Keysight Success Stories: Li-Ion self-discharge

Completing Li-Ion Cell Self-Discharge Testing in Just Two Hours

Propelled by the growing demand for electric vehicles (EVs), the worldwide market for lithium-ion (Li-Ion) batteries is projected to pass $40 billion by 2024. The main applications will be EVs, hybrid electric vehicles (HEVs), and a variety of battery-based energy storage systems (ESSs).

During normal usage, a cell loses stored energy in a process called self-discharge. Losing charge over time can occur even when a cell is not in use. Causes range from chemically unstable electrodes, impurities in the electrolyte, or simple aging of the battery. Warm temperatures will cause cells to self-discharge at a faster rate.

In manufacturing, individual batches of cells may exhibit different self-discharge behavior within the same production process. Consequently, battery makers choose to thoroughly test their cells and batteries as a way to assess product quality, reliability, and performance.

This situation faced one of the world’s leading original equipment manufacturers (OEMs) of Li-Ion cells. Its traditional approach to self-discharge testing was taking up to two weeks, and this was making it difficult to keep up with increasing order growth, product mix, and production volume.

### Organization:
Major OEM of electric-vehicle batteries

### Challenges:
- Reducing the time needed to perform Li-Ion cell self-discharge tests
- Performing design verification fast enough to meet tight delivery deadlines

### Solutions:
- Making precise measurements in R&D with the Keysight BT2191A self-discharge measurement system
- Accelerating production test with the Keysight ET2152A self-discharge analyzer and BT2155A analysis software

### Results:
- Slashed self-discharge test time from two weeks to two hours
- Reduced storage space by 80 percent on the manufacturing floor
The Challenge: Testing Faster to Meet Tighter Deadlines

Cells that exhibit high levels of self-discharge are more likely to fail. These cells must be identified and the underlying cause determined (e.g., faulty material, process or test). Traditional test methods relied on measuring the gradual decline in open-circuit voltage (OCV), typically measured passively over a period of several weeks (Figure 1).

![Cell assembly/forming → Charging → Charge redistribution/rest](5-15 days)

- Measure OCV
- Suspect 4-12 weeks
- WIP storage
- Measure OCV

Pass
- Ship

Fail
- Recycle/discard

Figure 1. In manufacturing, the typical test cycle for Li-Ion cells can take several weeks.

A typical 100 kWh EV battery pack might have 8,000 standard “18650” cells (18 mm x 65 mm). For this OEM, order growth was ramping quickly and there was tremendous pressure to perform thorough testing in less time to meet increasingly tight delivery deadlines. As a leader in the industry, its approach to self-discharge testing was taking just two weeks—but a game-changing decrease in test time would provide a significant competitive advantage.

The OEM in this study has a global manufacturing footprint, with facilities located in some of today’s fastest-growing markets for EV, HEV, and ESS. Not only did it require a quick test solution, but the answer needed to meet global deployment requirements:

- Rapidly deployable
- Test plans are easy to replicate across different batches and different locations
- Have a compact form factor that is easy to integrate into the available space
The Solution: Innovating with A New and Faster Test Methodology

Working closely with the manufacturer’s technical team, our application specialists developed a deep understanding of the specific cell-level test requirements. Building on that knowledge, we proposed a comprehensive solution that met their key requirements for Li-Ion cell self-discharge testing. Upon acceptance, our team deployed a pair of fully commissioned solutions, one each for R&D and manufacturing, under extremely tight time constraints.

The two solutions deployed are the Keysight BT2191A self-discharge measurement (SDM) system in R&D, and the Keysight BT2152A self-discharge analyzer in manufacturing (Figure 2). The companion PC-based applications are the Keysight BT2192A self-discharge measurement system software and the Keysight BT2155A self-discharge analysis software.

Figure 2. The R&D team uses the BT2191A SDM system (left), and manufacturing test uses the compact BT2152A (right).
Both solutions implement Keysight’s new potentiostatic method that measures self-discharge in Li-Ion cells (Figure 3). In this configuration, the self-discharge current ($I_D$) continues to flow through the parallel resistance ($R_{SD}$), and this acts to decrease the voltage present across the effective capacitance of the cell. In the test setup, the BT2152A self-discharge analyzer holds the cell voltage constant, and it does this by applying a current equal to the self-discharge current. This closed-loop process measures the cell current very accurately.

![Figure 3. Keysight's closed-loop measurement process is much faster than the traditional OCV method.](image)

**The Results: Making Measurements in just Two Hours**

The OEM found that our solution surpassed the expectations of the manufacturing and R&D teams. In manufacturing, the BT2152A delivered three immediate benefits that were especially impressive. First and foremost, the potentiostatic method provides test results for a batch of 18650 Li-ion cells within two hours, not the two weeks previously needed for passive OCV measurements.

Part of the dramatic speed improvement is due to the ability to measure up to 32 cells simultaneously with the BT2152A. Another time-saver: the BT2155A software enables engineers to immediately evaluate cells connected to the analyzer without losing time writing a test procedure.

The third benefit: While testing cells, they must reside in a temperature-controlled storage area, and this consumes valuable space on the production floor. With the new approach, faster testing reduces the need for large production storage areas, providing an estimated 80% potential decrease in cell storage over the long term.
In R&D, the flexibility and sensitivity of the BT2191A SDM system has proven to be extremely useful. For example, the voltage applied to a cell is very stable at ±10 µVpk, and this helps minimize the continuous-charge current-redistribution noise that can invalidate self-discharge current measurements. Engineers are also able to accurately measure self-discharge currents down to ±(0.025% + 100 nA), and this is a key factor in varying-temperature scenarios.

**Going Forward**

Based on the success of the first two solutions, the OEM has begun deploying the Keysight SDM system in facilities that produce ESS products for commercial and industrial applications. With microvolt-level stability and nanoamp measurement range, both solutions will be able to provide fast and accurate self-discharge measurements well into the future.

**Related Information**

- Data Sheet: *Keysight BT2152A Self-Discharge Analyzer*, publication 5992-2450EN
- Data Sheet: *Keysight BT2191A Self-Discharge Measurement System and BT2192A software*, publication 5992-2292EN
- White Paper: *How to Shorten Li-Ion Self-Discharge Test Time*, publication 5992-2770EN
- Application Note: *Evaluate Li-Ion Self-Discharge of Cells in a Fraction of the Time Traditionally Required*, publication 5992-2517EN

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