

# DAQ Tools for Temperature Monitoring

A guide to the right test instruments for battery  
temperature monitoring

# Why is Temperature Profiling Important?

Charge and discharge currents increase the temperature of the batteries, and temperature directly affects the lifespan and storage capacity of batteries. Batteries tend to be efficient and provide a normal life span at room temperatures. When batteries are subjected to cold temperatures, their capacity is greatly reduced, and as temperatures increase above room temperature, their life span is reduced. At extreme temperatures, batteries can break down in several stages: leakage, smoke, fire, and explosion. Manufacturers often perform abuse tests to determine the temperatures for each of the stages of breakdown.

The increased adoption of consumer mobile devices has made heat measurement relevant, particularly when batteries charge and discharge. The rule of thumb for electronic devices is that for every 10 °C rises in temperature, the average reliability of an electronic device decreases by 50%. Or, if we can lower the temperature by 10 °C, we'll double the reliability and improve the expected mean time between failure ratings (MTBF) by two times.

This application note will help you select test instrumentation to set up and make the accurate battery charge and discharge temperature measurements so that you can make the appropriate capacity or life span trade-off and improve the reliability of your product or device.



# Why Choose a DAQ for Temperature Measurements?

You can make basic temperature measurements with an Infrared Digital Thermometer or a Digital Multimeter (DMM) with a thermocouple hooked up. So, why choose a Data Acquisition (DAQ) instrument? It's beneficial to use a DAQ when:

- You need to measure multiple temperature points in a single setup.
- Other types of measurements, such as voltage, current, resistance, or frequency, are necessary for the same test setup.
- You need to perform data logging over a period, and memory space is a potential issue.

## For more information

The DAQ970A and DAQ973A DAQ Instruments are general-purpose instruments that can be used for temperature measurements. Because they can measure across various input signals including AC/DC voltage, AC/DC current, 2/4-wire Ohm, frequency, and period, they are incredibly versatile. If you need scanning speed greater than 250 channels per second, or if the test coverage requires measurement from more than 100 channels per scan, we recommend the 34980A DAQ instrument.

For more information, visit [www.keysight.com/find/DAQ](http://www.keysight.com/find/DAQ)

# When and How to Select a Multiplexer for Temperature Measurements

Multiplexers allow a single measurement system to measure multiple channels. Temperature measurements often use several thermocouples or other sensors. Hence, multiplexers provide a way to connect each one to the measurement system. The multiplexer will also scan the sensors, measure one at a time and then automatically move to the next one. Multiplexers work well for temperature measurements because temperature changes much slower than the scan rate. Here are several multiplexer options for temperature measurements:

- When obtaining absolute temperature measurements, select a multiplexer with a built-in thermocouple reference junction. Keysight's DAQM900A, DAQM901A, DAQM902A offer this built-in capability.
- Determine the number of channels needed for your application. Each multiplexer provides a different number of channels available for testing. Keysight's DAQM908A provides up to 40 channels.
- A scanning speed of up to 80 channels per second is sufficient for most temperature measurement applications. If needed, faster scanning is available with DAQM902 multiplexer, up to 250 channels per second, and DAQM900A multiplexer, up to 450 channels per second.
- Most multiplexers can accept other input signals besides temperatures, such as AC/DC volts, 2-wire Ohms, Frequency, and Period. Some multiplexers can also measure AC/DC current.
- Multiplexers can also measure temperature using thermistors and RTDs. More accurate measurements can be made using 4-wire ohm measurements. The DAQM901A and DAQM902A are capable of both 2 and 4-wire ohm measurements.

	DAQM900A	DAQM901A	DAQM 902A	DAQM 908A
<b>Number of channels</b>	20	20+2	16	40
<b>Max Scan Speed</b>	450 ch/s	80 ch/s	250 ch/s	80 ch/s
<b>Number of Contacts</b>	2 or 4	2 or 4	2 or 4	1
Temperature				
Thermocouple	■	■	■	
2-wire RTD		■	■	■
4-wire RTD		■	■	
Thermistor		■	■	■
DC Volts	■	■	■	■
AC Volts	■	■	■	■
2-wire Ohms	■	■	■	■
4-wire Ohms	■	■	■	
Frequency	■	■	■	■
Period	■	■	■	■
DC current		■		
AC current		■		

**Table 1.** Comparison of Keysight's multiplexer cards: DAQM900A, DAQM901A, DAQM902A and DAQM908A.

# Choice of Temperature Sensors

The DAQ970A and DAQ973A models have universal inputs with built-in signal conditioning circuitry and software algorithms. This allows you to choose from various temperature sensors (Figure 5).

## Thermocouple

Popular thermocouple sensor types are types B, E, J, K, N, R, S, and T. Thermocouple types vary by operating range, chemical properties, sensitivity, melting point, and output. Depending on the test environment, some thermocouple types are more suited for use than others. As mentioned earlier, absolute temperature measurements are attainable with the thermocouple reference junction built into the 34901A, 34902A, and 34908A multiplexers

## Resistance Temperature Detector (RTD)

You have a choice of 2-wire and 4-wire type RTD sensors. Use the 4-wire type RTD sensor if your leads are very long, as this can affect the accuracy of temperature measurements. RTD sensors have superior stability, accuracy, and resistance-temperature linearity over other temperature sensors, such as the thermocouple and thermistor.

## Thermistor

Thermistors are either Negative Temperature Coefficient (NTC) or Positive Temperature Coefficient (PTC). With NTC, resistance decreases as temperature rises, while with PTC, resistance increases with temperature. NTC-type thermistors are more common, with ranges that include the 2.2K Ohm, 5K Ohm, and 10K Ohm types. Thermistors are more sensitive than thermocouples or RTD sensors but are not as linear as an RTD.

	Thermocouple	RTD	Thermistor
Common reasons for selection	<ul style="list-style-type: none"> <li>• Rugged</li> <li>• Versatile</li> <li>• Wide temperature range</li> <li>• Inexpensive</li> </ul>	<ul style="list-style-type: none"> <li>• High accuracy</li> <li>• Stability</li> </ul>	<ul style="list-style-type: none"> <li>• High sensitivity</li> <li>• Low thermal initiative (fast response)</li> </ul>
Additional Advantages	<ul style="list-style-type: none"> <li>• Self-powered</li> <li>• Wide variety of physical forms</li> </ul>	<ul style="list-style-type: none"> <li>• Most stable</li> <li>• More linear than a thermocouple</li> </ul>	<ul style="list-style-type: none"> <li>• High output</li> <li>• 2-wire Ohms measurement</li> </ul>
Disadvantages	<ul style="list-style-type: none"> <li>• Non-linear</li> <li>• Low voltage</li> <li>• Reference required</li> <li>• Least stable</li> <li>• Least sensitive</li> </ul>	<ul style="list-style-type: none"> <li>• Expensive</li> <li>• Current source required</li> <li>• Small resistance change</li> <li>• 4-wire measurement</li> <li>• Self-heating</li> </ul>	<ul style="list-style-type: none"> <li>• Non-linear</li> <li>• Limited temperature range</li> <li>• Fragile</li> <li>• Current source required</li> <li>• Self-heating</li> </ul>

**Table 2.** Comparison between the three types of temperature sensors: thermocouple, RTD, and thermistor.

# Considerations for Temperature Data Logging and Analysis

We mentioned earlier that a DAQ device is recommended for temperature measurement, especially when multiple temperature points are involved or when the temperature needs to be data logged and monitored over a period. As a DAQ instrument needs to be connected to a PC, some software applications are necessary for instrument connection, configuration, and data logging. An application that provides visualization, graphing, and reporting capabilities can also be beneficial.

Several test vendors offer software applications to connect, control and automate test instrumentation. Keysight offers BenchVue software, which provides an intuitive user interface so you can quickly set up and execute tests and get results faster. The Test Flow feature allows you to build your own automated tests, reducing significant test development time.

BenchVue supports hundreds of Keysight instrument types and models, and dedicated instrument apps are automatically launched upon instrument detection. The BenchVue Data Acquisition Control & Analysis app can be used for data acquisition, data logging, and data visualization. The app provides multiple data visualization displays and math capabilities, making it a powerful timesaving tool for instant monitoring, analysis, and reporting.

Task	Traditional approach without BenchVue	Approach with BenchVue
1 Instrument configuration	Manual configuration using the DAQ instrument front panel or automate with Keysight's Connect Expert software	Simple plug-and-play setup with user-friendly GUI
2 Measurement configuration	Manual configuration using the DAQ instrument front panel or programming using SCPI commands	Easily done through point-and-click on the user-friendly GUI (see figure 2)
3 Data logging configuration	Manual configuration via the DAQ instrument front panel to a USB stick or automated using PC connectivity	Easily done through point-and-click on the user-friendly GUI (see figure 3)
4 Data visualization	Charts are manually created	Data is easily displayed in strip, bar, histogram or XY chart formats (see example in figure 4)
5 File export	From the front panel, datalog file is saved onto a USB thumb drive before being transferred to a PC	Datalog file is directly saved onto PC memory and can be further exported to MATLAB, Excel, Word and .csv file formats
6 Report generation	Reports are manually created	Automatic report generation and export to Word or Excel
7 Multiple instrument integration and control	Requires programming using SCPI commands	Integrating multiple instruments is easy on a single interface

**Table.3** The BenchVue Data Acquisition Control & Analysis app can replace much of the manual work required of an engineer, from instrument configuration to report generation.

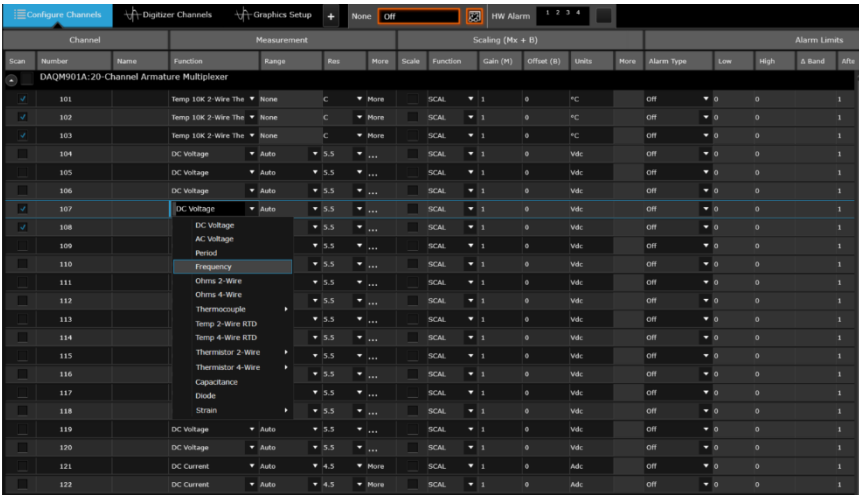


Figure 1. BenchVue Data Acquisition Control & Analysis app's configuration setup panel

## For more information

Details of how BenchVue is used in an actual temperature measurement application across multiple products and on multiple points are outlined in this application note: [Temperature Profiling a Battery During Charging and Discharging Using a DAQ](#)

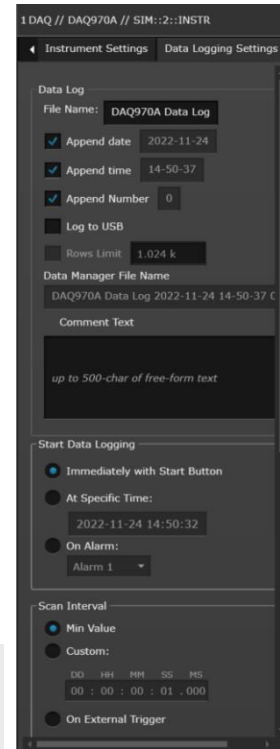


Figure 2. BenchVue Data Acquisition Control & Analysis app's data logging setup panel

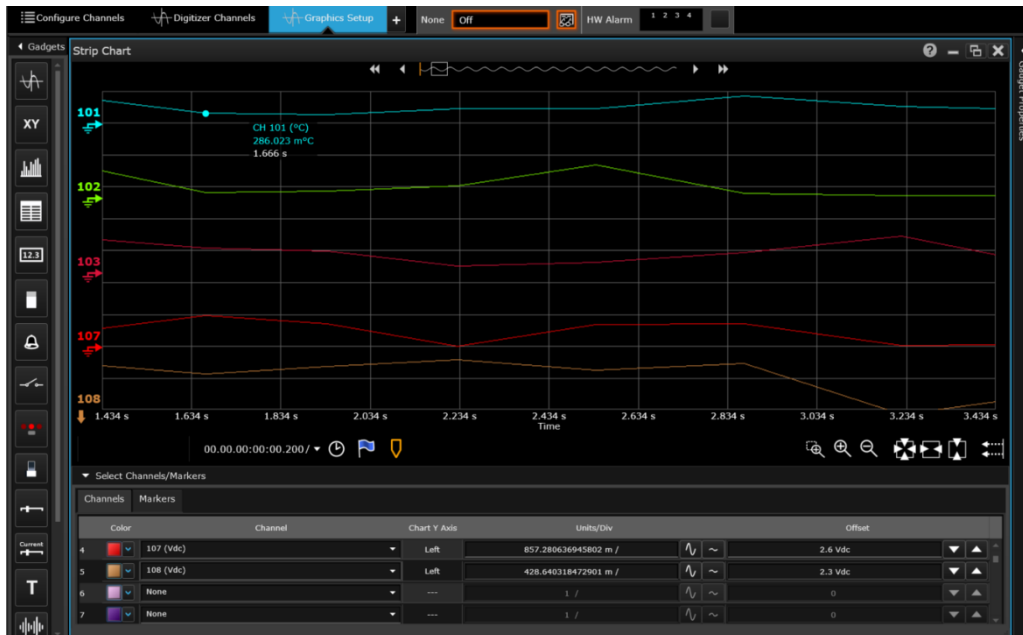


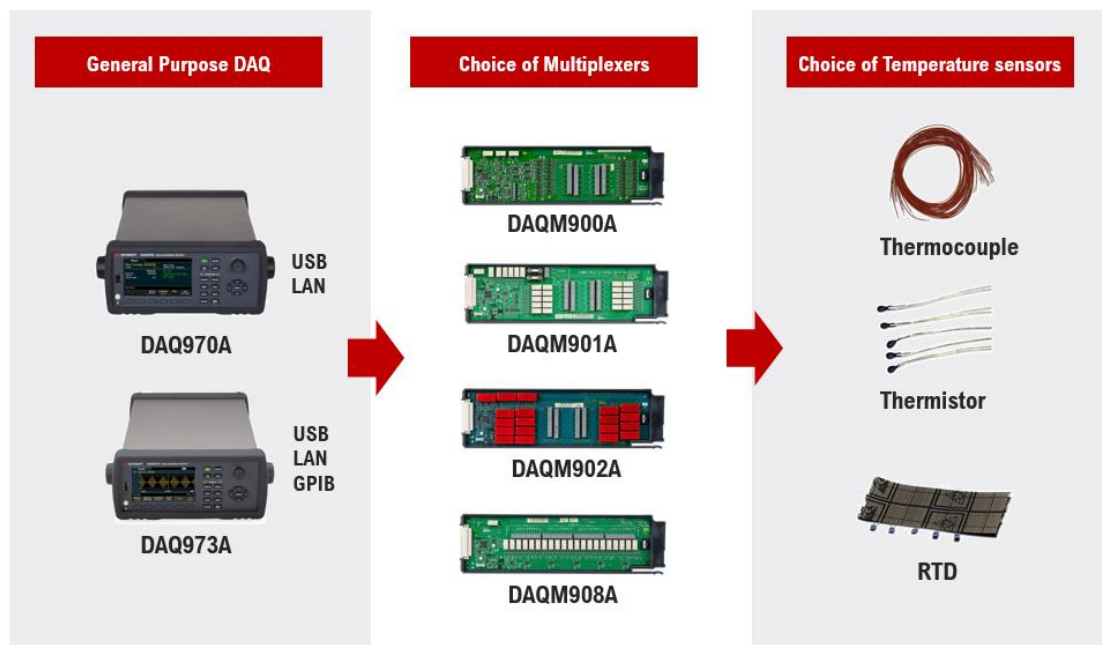
Figure 3. BenchVue Data Acquisition Control & Analysis app's graphical display panel with strip chart



# Summary

Selecting the appropriate instrument and software for temperature profiling can help you make more accurate temperature measurements and improve product reliability. In summary, some things you should consider are listed below:

1. How many measurement points do you need per test?
2. Does your application require different types of measurements or input sensors?
3. Is the instrument scalable in the long term? A scalable instrument will likely mean a lower cost of investment for you.
4. Will you be able to integrate the instrument easily into your current 'system'?



**Figure 4:** Hardware considerations for temperature measurement: DAQ instruments, multiplexers, and sensors.

## For more information

- For more information on Keysight General-Purpose DAQ / Data Loggers, please go to [www.keysight.com/us/en/product/DAQ970A/data-acquisition-system-usb-lan.html](http://www.keysight.com/us/en/product/DAQ970A/data-acquisition-system-usb-lan.html)  
[www.keysight.com/us/en/product/DAQ973A/data-acquisition-system-usb-lan-gpib.html](http://www.keysight.com/us/en/product/DAQ973A/data-acquisition-system-usb-lan-gpib.html)
- If you are looking for scan speeds above 250 scans per second or if you need more than 100 channels per DAQ instrument, please go to:  
[www.keysight.com/us/en/product/34980A/multifunction-switch-measure-unit.html](http://www.keysight.com/us/en/product/34980A/multifunction-switch-measure-unit.html)
- For more information on the Keysight BenchVue software platform, please go to:  
[www.keysight.com/us/en/products/software/pathwave-test-software/benchvue-software.html](http://www.keysight.com/us/en/products/software/pathwave-test-software/benchvue-software.html)
- Keysight Technologies, Inc. offers a range of Temperature Sensor and Probes For a more in-depth information on temperature measurements, download the “[Practical Temperature Measurements](#)” application note

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