WHITE PAPER

Measuring IoT Battery Life with Test Software and Hardware

Battery Life Is a Critical Aspect of IoT Infrastructure and Consumer Electronic Devices

Battery life can contribute significantly to the cost and reliability of Internet of Things (IoT) infrastructure. Smart agriculture and industrial sensors, for example, often are expected to operate for 10+ years between charges.

Costs associated with monitoring and replacing failed batteries can be considerable. Statista estimates there are 10 billion active IoT devices worldwide in 2021, and a substantial percentage of them are battery-operated. The cost of replacing all those batteries, including labor, new batteries, and disposal of the old batteries, is significant. Also, expenses can soar because of infrastructure downtime caused by failed batteries. In the healthcare market, the cost is not just financial; it can be a matter of life and death.

For consumer electronic devices, battery life is a critical purchase consideration. For example, battery life is a key differentiator for smartwatch makers, with one manufacturer claiming its battery lasts ten days between charges. Poorly performing batteries can lead to low sales or a product completely failing in the market. Therefore, manufacturers must maximize battery life, and the battery life that companies advertise must match customers' experiences.

Battery life contributes to the cost and reliability of IoT-based infrastructure, including 5G, IoT connected factories, IoT security, smart farming, and connected healthcare systems, and more. Battery life can also be a key purchasing factor for consumer electronic IoT devices.

Another consideration is that while batteries are cheap, replacing them is not. Consumers can get sticker shock when they learn that replacing a battery can cost more than the entire IoT device.

For IoT-based infrastructure and consumer electronic IoT devices, designers must understand power consumption patterns and whether devices meet battery life requirements. In this white paper, learn how to overcome this challenge by gaining critical insights into battery run-down to predict battery life accurately.

This white paper looks at the following topics:

- Considerations for Run-Down Testing Using a Battery
- Value of Using a Battery Emulator vs. a Power Supply
- How to Accurately Measure Battery Run Down
- Software and Hardware Solution for Run-Down Testing Using a Battery
- Software and Hardware Solution for Run-Down Testing Using a Battery Emulator

Considerations for Run-Down Test Using a Battery

A battery run-down test measures the length of time a device can operate from a full battery charge. Getting this measurement is easier said than done, as design engineers must consider many aspects of this test.

Here are four considerations for battery run-down testing:

CONSIDERATION 1	**CONSIDERATION 2**	**CONSIDERATION 3**	**CONSIDERATION 4**
Inconsistencies in battery life	Battery's charging condition	Different use cases	Determine when the IoT device stops working or the battery fully discharges
Inconsistencies in battery life are common, even from a single manufacturer, because the batteries may come from different manufacturing batches or factories.	Use a new, fully charged battery when performing the test. Old or partially charged batteries will have lower run time.	Different operating modes of the IoT device operate at different current levels.	Devices may not have an LED that indicates a low battery charge.
RECOMMENDATION	**RECOMMENDATION**	**RECOMMENDATION**	**RECOMMENDATION**
Perform the run-down test with batteries bought at different times.	A test operator should fully charge the battery and use a cycler to condition it by cycling it from fully discharged to fully charged.	Keep the use case and its test parameters constant.	Measure the battery voltage at the low voltage threshold and use that measurement to indicate when the device stops working.

Value of Using a Battery Emulator vs. a Power Supply

Some design engineers use a basic power supply to emulate a battery for run-down testing. This method is not accurate unless the engineer uses a specialized power supply equipped with battery emulation software. This battery emulator must be able to model its output according to a battery profile. A standard power supply does not perform like a battery.

Battery emulators use specialized features such as a programmable output resistance and fast transient response to model the behavior of a real battery. A battery emulator will program its output according to a model created from a real battery. The typical parameters in the model are state of charge (SoC), open-circuit voltage (Voc), and series resistance (Ri). By following a relationship between these parameters, a battery emulator will adjust its output in real time to model the behavior of a real battery.

How to Accurately Measure Battery Run Down

Device design engineers need fast visual insights into voltage and current during the run-down test. Graphing these values versus time gives a clear picture of battery run down.

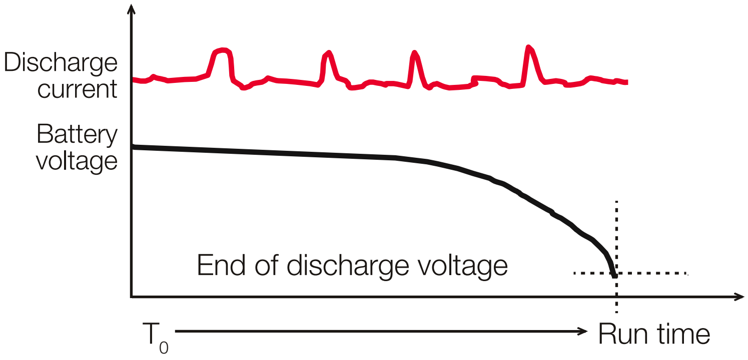


Figure 1. Battery run-down test results

To measure the voltage and current flowing through the battery and the IoT device, testers usually need the following:

- two digital multimeters (DMMs)
- two-channel data logger or two-channel digitizer
- oscilloscope

Battery voltage measurement is less critical than current measurement. A normal DMM or data logger can capture a decaying voltage waveform. However, current measurement requires a fast digitizer, as each IoT device transitions quickly among sleep mode, standby mode, active mode, and wireless data transmission mode.

An IoT device can draw up to hundreds of milliamperes in the active mode but will only draw microamperes or even hundreds of nanoamperes during the sleep mode. High current spikes and transient effects occur when a user turns a device on and off frequently. A DMM cannot capture the rapidly changing current waveform. Additionally, a DMM in ammeter mode has a burden voltage, as there is a calibrated current shunt inside the DMM. This reduces the voltage at the DUT and burdens the overall circuit up to hundreds of millivolts.

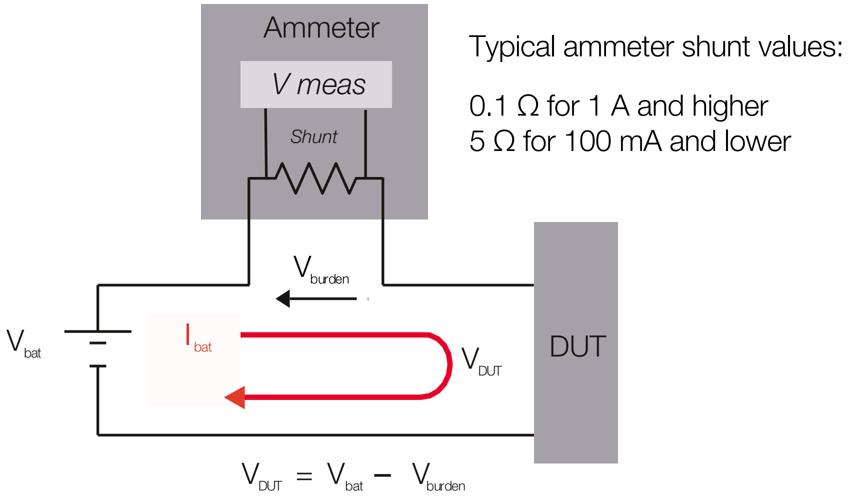


Figure 2. DMM presents burden voltage when measuring current

For example, on a 100-mA measurement range, 50 mA of battery current yields a burden voltage of 250 mV. Therefore, a 4.2-V battery yields just 3.95 V at the device under test.

Digitizers offer a better choice when measuring rapidly changing waveforms for an extended period as they have enough bandwidth to capture any rapid changes in the waveform. However, a current shunt is needed as digitizers do not directly measure current.

Selecting the right shunt for a wide dynamic current measurement that switches from microamperes to amperes is essential. If the selected shunt size is for measuring low current, there will be a large voltage drop across the shunt, creating burden voltage on the circuit. If the selected shunt size is for measuring high current, there will be inaccuracy in the low current measurement as there may not be sufficient voltage to pass through the digitizer. Therefore, a design engineer must compromise between burden voltage and low current inaccuracy when selecting the current shunt size.

The oscilloscope is the best choice for displaying both the current and voltage measurements of the waveform, as it has good bandwidth for dynamic current measurement and an excellent update rate. In addition to that, oscilloscopes have good time correlation with the digital bus and various triggering capabilities to capture the signal accurately.

As with digitizers, oscilloscopes require the correct current shunt to ensure a good low-current measurement and tolerable burden voltage at a high-current measurement. Oscilloscopes also can be used with high-sensitivity current probes as low as 50 µA and have a maximum current range of 5 A. This allows oscilloscopes to display both the large signals and details on fast and wide waveforms. The limitation of this solution is that it cannot perform long-term measurements.

Software and Hardware Solution for Run-Down Testing Using a Battery

Keysight Technologies offers the N6781A and N6785A battery drain analyzers and turnkey software for performing run-down tests for battery-powered IoT devices requiring up to 3 A (N6781A) or 8 A (N6785A) of current. These modules are two-quadrant source and measure units (SMUs) that plug into the N6705C DC power analyzer mainframe.

Users can configure the N6781A and N6785A as zero-burden ammeters, meaning there is a zero voltage drop across the instrument as it measures the current flow between the battery and the IoT device. Both modules also offer a unique feature called seamless ranging. This capability allows instant and automatic range change and measures currents from microamperes to amperes at a speed of 100,000 samples per second without losing any data during the range change. The seamless ranging feature makes it ideally suited for measuring dynamic currents during run-down tests. Furthermore, it can simultaneously measure the voltage across the battery.

With the Keysight BV9200B / BV9201B PathWave BenchVue Advanced Power Control and Analysis software, a user can quickly set up a battery run-down test. The run-down measurements can be captured and plotted without coding any software.

Stopped

Horizontal: 2 s /

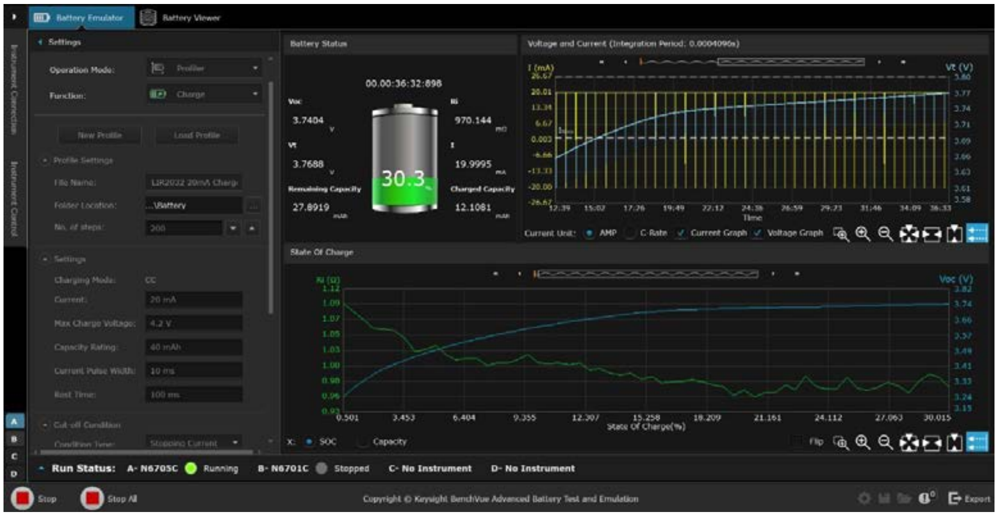
	Marker 1	Measurements Between Markers						Marker 2
Time	1.499136 s	Δ = 14.765261 s						16.264397 s
	Avg	Min	Avg	Max	Peak to Peak	Charge / Energy	Charge / Energy	Avg
A-V1	19.863586426 V	3.432981491 V	16.630449035 V	19.957895279 V	16.524913788 V	---	---	7.392371178 V
A-I1	661.963344 mA	202.647895 mA	545.848302 mA	1.021880865 A	819.23297 mA	2.238838 mA h	8.059816121 C	951.767266 mA
A-V3	20.000156403 V	3.655757427 V	16.742641612 V	20.035037994 V	16.379280567 V	---	---	8.329306602 V

	Output 1		Output 2		Output 3		Output 4	Formula (A)	
A	V1 10 V /	-10.234 V	V2 1 V /	0 V	V3 10 V /	20.326 V	No Module	F1 1 V /	0 V
B	I1 500 mA /	9.498 mA	I2 1 A /	0 A	I3 500 mA /	1.499 A		F2 1 V /	0 V
C	P1 1 W /	0 W	P2 1 W /	0 W	P3 1 W /	0 W		F3 1 V /	0 V

Figure 3. Keysight PathWave BenchVue Advanced Power Control and Analysis software

Software and Hardware Solution for Run-Down Testing Using a Battery Emulator

A secondary approach uses the Keysight BV9210B PathWave BenchVue Advanced Battery Test and Emulation application software. This software, along with the N6705C DC power analyzer and the N6781A and N6785A SMU modules, offers a solution that profiles and emulates a battery. The design engineer can connect a battery of any chemistry to the module, and the software will create a battery model of up to 200 points consisting of the Voc, Ri, and SoC. The software can create the model by charging or discharging a battery.


Operation Mode: Profiler
Function: Charge

Profile Settings
File Name: LIR2032 20mA Charg
Folder Location: ...\Battery
No. of steps: 200

Settings
Charging Mode: CC
Current: 20 mA
Max Charge Voltage: 4.2 V
Capacity Rating: 40 mAh
Current Pulse Width: 10 ms
Rest Time: 100 ms

Cut-off Condition
Condition Type: Stopping Current

Battery Status
00.00:36:32:898
Voc: 3.7404 V
Ri: 970.144 mΩ
Vt: 3.7688 V
I: 19.9995 mA
Remaining Capacity: 27.8919 mAh
Charged Capacity: 12.1081 mAh
30.3 %

Voltage and Current (Integration Period: 0.0004096s)
Current Unit: ● AMP ○ C-Rate ☑ Current Graph ☑ Voltage Graph

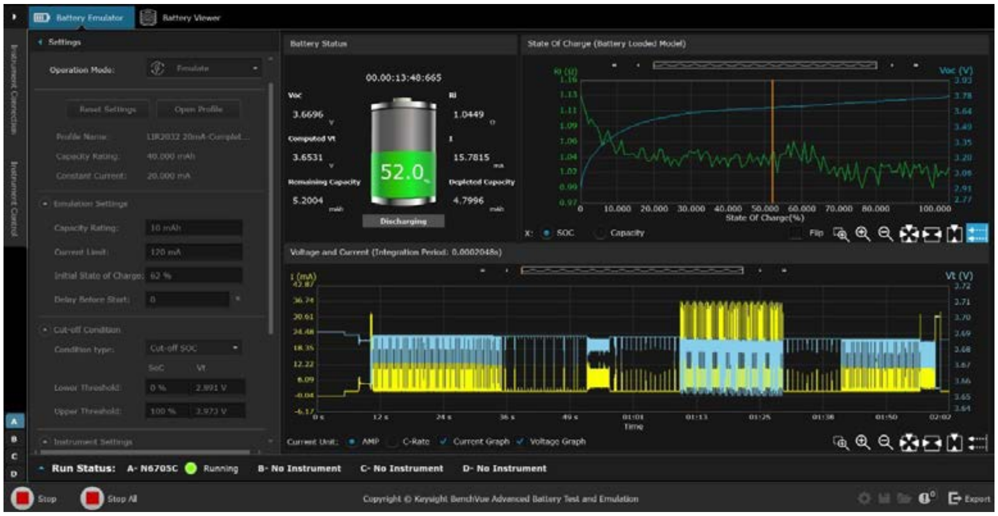
State Of Charge
X: ● SOC ○ Capacity

Run Status: A- N6705C ● Running B- N6701C ● Stopped C- No Instrument D- No Instrument

Copyright © Keysight BenchVue Advanced Battery Test and Emulation

Figure 4. BV9210B creating a battery model

Once the software creates a model, it can be loaded into emulation mode, and the software will follow the battery model in real time to emulate the battery behavior. Instead of using the actual battery during the test, the test operator can use the battery emulator. One of the advantages of using a battery emulator is that the test operator can quickly set the SoC during a specific test. For example, you might want to run a test where your device runs off a battery at a 50% SoC. Using a battery would require charging or discharging it to that SoC, which could take hours. The battery emulator does this in less than a second.



Operation Mode: Emulate

Profile Name: LIR2032 20mA-Complet...
Capacity Rating: 40.000 mAh
Constant Current: 20.000 mA

Emulation Settings
Capacity Rating: 10 mAh
Current Limit: 120 mA
Initial State of Charge: 62 %
Delay Before Start: 0

Cut-off Condition
Condition type: Cut-off SOC

	SoC	Vt
Lower Threshold:	0 %	2.891 V
Upper Threshold:	100 %	2.973 V

Instrument Settings

00.00:13:48:665
Voc 3.6696 V
Computed Vt 3.6531 V
Remaining Capacity 5.2004 mAh
Ri 1.0449 Ω
I 15.7815 mA
Depleted Capacity 4.7996 mAh
52.0 %
Discharging

Run Status: A- N6705C Running B- No Instrument C- No Instrument D- No Instrument

Figure 5. BV9210B emulating a lithium-ion battery powering a device under test

This solution allows the design engineer to profile and emulate a battery quickly and easily. An engineer will gain insight into the behavior of a device powered by a battery at various SoCs. The engineer can use this insight to change the design, resulting in a longer battery run time.

Learn More

For more information, please visit the following pages:

- Keysight N6705C DC power analyzer
- Keysight BV9200B PathWave BenchVue Advanced Power Control and Analysis software
- Keysight BV9201B PathWave BenchVue Advanced Power Control and Analysis software
- Keysight BV9210B PathWave BenchVue Advanced Battery Test and Emulation application software
- Keysight Source / Measure Unit (SMU) Modules, N6700 Power System

Learn more at: www.keysight.com

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