Discern good versus bad cell self-discharge performance in as little as minutes instead of weeks with newly implemented technique – save cost and accelerate time-to-market.
How to Shorten Li-Ion Self-Discharge Test Time?

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The Li-ion cell market is experiencing explosive growth as electric vehicles become more pervasive. This trend calls for higher capacity cells with better performance. Optimizing time and cost in the evaluation of cells becomes ever critical. A new test approach can help alleviate the impact on cost and time-to-market of the important, yet time-consuming evaluation of self-discharge performance of cells.

What Is Self-Discharge and Why Is It Important?

Li-ion cells will lose charge over time even when not connected to any load. This process is known as self-discharge. Figure 1 depicts the self-discharge model as a parallel resistance $R_{SD}$ through which the self-discharge current $I_{SD}$ flows. When not connected to any load, the cell discharges through the high-value $R_{SD}$. Over weeks or months, this self-discharge path depletes the stored energy in the cell, causing $V_{CELL}$ to drop.

Some amount of self-discharge is a normal attribute resulting from chemical reactions taking place within the cell. Loss of stored energy however leads to lower-than-desired cell available capacity. And when cells are assembled into multiple-cell battery packs, differing rates of cell self-discharge leads to cell imbalances within the battery.

Self-discharge can also result from leakage current paths existing within the cell. Particulate contaminants and dendrite growths produce internal “micro-shorts”, creating such leakage current paths. These are not normal attributes and they can lead to catastrophic failure of the cell. Cells with high levels of self-discharge are indicative of latent failures.

It is therefore important to measure and evaluate self-discharge in the design and manufacturing of cells. During the design of the cell, it is a top priority to eliminate possible causes of high self-discharge. In manufacturing, it is critical to screen out any cells exhibiting abnormally high self-discharge as early as possible in the process.
The Challenge and Drawback of the Open-Circuit Voltage Method

Conventionally, self-discharge performance is evaluated by measuring the decrease of a cell's open-circuit voltage (OCV) over time. It is relatively easy to measure using a voltmeter or digital multimeter. The challenge lies not in the measurement complexity but the time required to evaluate the self-discharge performance of the cell from the changes in the OCV.

Compared to other types of rechargeable cell chemistries, Li-ion cells have rather low self-discharge. They typically lose about 0.5 to 1% of their charge per month. Since ISD is very small, typically a few to a few hundred microamperes (depending on cell size), the cell's voltage drops very slowly. Because Li-ion cells have very little change in OCV as they discharge, it takes weeks to months to detect a significant loss of a cell's state of charge (SOC), and to discern a good cell from a bad one with high self-discharge.

It is a challenge for designers, users, and manufacturers to quickly measure the self-discharge behavior of their cells using the OCV method. The time spent on any one cell measurement is not very long but a series of these measurements spread over weeks or months, can have a big impact on design cycle time. During this evaluation process, the designers must store and keep track of the cells under temperature-controlled conditions since the cell voltage varies with temperature. This not only constrains the design cycle, but also the time to market. If multiple test cycles are needed with design iterations, the delay is multiplied by the number of test cycles. Delay in first shipment of new designs creates opportunity loss, and potential market-share loss to the competition.

In manufacturing, self-discharge characterization adds considerable work-in-progress (WIP), with complexities and hazards of storing large quantities of cells for extended periods of time. This problem is worse for larger capacity cells. These cells are higher-value inventory, have longer settling times than smaller cells, and present more risk while sitting in inventory.
The Potentiostatic Method

To measure cell self-discharge performance, you would really like to measure the self-discharge current of the cell. Under static conditions, if you could measure this current, it would tell you whether the cell was good or bad much sooner than waiting for the OCV to change. The OCV method which measures the cell’s open-circuit voltage over time, is an indirect and imprecise indicator of what the cell’s self-discharge rate is.

The Potentiostatic method is illustrated in Figure 2. This method evaluates the self-discharge of cells by measuring the self-discharge current $I_{SD}$. The rate of self-discharge is directly measured as current is coulombs per second. In other words, charge loss over time. With this method, cells can be evaluated in a much shorter time as compared to the OCV method. Test time is a few hours or less to determine the self-discharge current. Cells having unacceptably high self-discharge can be discerned from good cells in even less time, typically well under an hour.

With the Potentiostatic method, a low noise, very stable DC source is set to match the cell’s OCV. The DC source is then connected to the cell through a micro-ammeter to measure the current flowing between the DC source and cell. When the cell continues to self-discharge, the DC source takes over, furnishing sufficient current to maintain the cell at a constant voltage and SOC. When the DC source comes to equilibrium with the cell, $I_{SD}$ transitions from being sourced internally to being totally furnished externally from the DC source. $I_{SD}$ can then be directly measured using the micro-ammeter.

Figure 2. Potentiostatic method evaluates a cell’s self-discharge by measuring the $I_{SD}$. 
New Potentiostatic Solutions

Keysight has worked together with cell designers and manufacturers to address the challenges in self-discharge measurement and created two new solutions: BT2191A Self-Discharge Measurement System and BT2152A Self-Discharge Analyzer. Both solutions employ the Potentiostatic technique and provide microvolt-level stability and resolution plus several features for quick and accurate measurement of cell's self-discharge current.

The BT2191A is created with designers in mind and delivers a revolutionary reduction in the time required to measure cell self-discharge current. It directly measures self-discharge current in as little as 1-2 hours instead of monitoring cell open circuit voltage over weeks or months. Besides self-discharge current, cell voltage and temperature are also measured. Engineers can dramatically reduce the design cycle-time, help optimize self-discharge performance and characteristics of battery cells, and achieve decreased time-to-market.

For Li-ion cell manufacturers, the BT2152A offers a new type of analyzer that can measure self-discharge current on up to 32 cells at the same time. Test throughput is greatly boosted besides the significant time reduction gained using the newly implemented technique. More importantly, good versus bad cells can be clearly distinguished in the self-discharge current in typically less than 30 minutes. This helps manufacturers achieve dramatic reductions in WIP inventories, working capital and facility costs. Figure 3 displays self-discharge currents on eight 18650 cylindrical, all logged at the same time. The one cell that stands out of the group with high self-discharge can be observed within minutes.

![Figure 3. Discerning good cells from high self-discharge cells with the BT2152A.](image-url)
Conclusion

It is important that the self-discharge of Li-ion cells is tested. High levels of self-discharge are indicative of latent failures. These cells must be identified and separated from good cells to prevent potentially catastrophic failures, and the underlying cause in either the cell's design or manufacturing process be identified and corrected. The new Potentiostatic solutions from Keysight, enable designers and manufacturers address the cell self-discharge measurement challenges with revolutionary reduction in time, save cost and accelerate time-to-market.

The BT2191A Self-Discharge Measurement System is a single channel system ideally suited for cell design and evaluation work. To learn more, please visit: www.keysight.com/find/bt2191a

The BT2152A Self-Discharge Analyzer provides 32 measurement channels ideally suited for screening out cells having high self-discharge from good ones in manufacturing. To learn more, please visit: www.keysight.com/find/bt2152a