Keysight Technologies
How to Select Test Instrumentation for Temperature Profiling of Battery Charge and Discharge
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 measurement of heat relevant, particularly for when batteries charge and discharge. The rule of thumb for electronic devices is that for every 10°C rise 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. In other words, we can improve the expected meantime between failures ratings (MTBF) by two times, if the operating temperature is lowered 10°C.

This application brief will help you select test instrumentation to set up and make 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.

Figure 1. A typical battery powered 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 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 in the same test setup.
- You need to perform data logging over a period, and memory space is a potential issue.

Keysight’s DAQ Instruments

The 34970A and 34972A 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.

Table 1. Comparison of Keysight’s multiplexer cards: 34901A, 34902A and 34908A.

<table>
<thead>
<tr>
<th></th>
<th>34901A</th>
<th>34902A</th>
<th>34908A</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of channels</td>
<td>20 + 2</td>
<td>16</td>
<td>40</td>
</tr>
<tr>
<td>Max scan speed</td>
<td>60 ch/s</td>
<td>250 ch/s</td>
<td>60 ch/s</td>
</tr>
<tr>
<td>Number of contacts</td>
<td>2 or 4</td>
<td>2 or 4</td>
<td>1</td>
</tr>
</tbody>
</table>

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, so 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:

- Select a multiplexer with a built-in thermocouple reference junction when you need to obtain absolute temperature measurements. Keysight’s 34901A and 34902A 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 34908A provides up to 40 channels.

- Scanning speed of up to 60 channels per second is sufficient for most temperature measurement applications. If needed, faster scanning is available with 34902A multiplexer, up to 250 channels per second.
- Most multiplexers can accept other types of input signals besides temperature, 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 349701A and 34902A are capable of both 2 and 4-wire ohm measurements.
Choice of Temperature Sensors

The 34970A and 34972A DAQ models have universal inputs with built-in signal conditioning circuitry and software algorithm. This gives you the flexibility to choose from a range of temperature sensors (Figure 5).

Thermocouple

Popular thermocouple sensors types are the type B, E, J, K, N, R, S and T. Thermocouple types vary by their operating range, chemical properties, sensitivity, melting point, and output. Depending on the test environment, some thermocouple types are more suited for use over 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 are known for having 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) types. 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 thermocouple or RTD sensors but are not as linear as an RTD.

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

<table>
<thead>
<tr>
<th>Common reasons for selection</th>
<th>Thermocouple</th>
<th>RTD</th>
<th>Thermistor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rugged</td>
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<tr>
<td>Versatile</td>
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<td></td>
<td></td>
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<tr>
<td>Wide temperature range</td>
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<td></td>
<td></td>
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<tr>
<td>Inexpensive</td>
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<td></td>
<td></td>
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<tr>
<td>High accuracy</td>
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<tr>
<td>Stability</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>High sensitivity</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Low thermal initiative (Fast response)</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Additional Advantages</th>
<th>Thermocouple</th>
<th>RTD</th>
<th>Thermistor</th>
</tr>
</thead>
<tbody>
<tr>
<td>Self-powered</td>
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<tr>
<td>Wide variety of physical forms</td>
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<tr>
<td>Most stable</td>
<td></td>
<td></td>
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<tr>
<td>More linear than thermocouple</td>
<td></td>
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<tr>
<td>High output</td>
<td></td>
<td></td>
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<tr>
<td>2-wire Ohms measurement</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Disadvantages</th>
<th>Thermocouple</th>
<th>RTD</th>
<th>Thermistor</th>
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</thead>
<tbody>
<tr>
<td>Non-linear</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Low voltage</td>
<td></td>
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<td></td>
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<tr>
<td>Reference required</td>
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<tr>
<td>Least stable</td>
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<td></td>
<td></td>
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<tr>
<td>Least sensitive</td>
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<tr>
<td>Expensive</td>
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<tr>
<td>Current source required</td>
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<td></td>
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<tr>
<td>Small resistance change</td>
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<tr>
<td>4-wire measurement</td>
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<tr>
<td>Self-heating</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Non-linear</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Limited temperature range</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Fragile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Current source required</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Self-heating</td>
<td></td>
<td></td>
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</tbody>
</table>
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 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 capability 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 then 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 time-saving tool for instant monitoring, analysis and reporting.

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.

<table>
<thead>
<tr>
<th>Tasks</th>
<th>Traditional Approach without BenchVue</th>
<th>Approach with BenchVue</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 Instrument configuration</td>
<td>Manual configuration using the DAQ instrument front panel or automate with Keysight’s Connection Expert software</td>
<td>Simple plug-and-play setup with user-friendly GUI</td>
</tr>
<tr>
<td>2 Measurement configuration</td>
<td>Manual configuration using the DAQ instrument front panel or programing using SCPI commands</td>
<td>Easily done through point-and-click on the user-friendly GUI (see Figure 2)</td>
</tr>
<tr>
<td>3 Data logging configuration</td>
<td>Manual configuration via the DAQ instrument front panel to a USB stick or automated using PC connectivity</td>
<td>Easily done through point-and-click on the user-friendly GUI (see Figure 3)</td>
</tr>
<tr>
<td>4 Data visualization</td>
<td>Charts are manually created</td>
<td>Data is easily displayed in strip, bar, histogram or XY chart formats (see example in Figure 4)</td>
</tr>
<tr>
<td>5 File export</td>
<td>From the front panel, datalog file is saved onto a USB thumb drive before being transferred to a PC</td>
<td>Datalog file is directly saved onto PC memory and can be further exported to MATLAB, Excel, Word and .csv file formats</td>
</tr>
<tr>
<td>6 Report generation</td>
<td>Reports are manually created</td>
<td>Automatic report generation and export to Word or Excel</td>
</tr>
<tr>
<td>7 Multiple instrument integration and control</td>
<td>Requires programming using SCPI commands</td>
<td>Integrating multiple instruments is easy on a single interface</td>
</tr>
</tbody>
</table>
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: Battery Temperature Profiling While Charging and Discharging, literature number 5992-2453EN.
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”?

![Diagram of General Purpose DAQ, Choice of Multiplexers, and Choice of temperature sensors]

Figure 5: Hardware considerations for temperature measurement: DAQ instruments, multiplexers, and sensors.

Additional Information

For more information on Keysight General-Purpose DAQ / Data Loggers, please go to:
www.keysight.com/find/34970A
www.keysight.com/find/34972A

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/find/34980A

For more information on the Keysight BenchVue software platform, please go to:
www.keysight.com/find/BenchVue

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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