Keysight Technologies

Measuring Battery Life on Battery-Powered Medical IoT Devices

Application Note

Integration of modern connectivity technology into patient care continues to grow as more and more healthcare and medical devices are connected one way or another. In the new age of Internet of Medical Things (IoMT), these battery-powered wireless medical IoT devices have become increasingly prevalent in our daily lives. Examples of traditional and emerging classes of medical IoT devices include fitness bands and smart watches with their ability to monitor pulse and heart rate, blood pressure monitors, pacemakers, pulse oximeters, glucose monitors, thermometers, hearing aids, and a range of other devices in prototype, which will likely be ready for introduction before year's end.

These classes of medical IoT devices have common traits. They are low power, battery-operated, mobile, lightweight, have a small form factor, and support wireless connectivity. Depending on the severity of insufficient battery life in these devices, the consequences can range from inconvenience to life-threatening situations. As a result, understanding the power consumption patterns and battery life requirements of medical IoT devices is absolutely essential for any designer developing such devices.

Considerations for Battery Run-Down Test

Battery run-time is determined by battery run-down test. To perform this test, measure the time taken to deplete a fully charged battery or in other words until the battery stops working. The measured time will be the battery run-time. However, this is easier said than done as there are many aspects in this test that every design engineer needs to take into consideration.

Here are the top 4 considerations for battery run-down test:

Consideration 1: Inconsistencies in battery life

Inconsistencies in the battery life between different batteries is common even though they are from the same manufacturer. This is because the batteries may come from different manufacturing batch or factory site.

Recommendation:

Perform the run-down test a couple of times with different batteries.

Consideration 2: Battery's charging condition

It is highly recommended that a fully charged battery is used when performing the test. If the battery is old or partially charged, it will affect the run-time results.

Recommendation:

Ensure that the battery is fully charged and condition the battery by using a battery cycler to cycle the charging of the battery from fully discharged to fully charged.

Consideration 3: Medical IoT device use case

Different modes of the IoT device will draw different amount of current for consumption.

Recommendation:

Set the use case test parameters on a device as the constant variable. Hence during the run-down test, the variable is constant across each test.

Consideration 4: Determine when the IoT device stops working or the battery is fully discharged

Some IoT devices have a low battery LED indication to signal that the battery power is low. However, IoT devices like pacemakers do not have a low battery indicator.

Recommendation:

Measure the battery voltage when it reaches a certain low voltage threshold and use that as the indicator of when the IoT device stops working.

Power Supply as Battery Simulation

Some design engineers may use a power supply to simulate the battery for the run-down test. However, this method is not accurate or practical as it will introduce more errors and variables to the overall testing. Using a power supply is also not a suitable method as it will never run down like a battery.

However, a power supply with specialized features such as controllable output resistance and excellent transient response on current pulses drown can be used to emulate the battery. This approach is very complicated as the power supply's output voltage needs to drop off as the charge is pulled from the power supply into the medical IoT device during the run-down test. The simulation data collection process will be time consuming and the results will be questionable as they may not match with the results obtained using a battery.

Hence, until a more realistic simulation approach is available, a run-down test using batteries is still the preferred method.

More than Run-Time

When designing a medical IoT device, the design engineer will want to view more and obtain more insight into what is happening during the run-down test. By plotting a voltage and current versus time graph, a much clearer picture of the battery run-down can be achieved.

In order to measure the voltage and current flowing through the battery and the medical IoT device, the tester normally needs the following:

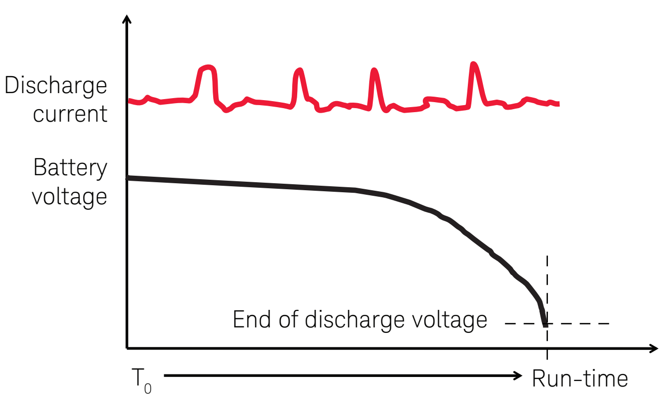
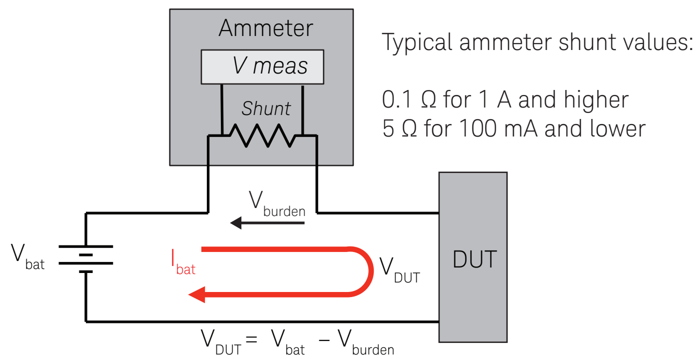


Figure 1. Battery run-down test results

- 2 Digital multimeters (DMMs)
- 2-channel data logger or 2-channel digitizer
- Oscilloscope

Battery voltage measurement is less critical when compared to the current measurement. In order to capture a decaying voltage waveform, a normal DMM or data logger is sufficient for the measurement. However, a current measurement requires a fast digitizer as each IoT device has different current consumption scheme such as sleep mode, standby mode, active mode, and wireless data transmission mode (for wireless device). An IoT device can draw up to hundreds of milliamperes in the active mode, but will only draw microamperes during the sleep mode. High current spikes and transient effects occur when the device is turned on and off frequently. A DMM will not be suitable for capturing the rapid changing current waveform. Additionally, DMM is a burden voltage when it is configured as an ammeter as there is a calibrated current shunt built inside the DMM. This will reduce the voltage at the DUT and burden the overall circuit up to hundreds of millivolts.



Example calculation of burden voltage of ammeter:

On 100 mA range, 50 mA of I_{bat} yields V_{burden} of 250 mV, so a 4.2 V battery would be reduced to 3.95 V at the DUT.

Figure 2. DMM presents burden voltage when measuring current

Digitizers offer the better choice when measuring rapidly changing waveforms for a long period of time 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 important. If the selected shunt size is for measuring low current, there will be a large voltage drop across the shunt and this will create 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 compromise has to be made between burden voltage or low currents 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. Like the digitizers, oscilloscopes must be used with the right current shunt to ensure a good low current measurement and tolerable burden voltage at high current measurement. Oscilloscopes can also be used with high sensitivity current probes that go down to as low as 50 µA and have a maximum current range of 5 A. This allows both the large signals and details on fast and wide waveforms to be displayed. The limitation on this solution is that it is not able to perform long-term measurements.

Figure 3. Keysight N6781A and N6785A Battery Drain Analyzer is a two-quadrant source and measure unit (SMU) module that plugs into N6705B DC Power Analyzer mainframe and 14585A Control and Analysis Software is a turnkey solution for battery run-down tests on battery powered medical IoT devices

Solution for Battery Run-Down Test

Keysight Technologies offers the N6781A Battery Drain Analyzer and turnkey software for performing run-down tests for battery powered medical IoT devices requiring up to 3 A of current. The N6781A can be configured as a zero-burden ammeter. This means that there is zero voltage drop across the instrument as it measures the current flow between the battery and the IoT device. It also offers a unique feature called seamless ranging. This allows instant-and-automatic range change and measure 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 also simultaneously measure the voltage across the battery.

With the Keysight 14585 Control and Analysis Software, a battery run-down test can quickly be set up and the run-down measurements can be captured and plotted without coding any software.

Figure 4. Battery run down test result

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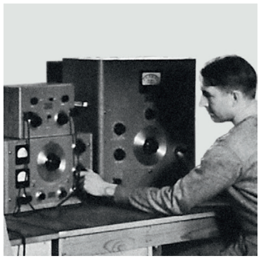
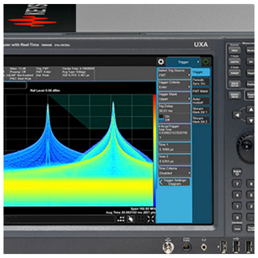


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