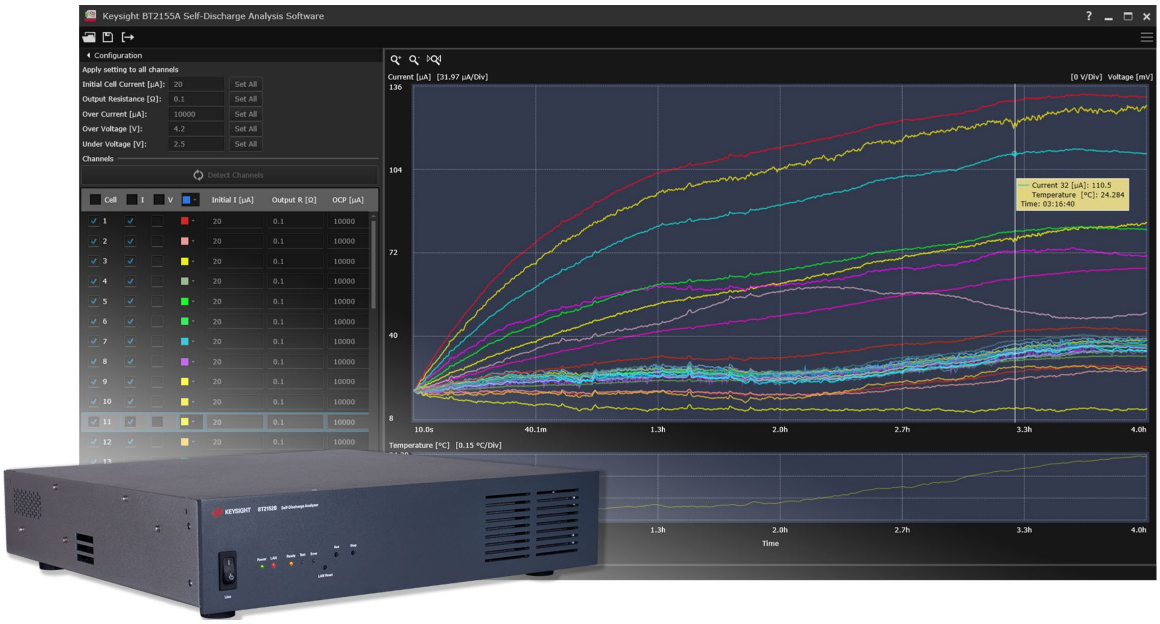
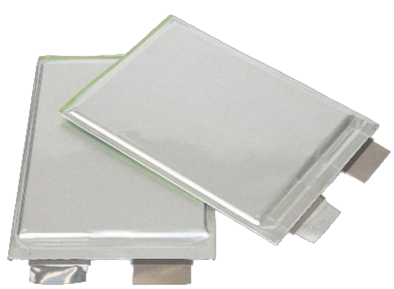
BT2152B Self-Discharge Analyzer
BT2155A Self-Discharge Analysis Software

A New Way of Looking at Li-Ion Cell Self-Discharge

- Revolutionary reduction in the time required to discern good vs. bad cell self-discharge performance in manufacturing
- Gain dramatic reductions in work-in-process, working capital, and facility costs
- Eliminate days or weeks of cell storage time





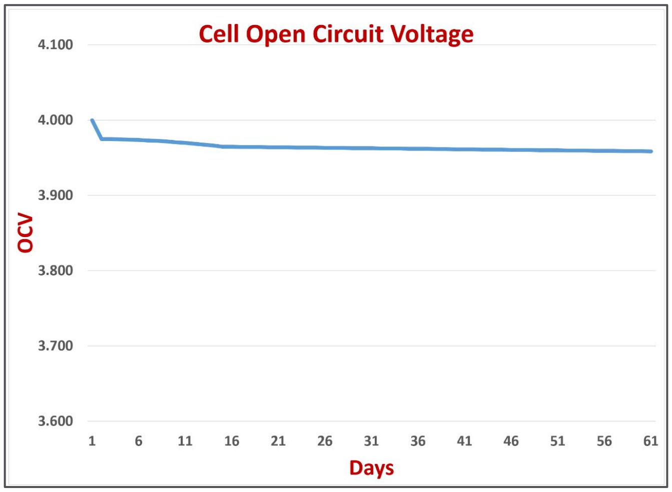
KEYSIGHT TECHNOLOGIES

The Challenge in Evaluating Self-Discharge

- Li-Ion cell market growing fast
- Self-discharge evaluation takes a long time
- Huge impact on manufacturing inventory

The Li-Ion cell market is experiencing explosive growth, and this growth creates stress on cell manufacturing operations, with pressures on process costs, inventories, and deliveries.

It's a challenge for Li-Ion cell manufacturers to quickly discern whether newly formed cells exhibit acceptable self-discharge behavior.



Traditionally, self-discharge isn't a complicated measurement – it's relatively straightforward to measure how the open circuit voltage (OCV) of cells changes over time. The issue is how long it takes for that OCV to change enough to reliably tell whether the self-discharge of your cells is within acceptable limits.

Cell manufacturers keep far greater numbers of cells in work-in-process inventory than they would like because of the time required to measure the change in cell OCV. That negatively impacts work-in-process inventory metrics, and it consumes expensive floor space to hold that inventory in temperature-controlled environments.

What is self-discharge current?

Most Li-Ion cells will gradually discharge even if they're not connected to anything. This loss of stored energy leads to lower-than-desired available capacity from the cell.

When cells are assembled into multiple-cell battery packs, differing rates of cell self-discharge leads to cell imbalances within the battery. Typical battery management systems will discharge all the cells to the level of the lowest cell, decreasing effective battery life.

A simple model of self-discharge in Li-Ion cells is modeled in Figure 1.

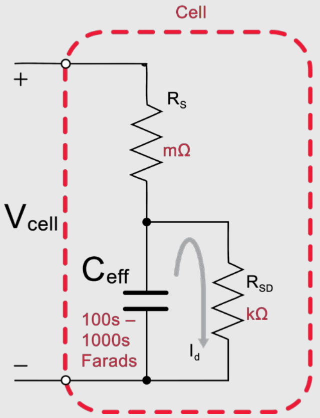


Figure 1: Simplified model of Li-Ion cell self-discharge

- C_{eff} is the effective capacitance of the cell, storing the cell's charge.
- R_S is the cell internal or series resistance. R_S causes the cell voltage to drop as you pull more current from the cell, since $V_{cell} = V_{ocv} – (I * R_S)$.
- R_{SD} is the parallel resistance through which the self-discharge current flows. When nothing is connected to the cell (open circuit), C_{eff} discharges through the high-value R_{SD}, generating tens or hundreds of µA of self-discharge current (I_d). Over weeks or months, this self-discharge path depletes the stored energy in C_{eff}, thus causing V_{cell} to drop.

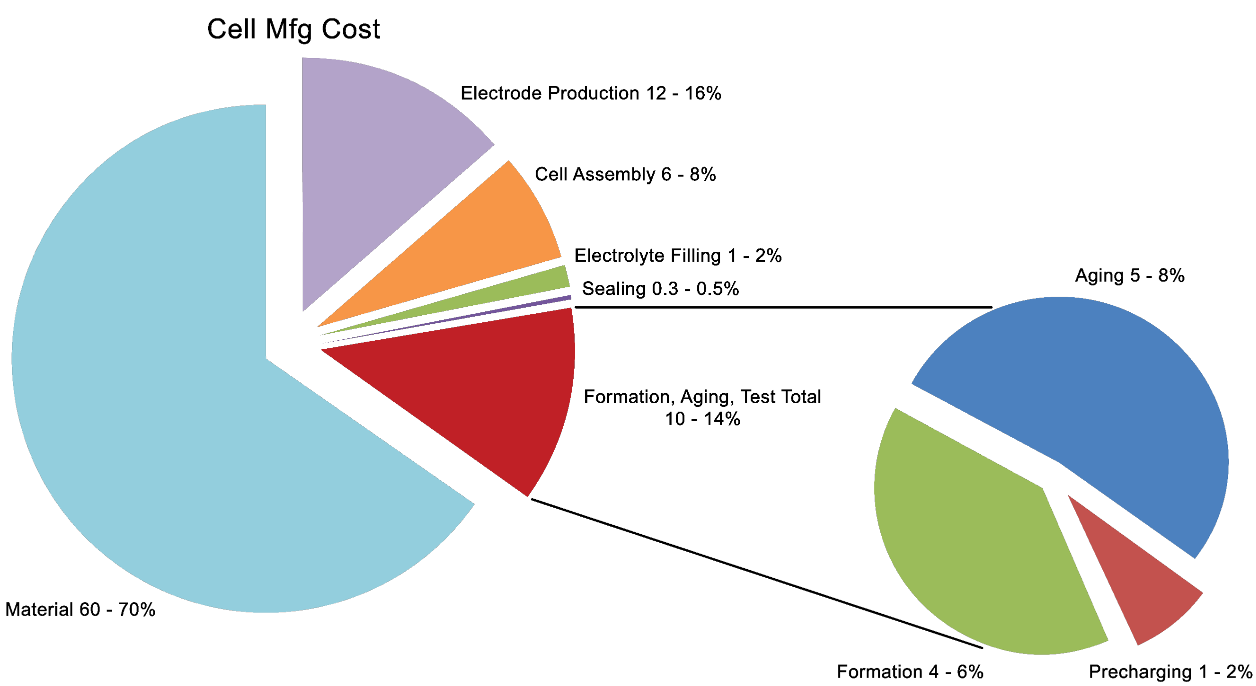
This problem is worse for larger capacity cells, where a lot of the market growth is these days. Those larger-capacity cells are higher-value inventory, and present more risk while sitting in inventory. Larger-capacity cells have longer settling times than smaller cells, which causes longer measurement times.

How Large Is This Financial Issue?

The time required to evaluate self-discharge impacts:

- Manufacturing inventory
- Working capital costs
- Facility cost and usage
- The delay in the feedback loop from test results to manufacturing process adjustments

Cell manufacturers are looking at every opportunity to reduce cell costs. Industry research shows that while materials are over half of the cost of a cell, process costs also represent a significant opportunity for improvement. Research indicates that the formation, aging, and test portion of the manufacturing process typically represents 10 – 14% of cell costs. And the aging process alone is 5 – 8% of the total cost.



What Drives the Aging Time?

Today, most of the total aging time is often caused by the time required to determine if the cells' self-discharge behavior is within acceptable limits. This large time period is driven by how long it takes for the change-in-OCV (ΔOCV) measurement. Reducing the amount of time cells spend in the aging step as work-in-process inventory provides savings that flow directly to the bottom line.

A Better Way to Evaluate Li-Ion Cell Self-Discharge

Precision potentiostatic measurement directly measures self-discharge current

To measure self-discharge performance, you would like to directly measure the self-discharge current of the cell. This would tell you whether the cell was good or bad much sooner than waiting for the cell's open circuit voltage to change enough to reliably indicate good vs. bad behavior.

A high-performance potentiostatic analyzer can hold the cell voltage constant and stable. However, the cell will continue to self-discharge.

In the model in Figure 2, self-discharge current flows through the parallel resistance R_{SD}, which acts to decrease the voltage on the effective capacitance of the cell. But the cell voltage is being held constant by the potentiostatic analyzer, because the analyzer supplies current to the cell equal to the cell's self-discharge current. The analyzer accurately measures the current being supplied.

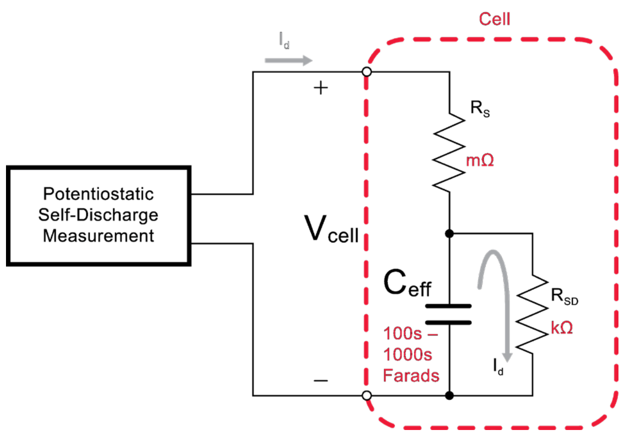


Figure 2: Self-discharge cell model

A New Solution for Self-Discharge Testing

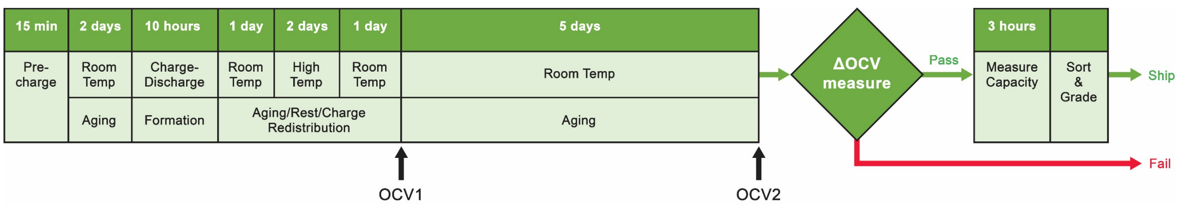
A potentiostatic analyzer capable of making this self-discharge measurement must have these important characteristics:	Keysight's Self-Discharge Analyzer has the characteristics needed for quickly making this type of self-discharge measurement:
Current Measurement	
The analyzer needs to accurately measure low-level self-discharge currents in the range of 10's or 100's of µA.	Accurately measures low-level self-discharge currents with an uncertainty of ± (0.30% + 250 nA)
Voltage Stability	
The analyzer should not disturb the cell. • The voltage applied to the cell by the analyzer must precisely equal the cell voltage. It must quickly match the cell voltage. Otherwise, the cell either charges or discharges, initiating charge-discharge, charge redistribution, and RC settling currents that mask the self-discharge current you're measuring. • The voltage applied to the cell must be very stable. Any instability or noise in the applied voltage causes the cell to continually slightly charge and discharge, causing noise currents on the self-discharge current measurement.	Minimum disturbance of the cell. • The voltage applied to the cell is quickly matched (± 1.25 µV) to the actual cell voltage. This minimizes any new charge or discharge, and thus limits any new RC settling to a minimum. • The voltage applied to the cell is very stable (± 3 µVpk) to minimize continuing charge-discharge and other current noise on the self-discharge current measurement.

Process Improvements and Cost Savings in Self-Discharge Testing

Potential improvements in the aging process and resulting cost savings from directly measuring self-discharge current can be seen by examining two models representing common aging processes in cell manufacturing. With each model, the traditional ΔOCV method is compared to directly measuring self-discharge current for all or some of the cells.

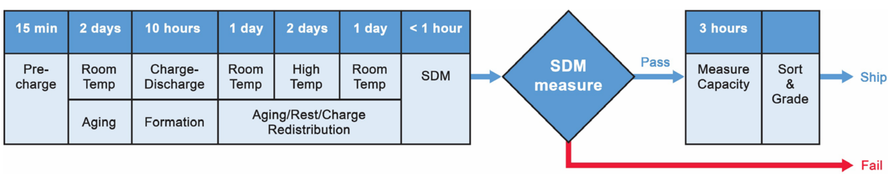
“Straight” Process Model – all cells are evaluated in a common process

Traditional ΔOCV Method



Determining good vs. bad self-discharge performance is based on the ΔOCV over the last 5-day aging period. Two OCV measurements are made, one after the 4-day aging period, and one after the 5-day aging period.

Direct self-discharge current measurement



Aging time per cell reduced by 45%

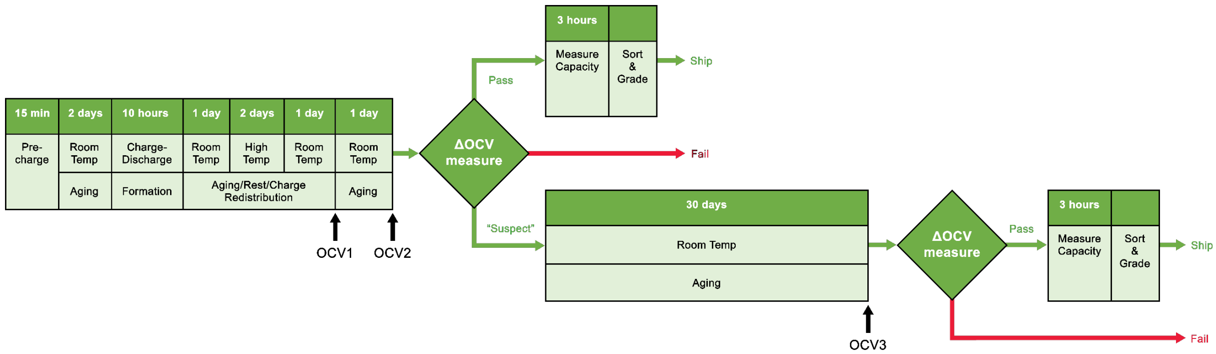
Determining good vs. bad self-discharge performance is based on the direct self-discharge measurement made after the 4-day aging period. This measurement typically takes about 1 hour or less, saving 5 days of aging.

With this process model, using direct self-discharge measurement reduces the aging time per cell by ~45% (5 of 11 total days) for 100% of the cells. This directly impacts Work-in-Process inventory and facilities requirements.

Cost savings models for Working Capital Costs and Facilities Costs comparing the ΔOCV method vs. direct self-discharge measurement (SDM) are shown below. As shown, these models use data representing a process producing 60 Ah cells at a rate of 48,000 cells/day (~16 million cells/year or ~3.6 GWh/year). These models are built using Microsoft Excel and are available for you to download and modify to fit your situation for each type of cell you make at www.keysight.com/find/BT2152B.

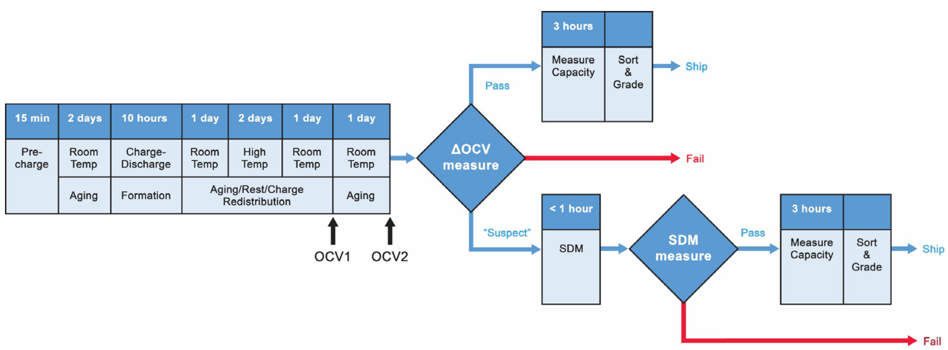
“Suspect Cell” Process Model –cells that are not clearly good or bad are subjected to further aging and evaluation

Traditional ΔOCV Method



Determining good vs. bad self-discharge performance is based on a 2-step process. In the first step, the cells which are clearly good and clearly bad are separated from “suspect” cells by a ΔOCV test done after the 5-day aging period, where ΔOCV = (OCV2 – OCV1). The cells designated as “suspect” are then subjected to a longer aging period followed by a second ΔOCV test, where ΔOCV = (OCV3 – OCV2). Most of the cells require less aging with this process, but the “suspect” portion of the cells requires much longer aging to determine whether they exhibit acceptable self-discharge behavior.

Direct self-discharge current measurement



If “suspect” rate = 10%, cells in aging reduced by 30%

If “suspect” rate = 15%, cells in aging reduced by 39%

Determining good vs. bad self-discharge performance is again based on a 2-step process. The first step uses the same ΔOCV test where ΔOCV = OCV2 – OCV1. The “suspect” cells then have a direct self-discharge measurement. This measurement typically takes about 1 hour or less, eliminating the very long traditional “suspect” aging period, typically lasting 4 weeks or more.

If 10% of total cell production is classified as “suspect”, requiring additional test or aging beyond the first ΔOCV test, using direct self-discharge measurement reduces the total aging time for “suspect” cells by ~81% (7 vs. 37 days). This method provides a 30% reduction in the total number of cells in aging due to elimination of the long “suspect” aging step. This directly impacts Work-in-Process inventory and facilities requirements.

Cost savings models for Working Capital Costs and Facilities Costs comparing the ΔOCV method vs. direct self-discharge measurement (SDM) are shown below. As shown, these models use data representing a process producing 60 Ah cells at a rate of 48,000 cells/day (~16 million cells/year or ~3.6 GWh/year). These models are built using Microsoft Excel and are available for you to download and modify to fit your situation for each type of cell you make at www.keysight.com/find/BT2152B.

Cost Saving Models for Working Capital and Facilities Costs

The savings from reducing the time that cells are kept in the aging process will depend on many things, including:

- The types of cells manufactured
- Cell defect rates & “suspect” rates
- Cell aging periods (at both room and elevated temperatures) required to discern good vs. bad cells
- Cell manufacturing volumes
- Cell manufacturing cost
- The target rate of return on working capital
- Floor space consumed by cell work-in-process inventory (aging areas)
- The cost of floor space

Estimating the actual cost savings from more quickly evaluating self-discharge performance has many aspects, such as:

- Reduced working capital costs for work-in-process
- Reduced facility costs (cost of space, cost of temperature control of that space)
- Reduced defects and scrap from being able to detect process deviations more quickly than waiting the traditional time required for open-circuit voltage measurements.

A simple model can compare estimated working capital and facilities cost savings resulting from reducing aging time by direct self-discharge current measurement. This allows you to rapidly discern good vs. bad self-discharge performance of cells.

This is shown below for both the “Straight” Process and the “Suspect Cell” Process. The comparisons estimate the cost savings resulting from reduced aging periods by using direct self-discharge current measurement vs. the traditional ΔOCV method.

These examples use data representing a process producing 60 Ah cells at a rate of 48,000 cells/day (~16 million cells/year or ~3.6 GWh/year). These models are built using Microsoft Excel and are available at www.keysight.com/find/BT2152B for you to download and modify to fit your situation for each type of cell you make. The assumed values used in the model are shown below.

"Straight" Process Model

Cost model assumptions	Traditional ΔOCV Method	Direct SDM
Cell volume (Cells/day)	48,000	48,000
Cell volume (cells/yr)	16,224,000	16,224,000
% cells tested (ΔOCV or SDM)	100%	100%
Total aging period (days)	11	6
Number of working days/yr	338	338
Average mfg cost ($/cell)	$30.00	$30.00
Target rate of return on capital	8%	8%
Number of cells per tray	25	25
Average net area per stack of trays (sq m)	2	2
Number of trays per stack	10	10
Cost of facility space ($/square m)	$10	$10
Tester Utilization Rate	95%	95%

"Suspect Cell" Process Model

Cost model assumptions	Traditional ΔOCV Method	Direct SDM
Cell volume (Cells/day)	48,000	48,000
Cell volume (cells/yr)	16,224,000	16,224,000
% cells tested in first ΔOCV test	100%	100%
Total aging period before first test (days)	6	6
Suspect rate	10%	10%
Total aging period before second test (days)	30	0
Number of working days/yr	338	338
Average mfg cost ($/cell)	$30.00	$30.00
Target rate of return on capital	8%	8%
Number of cells per tray	25	25
Average net area per stack of trays (sq m)	2	2
Number of trays per stack	10	10
Cost of facility space ($/square m)	$10	$10
Tester Utilization Rate	95%	95%

The estimated annual cost savings of working capital and facilities are as follows:

"Straight" Process Model

WIP Working Capital Cost Comparison	Traditional ΔOCV Method	Direct SDM
Working Capital Cost = (Value of WIP in aging period)*(Rate of return on capital)		
WIP Working Capital Cost/year =	**$1,333,895**	**$727,579**
WIP Working Capital Cost/year savings		**$606,316**

"Suspect Cell" Process Model

WIP Working Capital Cost Comparison	Traditional ΔOCV Method	Direct SDM
Working Capital Cost = (Value of WIP in aging period)*(Rate of return on capital)		
WIP Working Capital Cost/year =	**$1,091,368**	**$727,579**
WIP Working Capital Cost/year savings		**$363,789**

Warehouse/Facility Cost Comparison	Traditional ΔOCV Method	Direct SDM
Warehouse/Facility Cost = Cost of facility space consumed by cells in aging period		
Warehouse/Facility Costs/year =	**$44,463**	**$24,253**
Warehouse/Facility Costs/year savings		**$20,211**

Warehouse/Facility Cost Comparison	Traditional ΔOCV Method	Direct SDM
Warehouse/Facility Cost = Cost of facility space consumed by cells in aging period		
Warehouse/Facility Costs/year =	**$36,379**	**$24,253**
Warehouse/Facility Costs/year savings		**$12,126**

As you can see, there can be very significant working capital and facilities costs savings resulting from being able to reduce the time needed to discern good vs. bad self-discharge performance of cells. And these estimated costs are only part of the cost savings to be realized. Additional gains include:

- Reduced HVAC costs associated with reduced floor space required for aging and storage.
- Getting test results for self-discharge much more quickly creates a dramatic reduction in the time to detect manufacturing process variations from the time when those variations started. That allows you to make process corrections earlier, potentially saving significant cell scrap since you have less WIP.

Every cell manufacturer is trying to capture as much of the rapid growth of the Li-Ion cell market as possible. That places a lot of pressure on manufacturing operations to reduce their total cost envelope, and to shorten delivery times. Every manufacturer is looking to make breakthrough reductions in process costs and to reduce delivery times.

The time required to realize a payback on the investment in direct self-discharge measurement will depend on many factors that depend on the specifics of each installation. Considering that both the ΔOCV and SDM methods have roughly similar costs for fixturing, material handling, and software, the primary investment cost difference between the two methods is in the cost of the measuring equipment (precision DMM + multiplexers vs. self-discharge analyzers).

The investment cost of self-discharge analyzers, combined with achievable SDM test execution times, indicates that the payback for SDM can be within 2 years, but will be highly dependent on the specifics of your process and installation. Keysight is ready to work with you on how self-discharge measurement can improve your cell manufacturing process.

You can download a copy of the worksheet used to model these costs at www.keysight.com/find/BT2152B and insert your own data to estimate your cost situation.

Keysight BT2152B Self-Discharge Analyzer

- Quickly & accurately measure self-discharge current
- Measure self-discharge current value in 1-2 hours
- Discern good vs. bad cells in < 30 minutes

The BT2152B Self-Discharge Analyzer quickly and accurately measures cell self-discharge current on up to 32 cells. Keysight's patent-pending implementation of the measurement technique delivers a revolutionary reduction in the time required to discern good vs. bad self-discharge performance.

Testing indicates that for smaller cells like cylindrical 18650 or 21700 cells, the BT2152B can measure the self-discharge current in as little as 1 hour or less. And for larger capacity pouch cells (e.g., 10-60 Ah), the BT2152B can do this is in as little as 1-2 hours or less. That measurement time is much less than the days or weeks required to reliably detect enough change in the cell's open circuit voltage.

And of greater impact in cell manufacturing, the analyzer's measurements allow you to see a clear difference in the self-discharge current of good vs. bad cells in typically less than 30 minutes.

Figure 3 shows an example 1-hour test of 32 2.5 Ah 18650 cells. High-discharge rates on 8 of the cells were simulated by connecting various resistors (60 - 178 kΩ) around the cells, to create higher-discharge paths.

You can clearly see which current measurement traces belong to the high- and medium-discharge cells. The current measurement traces of the good cells are bunched together at about 20 µA. The difference between the good cells and the bad cells is clear within 20 minutes. A self-discharge measurement that fast will have a clear impact on cell aging times.

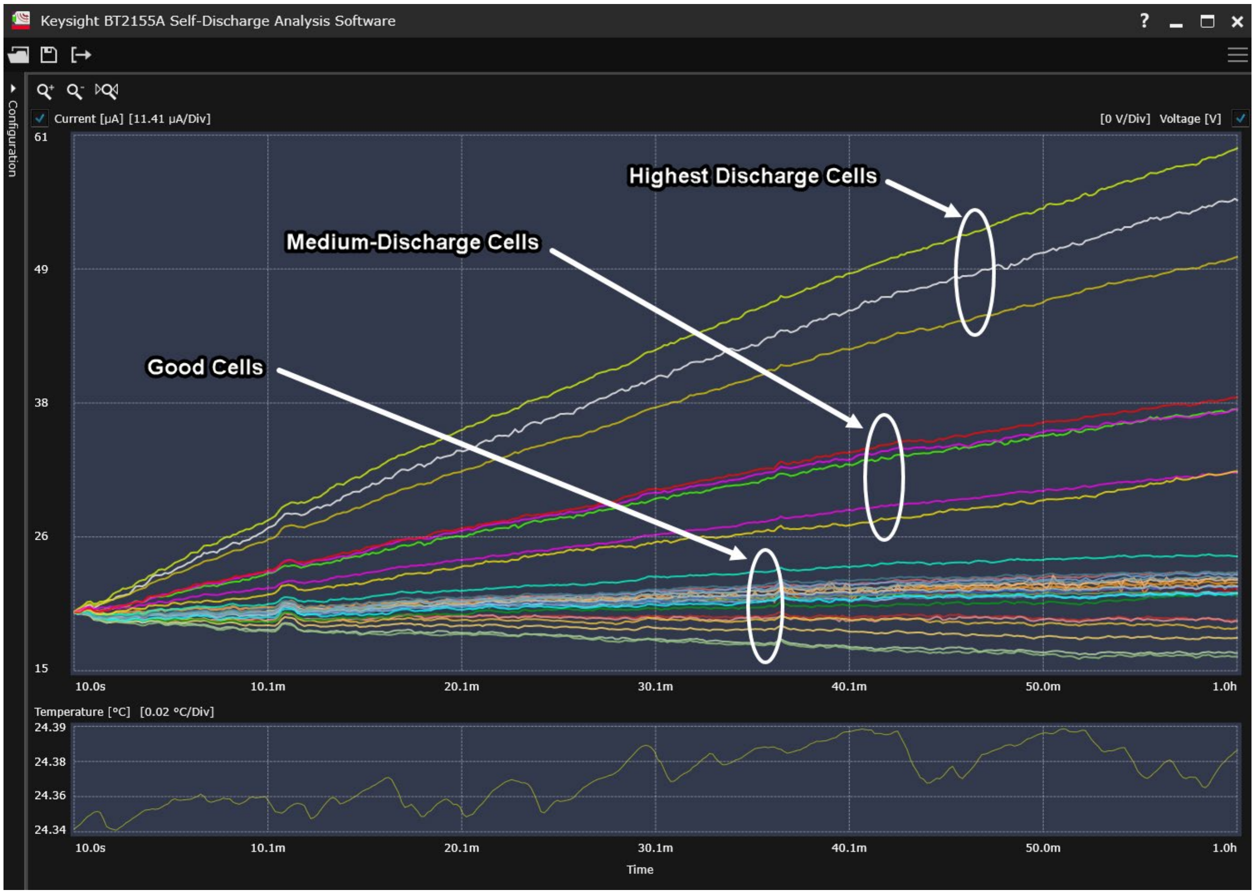


Figure 3: Self-discharge current test on 32 18650 cells. Eight cells had resistors (60 - 178 kΩ) in parallel to simulate high-discharge cells.

Built-in Noise Reduction Algorithms

For many cell measurements, the self-discharge measurement data can include significant noise, which complicates separating good vs. bad cells. This noise can also increase the amount of measurement time needed to reliably achieve the desired results. The BT2152B has built-in noise reduction algorithms based on median subtraction and median fitting methods. These methods can effectively remove most of this noise, and improve the reliability of good vs. bad cell classification.

To learn more about these noise removal capabilities, please refer to the Application Note *Removing Noise in Lithium-Ion Battery Cell Self-Discharge Data Sets* (5992-3979EN),

BT2155A Self-Discharge Analysis Software

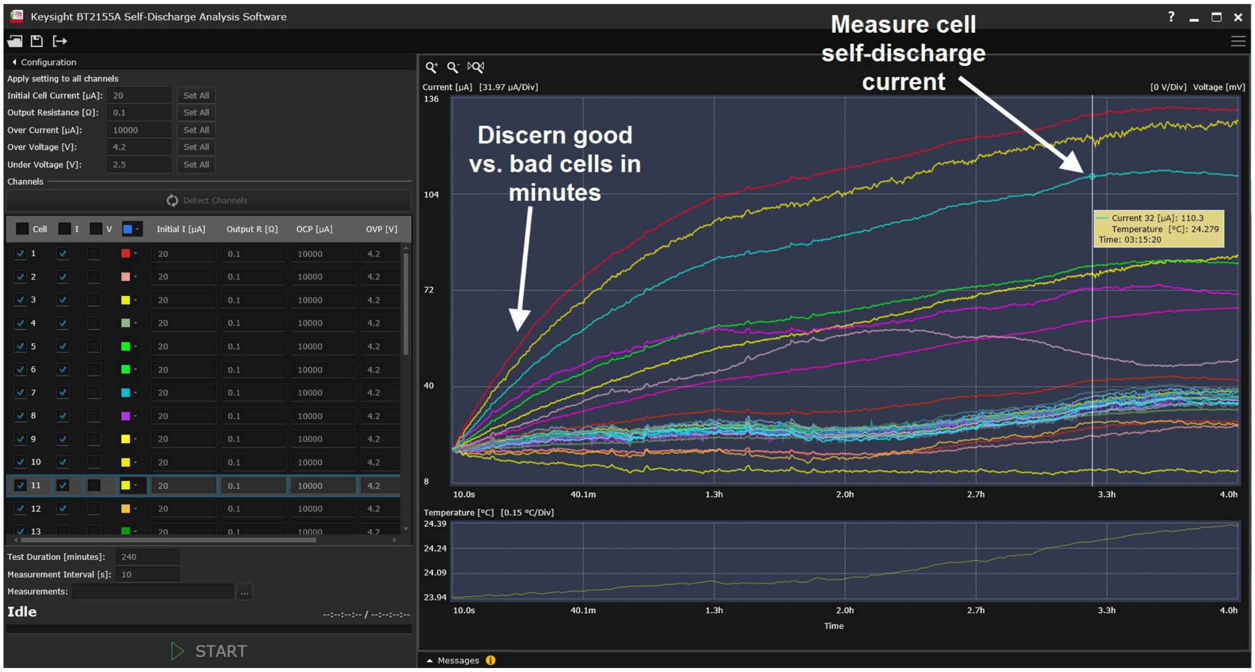


Figure 4: Results from 4-hour test of 18650 cells

- Measures and records cell self-discharge current & voltage using the BT2152B Self-Discharge Analyzer
- Controls the analyzer's channel configurations, measurement settings, test duration.
- Logs measurement data on all channels (current & voltage), and temperature on one group of up to 32 cells.
- Saves & loads measurements (test data and setup information) for display and analysis. Exports recorded test data to csv file.
- Matching function for initial cell voltage & current adjusts values for faster self-discharge measurement.
- Allows the user to adjust the effective total resistance value in series with the cell. This allows the user to select a total resistance value to optimize the RC settling time of the measurement.

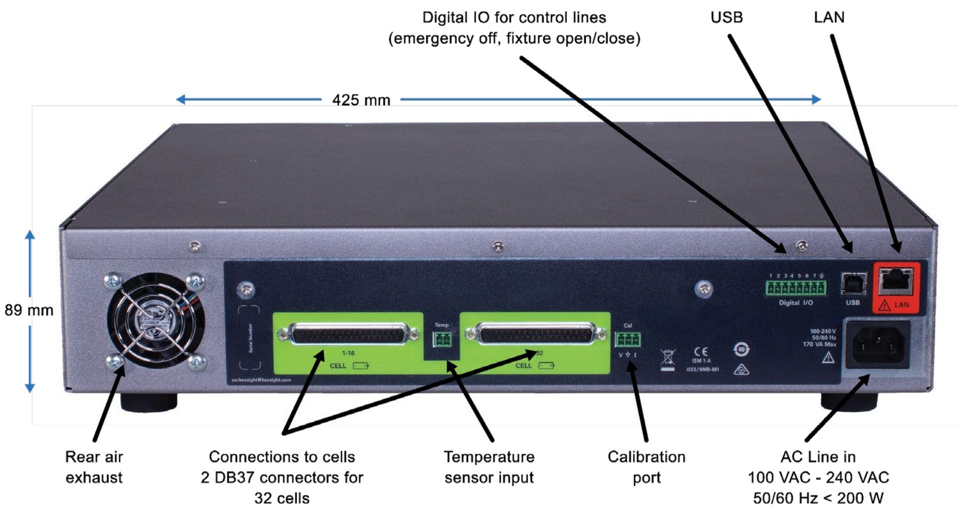
The BT2155A Self-Discharge Analysis Software provides easy control and analysis for measuring the self-discharge of a group of up to 32 cells in research, design, and evaluation applications. A free 90-day evaluation license is available to allow you to evaluate this self-discharge measurement method with your own cells.

The Keysight BT2155A Self-Discharge Analysis Software controls one BT2152B Self-Discharge Analyzer, measuring and recording up to 32 channels of Li-Ion cell self-discharge current and cell voltage. The software configures the analyzer's channel settings, such as initial voltage & current matching, channel limits (OVP, OCP, UVP), measurement intervals, and test duration. One temperature on a group of up to 32 cells is recorded vs. time with a thermistor. You can measure the initial OCV of each cell before the self-discharge test starts and select the delay time from the OCV measurement until the self-discharge measurements begin.

The software allows the user to adjust the effective total resistance of the measurement circuit in series with the cell. This allows the user to select a total resistance value to optimize the RC settling time of the measurement and the test time. The BT2155A supports precise control of that resistance value by calibrating the resistance of the wiring connections to the cells. This can be done either with a fast in situ calibration done with the cells-under-test connected to the analyzer, or by replacing the cells with calibration shorts.

Keysight BT2152B Self-Discharge Analyzer Details

Rear Panel



Connections to Cells or Fixturing

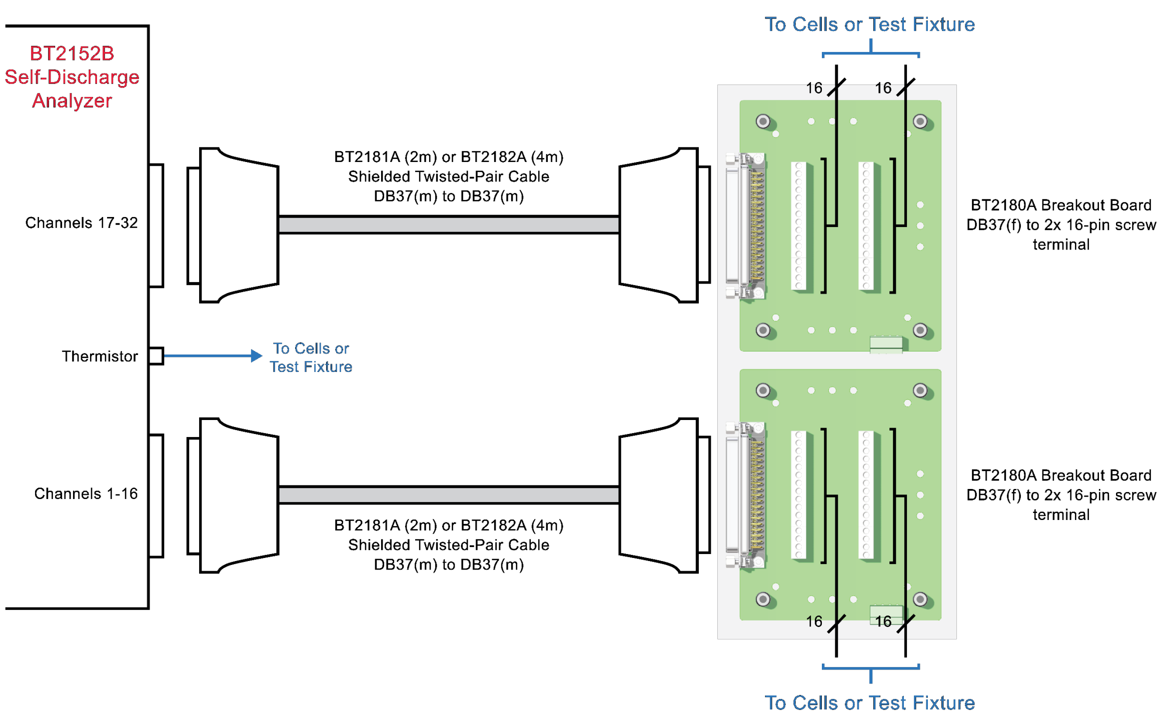


Figure 5: Typical connection to cells-under-test using shielded twisted-pair DB37 cables and breakout boards

For best measurement results, the cables that connect the BT2152B Self-Discharge Analyzer to the cells should have the following characteristics, which are found in the BT2181A and BT2182A cables.

- Use twisted pairs of wires for each channel for as much of the distance from analyzer to cell as possible.
- The bundle of the twisted pairs should be shielded, with a separate braided shield around the bundle.
- The braid should be connected to the DB37 connector housings, which are made of conductive metal.
- The DB37(m) connectors should have machined (not stamped) pins. The resistance of stamped pins is higher and has more variation than for machined pins, which can affect measurement performance.

The BT2180A Breakout Board provides two 16-pin screw-terminal connectors to support twisted-pair wiring to the cells. The board has feet to use on a table and 4 mounting holes for standoffs and/or to attach the board inside test fixtures or cabinets.

Keysight BT2152B Self-Discharge Analyzer Specifications

Number of channels	4 to 32 in 4-channel increments
Voltage range	+ 0.5 V to + 4.5V
Current measurement range	± 10 mA
Current measurement accuracy[1]	± (0.30% + 250 nA)
Voltage measurement accuracy[1]	± (0.04% + 0.1 mV)

Supplemental Characteristics

Voltage sourcing stability[2]	± 3 µV peak (measured over 24 hours at 1-minute integration) ± 0.85 µV peak (measured over 1-minute)
Initial cell voltage matching accuracy	± 1.25 µV typical
Initial cell current programming accuracy	± (0.3% + 250 nA) typical
Voltage/current measurement interval	1.0 s to 256 s in 1 second increments
Maximum number of readings	259200 per channel. One reading = one current and one voltage measurement
Max test duration (= measurement interval * max number of readings)	72 hours at 1 s measurement interval 750 days at 250 s measurement interval
Warm-up time after power-on	1 hour
Output leakage current when off [3]	≤ 1 µA
Required DUT isolation across channels [4]	≥ 10 MΩ
Minimum supported cell effective C	100 F
Minimum supported product of cell effective capacitance and cell effective series R	50 s

[1] Measurement accuracy specification applies after a 15 second settling delay and when using a minimum integration period of 1 minute
[2] As measured at output terminals.
[3] Assumes differential voltage across output terminals of no greater than ± 5 V
[4] Isolation of DUTs connected on different channels is required. Isolation is measured from either terminal of the DUT to earth or to either terminal of any other DUT to be connected to different channels of the same instrument.

Programmable Resistance	
Programmable resistance range	50 mΩ to 10 Ω • Performing an in situ wiring resistance calibration immediately before the self-discharge measurement is recommended for output resistance settings ≤ 100 mΩ.
Total programmable resistance accuracy. *Includes uncertainty of BT2152B programmable resistance function and uncertainty of wiring resistance calibration function.*	± (25 mΩ + 1.5mΩ/Ω of wiring resistance) • Applies to by-short, in situ HIGH current, and in situ MEDIUM current. For in situ LOW current, add ± 5 mΩ • By-short method has additional error term (not included) due to changes in contact resistance when replacing shorts with cells. • In situ calibration method provides results that include the cell's equivalent series resistance. This is not included in the By Short calibration method.

External Temperature Measurement	
Thermistor requirements	Negative Temperature coefficient (NTC) 10 kΩ Nominal Resistance at 25°C. Programable Beta value (4073 default).
Temperature measurement range	5°C to 100°C
Temperature measurement uncertainty	± 1.5°C
Maximum total lead resistance allowed	10 Ω

Environmental conditions	
Operating environment	Indoor use. installation category II (for AC input), pollution degree 2
Ambient temperature range	20°C to 30°C. Max rate-of-change (dT/dt) must be < 5 °C/hour.
Relative humidity	Up to 95% (non-condensing)
Altitude	Up to 2000 meters
Storage temperature:	–30°C to 70°C
Dimensions (H x W x D)	88.98 mm (3.50 in) x 425 mm (16.73 in) x 400 mm (15.75 in)
Weight	10.2 kg (22.5 lbs.)
AC input Nominal rating Input voltage range Power consumption	 100–120, 200–240 VAC 50/60 Hz ± 10% of nominal ratings < 200 W

Regulatory compliance	
EMC	Complies with European EMC Directive for test & measurement products Complies with Australian standard and carries C-Tick mark This ISM device complies with Canadian ICES-001 Cet appareil ISM est conforme à la norme NMB-001 du Canada
Safety	Complies with European Low Voltage Directive and carries the CE-marking. Conforms to US and Canadian safety regulations.
Declarations of Conformity for this product may be downloaded from http://regulations.corporate.keysight.com and clicking on "Declarations of Conformity."	

BT2152B & BT2155A Ordering Information

BT2152B Self-Discharge Analyzer: **Must choose one and only one channel option**

Product/Option	Description
BT2152B-004	4 Channels
BT2152B-008	8 Channels
BT2152B-012	12 Channels
BT2152B-016	16 Channels
BT2152B-020	20 Channels
BT2152B-024	24 Channels
BT2152B-028	28 Channels
BT2152B-032	32 Channels

Accessories for BT2152B Self-Discharge Analyzer

Product	Description
BT2180A	Breakout Board, DB37(f) to Screw-Terminals. For 16 measurement channels. One DB37(f) connector to connect to 16 channels of BT2152B. The DB37(f) connects on the board to two 16-pin screw terminal connectors (one for + terminal of all channels and one for – terminal of all channels). The screw terminal connectors support twisted-pair wiring (16-30 AWG) to the cells-under-test or to fixturing for the cells. Boards have feet to use on a table and 4 mounting holes for standoffs and/or to attach the board inside test fixtures or cabinets.
BT2181A	Cable, 2m, DB37(m) to DB37(m) for BT2152B.
BT2182A	Cable, 4m, DB37(m) to DB37(m) for BT2152B
	BT2181A and BT2182A are for 16 measurement channels; connects to DB37(f) on BT2152B rear panel. Cable has 18 pairs of twisted wires with shield and braided shield around bundle of twisted pairs; only 16 pairs are used for current measurement with BT2152B. Braid is connected to connector housing on both ends of cable. Connector pins are machined.
BT2183A	Verification Fixture for BT2152B. Fixture has two DB37(m) connectors mounted on a PC board that connect to both BT2152B rear panel connectors. All 32 measurement channels are connected to a pair of banana terminals for a DMM used for verification test of BT2152B.
BT2184A	BT2152B Rack Mount Kit without handles
E3663AC	Basic Rail Kit (rails are required to rack mount a BT2152B)

BT2155A Self-Discharge Analysis Software: **Must choose one and only one license option**

Product/Option	Description
BT2155A-1FP	Fixed Node-locked perpetual license Self-Discharge Analysis Software
BT2155A-1FY	Fixed Node-locked 12-month license Self-Discharge Analysis Software
BT2155A-1NP	Network Floating perpetual license Self-Discharge Analysis Software
BT2155A-1NY	Network Floating 12-month license Self-Discharge Analysis Software
BT2155A-1TP	Transportable perpetual license Self-Discharge Analysis Software
BT2155A-1TY	Transportable 12-month license Self-Discharge Analysis Software

For more information on Li-Ion cell self-discharge and Keysight's Self-Discharge Measurement Solutions

Information on the web:

Self-Discharge Measurement Solutions

BT2152B Self-Discharge Analyzer

BT2155A Self-Discharge Analysis Software

Application Notes:

Measure Lithium-Ion Self-Discharge of Cells in a Fraction of the Time Traditionally Required (5992-2517EN)

Removing Noise in Lithium-Ion Battery Cell Self-Discharge Data Sets (5992-3979EN)

Matching Response Times of Lithium Ion Cell Self Discharge Current Measurements (5992-4155EN)

Learn more at: www.keysight.com

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