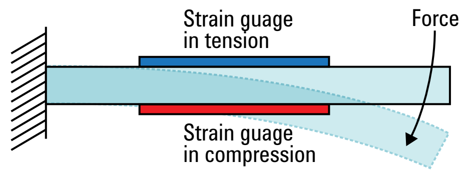
Use a Wheatstone bridge to provide offset nulling, increased gain and temperature drift compensation

You can null out the base resistance of a strain gauge by placing it in a bridge configuration, greatly increasing measurement sensitivity and accuracy. This configuration allows you to measure just the voltage caused by *change* in resistance. Using two or four strain gauges can provide two or four times the signal gain and also provide temperature compensation over using a single strain gauge in the bridge. Many strain-gauge-based sensors incorporate Wheatstone bridges for these reasons. A stable, fixed DC voltage source is needed for bridge excitation. The sensitivity of strain gauges in a bridge configuration is expressed in terms of mV/ V of excitation voltage.



Wheatstone half-bridge configuration

LOAD CELLS are sensors for measuring tensile or compressive measuring forces. They use resistive strain gauges bonded to a calibrated mechanical structure to provide a linear strain and output signal in response to the applied force.



Cantilever beam load cell

PRESSURE SENSORS measure vacuum and pressure, which is force applied per unit of area. Strain gauges are bonded to a diaphragm and provide a linear output signal in response to the applied pressure. A mV-output barometric pressure sensor is well suited for measuring and controlling an environmental chamber's vacuum for altitude testing. A DC excitation power supply is needed to bias a mV-output pressure sensor, as it is internally configured as a Wheatstone bridge. The data acquisition equipment's DMM can in turn easily measure the sensor's mV-output signal.

MEASUREMENT TIP

Select the correct type of pressure sensor for your application

There are several basic pressure measurements you must consider:

- Difference pressure (PSID) is relative to a second applied pressure
- Gauge pressure (PSIG) is relative to the ambient atmospheric pressure.
- Absolute pressure (PSIA) is relative to a total vacuum
- Sealed gauge pressure (PSIS) is relative to 1 atmosphere pressure at sea level.

Sensors for the first two pressure measurements have both sides of their diaphragm open, while the last two have one side sealed at their respective reference pressure. Each type of pressure reading is advantageous to a certain application. For example, an absolute pressure sensor is used for measuring barometric pressure, as it is relative to a vacuum.

Voltage or current output options

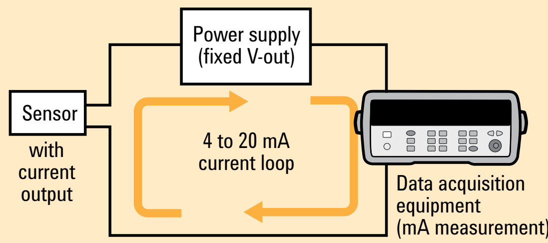
Many sensors are offered with voltage or current output options, each having advantages for different data acquisition system configurations. Even many self-powered sensors are alternately packaged as externally powered sensors incorporating voltage or current output circuitry. Voltage output sensors usually have a buffered full scale (FS) output of 1 to 5 volts, increasing the signal-to-noise ratio and improving measurement performance, especially when the distance increases between the sensor and data acquisition equipment. Current output sensors typically have a 0- or 4-mA to 20-mA-FS output. They are useful for systems with extremely long distances between the sensor and data acquisition equipment. For example, current output sensors are useful for monitoring a facility-sized process.

MEASUREMENT TIP

Consider current output sensors when you are sensing over long distances

When the distance between your sensor and data acquisition is appreciable, for example hundreds of meters, current output sensors connected in a 4- to 20-mA current loop provide you with a number of advantages:

- Large voltage drop in long wires is no longer an issue.
- The external power source can be located by the data acquisition equipment, simplifying furnishing power to a remote sensor.
- Only two wires are needed to carry both signal and power to the sensor.
- A 0-mA signal signifies an open current loop condition.



Summary

The sensors discussed are representative of modern sensors that detect a multitude of real-world attributes and in turn output a voltage, current or resistive analog signal, or a digital signal in proportion to their respective environmental stimuli. Some sensors operate autonomously, without needing external power, while others require power to be supplied. Beyond temperature, unique signal conditioning is often incorporated into the sensor itself, to provide a useful electrical output signal. The sensors' outputs are in turn easily measured by data acquisition equipment such as the Agilent 34972A data acquisition switch unit, bridging the divide between the real world and the digital data and simplify the task of creating just about any conceivable sensor-based data acquisition system configuration.

Environmental attribute	Sensor type	Common signal conditioning	Typical output signal	External power
Temperature	Thermocouple E,J,K,R,S,T	Linearization in DAQ equipment firmware	10's µV/°C	None
Temperature	RTD	Linearization in DAQ equipment firmware	385 or 392 mΩ/ °C	None
Temperature	Thermistor	Linearization in DAQ equipment firmware	0.04 Ω/Ω/ °C	None
Temperature	IC sensor	Conversion, linearization and amplification in sensor	20 mV/ °C	3.3-5 V bias
Humidity (RH)	Capacitive	Conversion, linearization and amplification in sensor	20 mV/ %RH	3.3-5 V bias
Humidity (RH)	Resistive	Conversion, linearization and amplification in sensor	20 mV/ %RH	3.3-5 V bias
Humidity (AH)	Thermal conductivity	Conversion, linearization and amplification in sensor	20 mV/ %AH	3.3-5 V bias
Strain	Strain gage	Wheatstone bridge	0.5-1 µV/V/µε	5-10 V excitation
Force	Load cell	Wheatstone bridge	2-10 mV/V FS	5-10 V excitation
Pressure	Pressure sensor	Wheatstone bridge	2-10 mV/V FS	5-10 V excitation
Most all	Most all	Voltage output option	0 to 1-5 V FS	3.3-30 V bias
Most all	Most all	Current output option	0 or 4 to 20 mA FS	12-24 V bias

Useful References

"Practical Strain Gage Measurements"
(AN 290-1)

"Practical Temperature Measurements"
(AN 290) P/N 5965-7822E

"Making High-Accuracy Temperature Measurements with the 34970A Data Acquisition Switch Unit"
(AN 1425) P/N 5988-8152EN

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