APPLICATION NOTE

Reliable EV Battery Testing Using Digital Multimeters

Keysight Benchtop 34465A/34470A Digital Multimeter

KEYSIGHT

Overview

Digital multimeters (DMMs) are gaining traction in the automotive sector as a result of fast-growing industry segments such as electric and plug-in hybrid vehicles.

According to MarketsandMarkets, "The global digital multimeter market size is anticipated to reach USD 1,047 million by 2024 from USD 847 million in 2019, growing at a CAGR of 4.3% during the forecast period," and "The automotive segment is expected to be the fastest-growing digital multimeter market, by application, during the forecast period. The growing demand for electric vehicles and self-driving cars in North America, Europe, and China is driving the requirement for digital multimeters." (MarketsandMarkets 2020)

MarketsandMarkets. 2020. *Digital Multimeter Market by Type (Handheld, Benchtop, Mounted), Ranging Type (Auto-ranging, Manual), Application (Automotive, Energy, Consumer Electronics & Appliances, Medical Equipment Manufacturing), and Region - Global Forecast to 2024*. Market Research, MarketsandMarkets, 178. Accessed August 2022. https://www.marketsandmarkets.com/Market-Reports/digital-multimeter-market-19694516.html

What is a Digital Multimeter?

A multimeter is a measuring device that can measure alternating current (AC) or direct current (DC) voltage, current, resistance, temperature, capacitance, and other parameters. Many features in a modern digital multimeter's internal system are miniaturized and enabled by digital and logic technology. Digital multimeters can have graphical displays, data logging and signal digitizing capabilities, programmability, and the ability to communicate with external devices thanks to digital technology.

Figure 1. Keysight Benchtop 34470A Digital Multimeter, 7.5 Digit, Truevolt DMM.

Electric and Plug-in Hybrid Vehicles Battery Testing

An electric vehicle (EV) comprises several critical components, notably the electric motor, inverters, and battery pack. The key competitive differentiators for an EV are usually tied to the EV's powertrain, battery capacity, and charge time, as these will be the deciding factors for the consumer when purchasing an EV.

Why EV battery testing matters

The battery is the EV subsystem that enables electrified transportation. Measurements and testing are critical during the design and production phases of battery cells because a faulty or poorly designed battery can result in decreased performance and a shorter battery service life. A faulty battery can even cause injuries or fatal accidents in some cases. Thus, batteries used in EVs must deliver an extremely high level of performance.

The key to formulating a good battery design is performance testing. It is a crucial process that involves the phases of design, production, and system integration to ensure that all batteries are of the highest quality in terms of operational performance and safety.

The following sections are some of the use cases of how battery manufacturers use a digital multimeter to test the batteries during production.

Figure 2. Why EV battery testing matters

Application and Uses Cases

In this section, we will look closely at the use cases of digital multimeters in the R&D bench testing of battery cells for energy storage and automotive applications.

Lithium-Ion batteries in EVs

Most electric vehicles utilizes lithium-Ion Batteries due to their superior energy density relative to other electrical energy storage systems. In addition, they have a high power-to-weight ratio, high energy efficiency, and good performance at high temperatures.

One characteristic of lithium-ion cells is a phenomenon called self-discharge. Self-discharge, sometimes called leakage, is when the stored energy gradually decreases over time due to the slight electrochemical reaction that results in small heat generation to an internal load inside the cell.

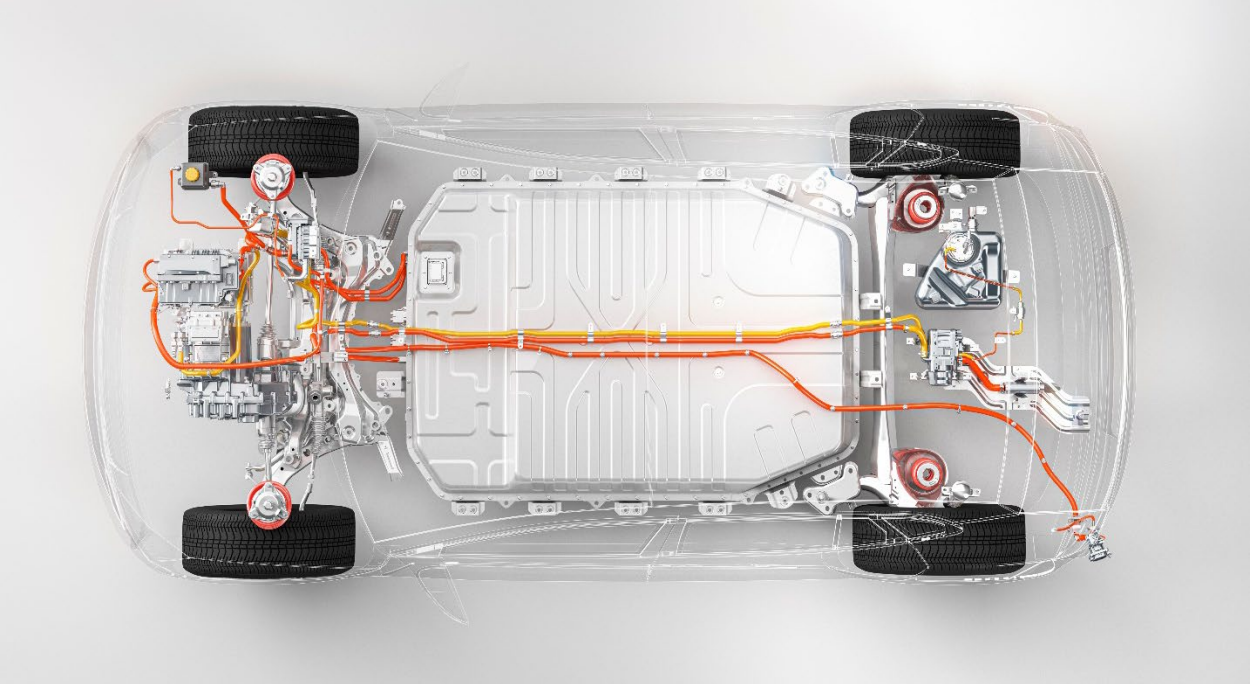

Figure 3. Lithium-ion batteries in EVs

1. Open circuit voltage (OCV) test

During the aging stage of the lithium-ion battery manufacturing process, the cells are placed in a storage area for up to a couple of weeks. During this time, electrical tests for OCV and self-discharge are performed to separate potentially defective cells. Typically, testing the battery's voltage values at this stage enables manufacturers to detect defects by detecting voltage drops exceeding the predefined value.

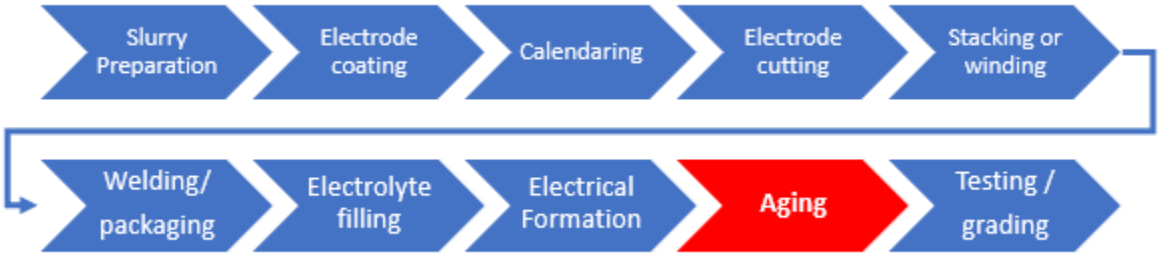

Figure 4. The lithium-ion cell manufacturing process

Measuring the OCV

You can measure the OCV of the battery cell with a digital multimeter. Put the digital multimeter in DC voltage reading mode, then attach the red probe to the battery's positive post, followed by the black probe to the negative post. Suppose the figures displayed on the digital multimeter indicate a value lower than the predefined value. In that case, the battery may be faulty. As shown in figure 6, unhealthy and faulty cells accumulated significantly different amounts of OCV as the aging process progressed.

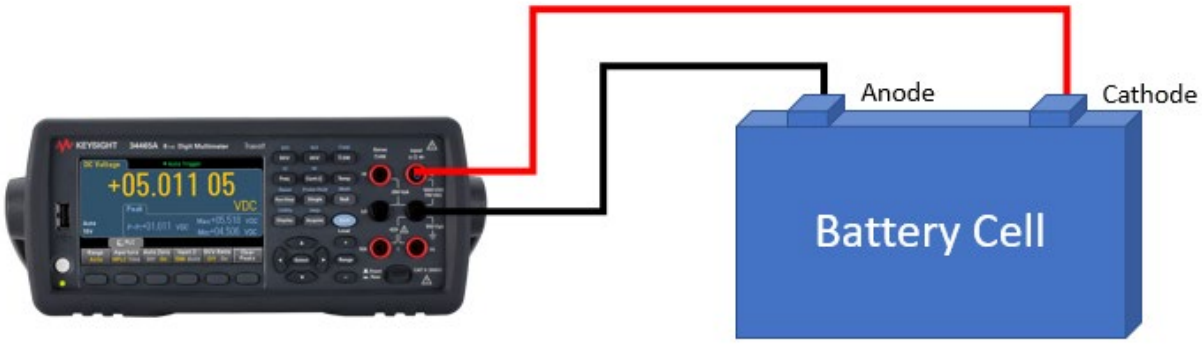

Figure 5. Measuring battery's OCV with bench DMM.

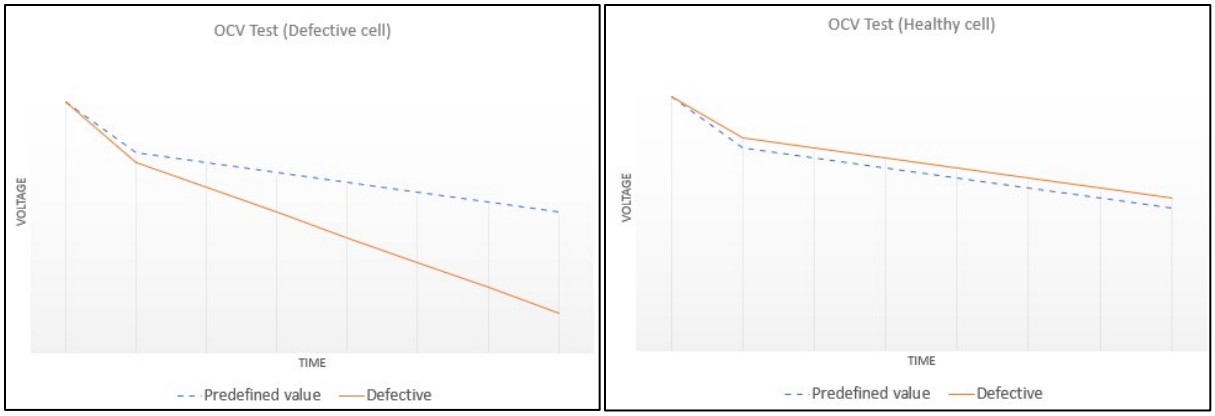

Figure 6. (Left) The SoC of a defective cell during the aging process falls below the predefined value. (Right) SoC of a healthy cell above the predefined value.

When a battery has a defect, such as leakages, it causes the battery voltage to drop. However, it takes time for a significant drop to be noticeable due to the comparatively small magnitude of the discharge. Most of the time, the variation of OCV is extremely small, and the aging process typically takes long hours to detect defective cells. In this case, it would be ideal to use a high-precision and high-resolution DMM to detect the relatively small difference in voltage drop following a short aging process.

Apart from having high precision and resolution when measuring the OCV of the battery, a digital multimeter with an autocalibration (ACAL) feature is also essential. A digital multimeter with ACAL can account for drift caused by changes in time and temperature. Temperature changes can affect battery OCV. Even though the temperature at the time of measurement varies by only a few degrees Celsius, the OCV value can vary by hundreds of microvolts. It is critical to keep the temperature stable during the measurement process and to avoid introducing instrument errors into the actual measurements.

Key DMM criteria

- High-Resolution
- High-Accuracy calculation
- Measurement stability using ACAL[1] – Automatic calibration

Recommendation

- 34465A 6.5 Digit Multimeter, Truevolt DMM
  www.keysight.com/us/en/product/34465A/digital-multimeter-6-5-digit-truevolt-dmm.html
- 34470A 7.5 Digit Multimeter, Truevolt DMM
  www.keysight.com/us/en/product/34470A/digital-multimeter-7-5-digit-truevolt-dmm.html

[1] For the 34465A and 34470A DMM's, Autocalibration compensates for drift caused by time and temperature change in DC voltage and resistance measurements, and adjusts some aspects of other measurement functions. Autocalibration (or ACAL for short) only takes about 20 seconds or less to perform.

2. Short circuit test

Battery safety is a major concern due to many accidents, for which short circuit has been considered one of the leading causes. During manufacturing, it is imperative to check for any short circuits between the electrode and the insulation. One example of manufacturing defects is the outer insulation short-circuiting the negative electrode and making contact with the electrolyte.

Checking for short-circuit

It is impossible to eliminate the risk of manufacturing defects caused by human error. Using the digital multimeter resistance mode to check for a short circuit between the electrode and the cell's enclosure is one way to reduce the risk of this happening. Suppose it does not show any signs of short circuits. In that case, the value you get when measuring the resistance between the positive electrode and the battery cell enclosure should be Overload (OL). If, on the other hand, the resistance reads 0 Ohm, this suggests a short circuit between the negative electrode and the compartment of the battery cell.

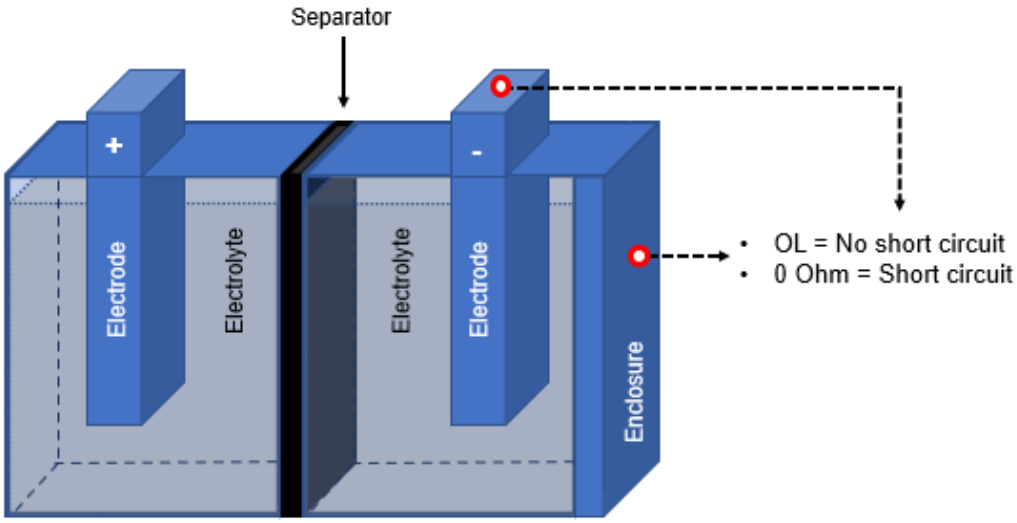

Figure 7. Check for a short circuit between the electrode and the battery cell's enclosure

Key DMM criteria

- High-accuracy
- Resistance measurement mode

Recommendation

- 34465A 6.5 Digit Multimeter, Truevolt DMM
  www.keysight.com/us/en/product/34465A/digital-multimeter-6-5-digit-truevolt-dmm.html
- 34470A 7.5 Digit Multimeter, Truevolt DMM
  www.keysight.com/us/en/product/34470A/digital-multimeter-7-5-digit-truevolt-dmm.html

3. Thermal performance test

An excessive rise in temperature has always been a significant challenge in the design of lithium-ion battery packs. It is normal for a battery to heat up due to the electrochemical reaction that occurs inside the battery and the small amount of internal resistance.

To get the best performance out of the battery, engineers must design a battery cell pack that can maintain a wide operating temperature range, say 15 °C to 35 °C. It is also critical to monitor the temperature of the battery cell during the design stage, as it can provide early indications of design flaws in the battery pack.

Monitoring battery temperature

You can use a digital multimeter to monitor the battery cell's temperature simply by switching to the temperature mode and using it with a thermocouple. A digital multimeter will serve you well during the early stages of the product life cycle because you can quickly troubleshoot and validate the battery system design before it goes into mass production. However, if you plan to monitor the temperature at multiple points in the battery system of a product, the best way to do so would be to use a data acquisition (DAQ) system.

For more information

See the blog post for how you can Monitor Battery Temperature Using a Data Acquisition System or Specialized Battery Test System.

Or

Refer to this technical white paper to Get to The Root of Battery Failures that highlights common temperature-related battery issues and will show you how Keysight test instruments can help you build better battery-operated applications

Key DMM criteria

- Temperature monitoring feature
- Thermocouple accessory
- High-accuracy

Recommendation

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Summary

We have only touched the surface of how digital multimeters can be useful in early battery research and development and the most important considerations when choosing the right digital multimeter for EV battery testing. However, It is necessary to consider improving testing efficiencies for larger EV battery test labs and high-volume battery manufacturing tests. One such area is the use of Keysight's revolutionary potentiostatic measurement method, which reduces the time required to discern between good and poor Li-ion cell self-discharge performance compared to the conventional OCV method. Get in touch with Keysight so that you can discuss your testing needs and find the optimal solution.

For more information

- For more information about Keysight 34465A 6.5 Digit Multimeter, visit www.keysight.com/us/en/product/34465A/digital-multimeter-6-5-digit-truevolt-dmm.html
- For more information about Keysight 34470A 7.5 Digital Multimeter, visit www.keysight.com/us/en/product/34470A/digital-multimeter-7-5-digit-truevolt-dmm.html
- To learn more about the DMM we offer, go to www.keysight.com/us/en/products/digital-multimeters-dmm.html
- To learn more about Keysight's revolutionary potentiostatic measurement method for Li-ion cells, go to www.keysight.com/us/en/product/BT2152B/self-discharge-analyzer.html
- To learn more about testing EV battery cells, modules, and packs, go to www.keysight.com/us/en/products/hev-ev-grid-emulators-and-test-systems/scienlab-battery-test-systems.html

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Published in USA, September 29, 2022, 3122-1781.EN