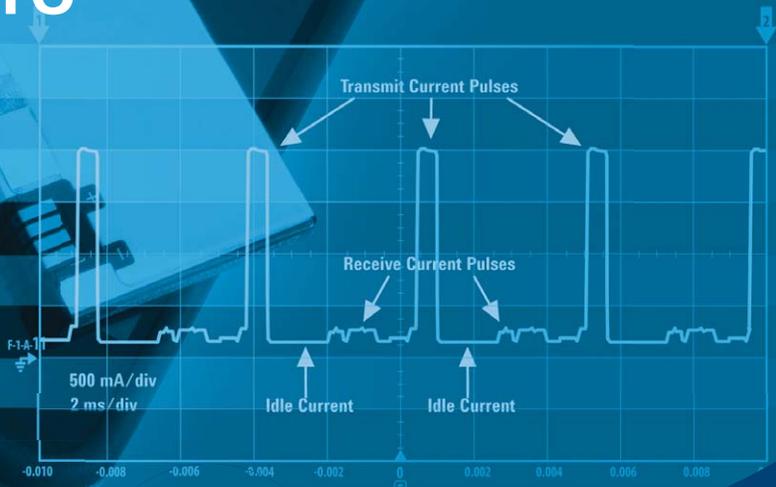
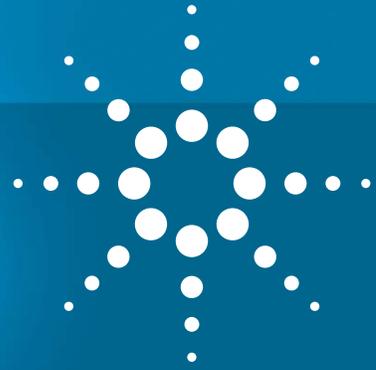


10 Tips to Optimize a Mobile Device's Battery Life



*A compendium
of 10 Agilent Technical Overviews*

Anticipate — Accelerate — Achieve



Agilent Technologies

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Introduction

As an increasing number of electronic devices are designed to be portable and integrated with multiple features, battery runtime has become a critical factor to product differentiation and customer satisfaction. These 10 technical overviews will give you essential tips for maximizing the battery life of your mobile device (like smart-phone, tablet, wireless sensor, or insulin infusion pump).

TIP

1

Current Drain Waveforms Yield Deeper Insights on Optimizing Battery Run Time

Technical Overview

Gaining deeper insights into a mobile device's operation is crucial for optimizing battery run time.

If you want to simply validate battery run time, you can treat the mobile device as a black box and either directly measure the run time or measure current drain for a prolonged period and extrapolate run time based on stated battery amp-hour capacity. Most conformance tests only validate battery run time.

However, optimizing battery run time usually requires the design team to use several different test methods to gain insights that go well beyond just validating battery run time. You need to test and characterize the device, its sub-circuits and the battery, both independently and in combination. A detailed characterization of battery current drain offers deeper insights into the device's operation so you can make informed tradeoffs for optimizing run time

High-speed, high-resolution current drain digitization yields deeper insights for optimizing battery run time.

Digitizing the battery current drain at 50 KSamples /second or greater and with a wide dynamic measurement range provides details yielding deeper insights for optimizing battery run time.

You can take a number of approaches, some of which have limitations:

- Current probes and oscilloscopes provide high-speed waveform digitization. However, limited dynamic range, inaccuracies, and noise limit their usefulness.
- A high-sampling-speed data acquisition system and an accurate current shunt can provide better accuracy and wider range compared to a current probe and oscilloscope. However, you must keep maximum tolerable current shunt peak voltage drop small so that it does not unduly affect the mobile device. However, keeping the shunt voltage drop small limits the measurement dynamic range and accuracy.
- Some specialized DC sources incorporate a high-speed digitizing, wide-dynamic-range measurement system that can accurately characterize a mobile device's current drain without the voltage drop issues you encounter when you use an external shunt resistor.

Example of gaining deeper insights from a device's current drain waveforms:

As one example, Figure 1 shows the current drain measured on a mobile phone during a call using the Agilent N6781A source/measure unit and companion 14585A software. The N6781A is a specialized battery emulator DC source tailored for powering a mobile device and measuring its current drain from η A to A at over 195 KSample/sec digitization rate. With both wide dynamic measurement range and high-speed digitizing, it quickly provides deeper insights for optimizing battery run time.

Just a few of the insights that were gained on the mobile phone include:

- Idle current base level value
- Idle period duration
- Current drain values and durations of activities during the idle period
- Transmit current value and RF power amp power added efficiency (PAE)
- Transmit current duration
- And more

With the right measurement capabilities, current drain is a window for gaining deeper insights for optimizing your mobile wireless device's battery run time..

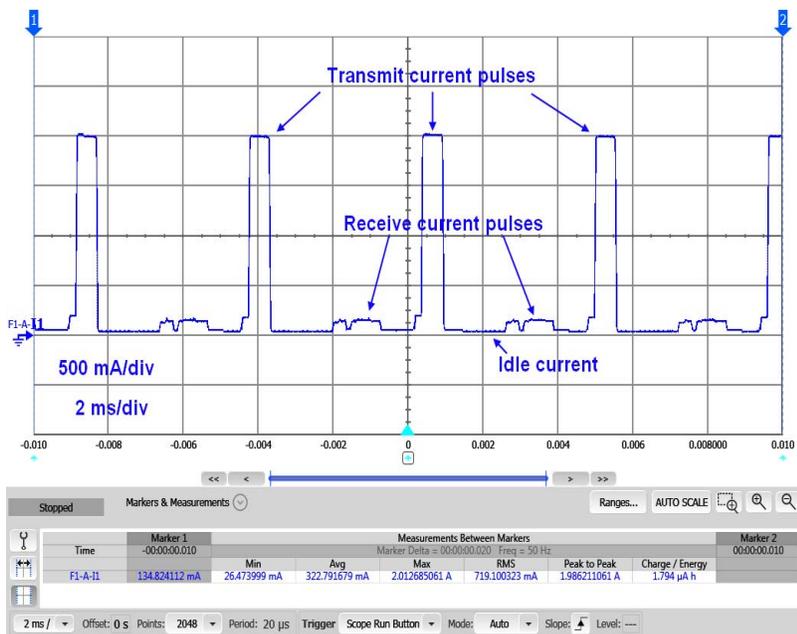


Figure 1: GPRS smart phone active mode current drain waveform details.

TIP

2

Improving Measurement Accuracy Assures Longer Battery Run Time for Power-saving Modes

Technical Overview

Evaluating a wireless mobile device's current drain for its power-savings operating modes is a fundamental task for optimizing its battery run time.

Mobile phones and many other mobile devices that have high-power active modes spend the majority of their time in standby or another similar type of power-savings mode. Other devices, like wireless sensors, may have only power-savings operating modes. Although the power consumption may seem negligible, because the devices spend long periods operating in power-savings modes, they can consume a major portion, or even all, of the battery's capacity.

The pulsed nature of current drain for power-savings operating modes dictates unprecedented measurement performance for optimizing a device's battery run time.

In a power-savings operating mode a mobile wireless device spends most of its time in a low-power sleep state, periodically waking up and briefly entering a higher-power active state to receive or transmit to a base unit. The resulting current drain is pulsed and has the following characteristics:

- Long period of tenths to tens of seconds
- Extremely low duty cycle of tenths to several percent
- Extremely high crest factor on the order of a hundred or higher

The base sleep current and the pulsed transmit current are often both significant portions of the overall average and hence both extremes, and everything in between, need to be accurately measured.

Accurately measuring current drain for power-saving operating modes proves to be a challenge for conventional test equipment. Even if the equipment (including digitizing data acquisition equipment) can adequately integrate the measurement over an appropriately long enough time, their fixed measurement ranges do not have sufficient dynamic range to accurately measure both the peak pulse and baseline sleep currents to provide accurate values for

predicting and optimizing battery run time. Because of the high peak but low average value, the equipment's offset error for the required measurement range often is comparable to the average value, resulting in unacceptably high measurement error. Workarounds are sometimes taken to improve some measurement aspect but they usually have a significant downside as a consequence.

Current drain measurement example for a power-savings mode:

Let's look at an example of power-savings operation. A wireless temperature transmitter has a pulsed current drain with the following characteristics:

- Period of 4 seconds
- Duty cycle of 0.17%
- Crest factor of 400

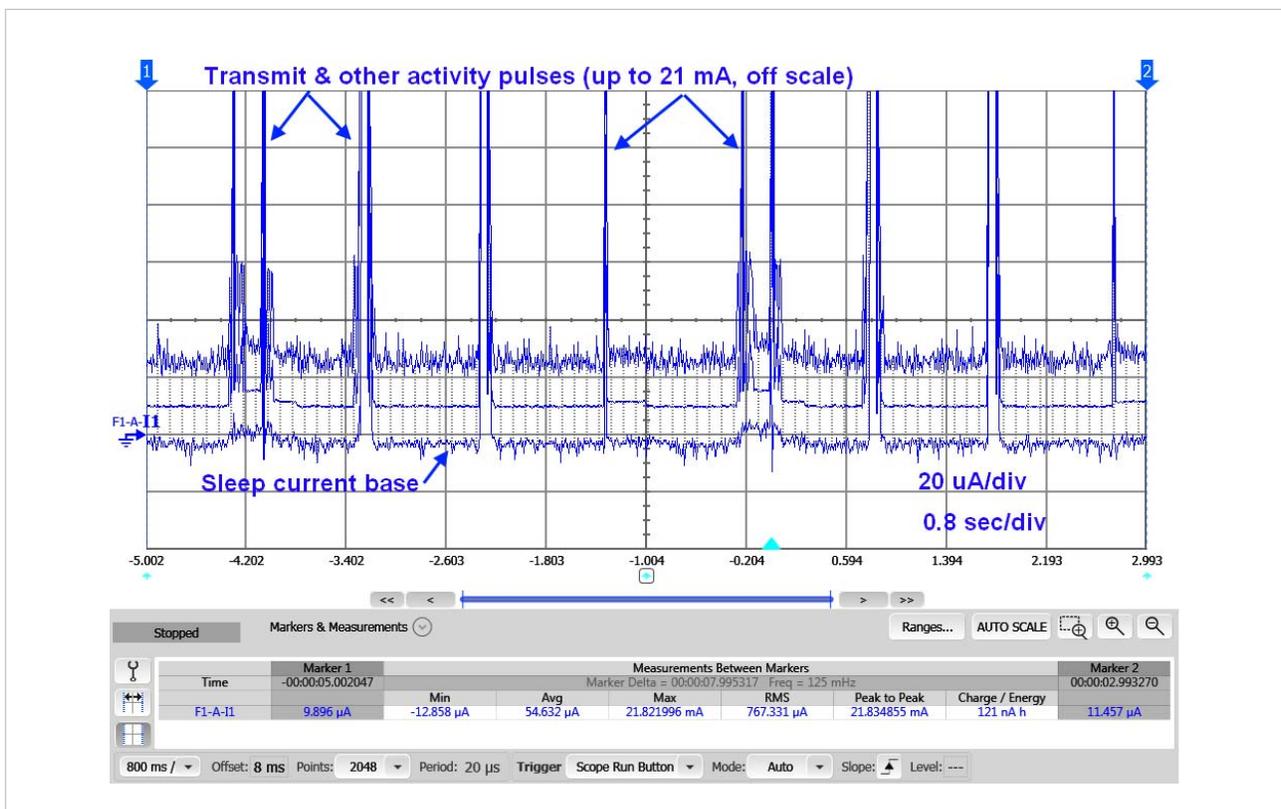


Figure1: Wireless temperature transmitter current drain, fixed ranging measurement

An Agilent N6781A DC source/measure unit was used to power and measure the temperature transmitter's current drain. The N6781A incorporates a high-speed digitizer for measuring current drain on wireless mobile devices. The current drain was first measured using the N6781A set to its fixed 100-mA measurement range, as shown in Figure 1. This is comparable to using conventional test equipment. However, the N6781A incorporates an innovative measurement system that seamlessly auto-ranges, continuously digitizing a mobile device's current drain from nanoamps to amps at more than 195 KSa/sec, providing accurate measurements over a greatly extended dynamic range. Figure 2 captures the improved result with the N6781A's seamless measurement ranging active.

Just a few of the improvements and resulting insights gained:

- 97X improvement in sleep current base measurement error, from 115% to 1.15%
- 77X improvement in overall average current measurement error, from 18.9% to 0.245%
- A 5X improvement in the noise floor, from 47 μA to 10 μA_{pp} , and high-speed digitizing yield greater insights into the sleep activities
- High-speed digitizing yields greater insights into the transmit activities

Having high-speed digitizing with extended dynamic measurement range provides useful insights for evaluating power-savings operating modes when optimizing battery run time of mobile wireless devices.

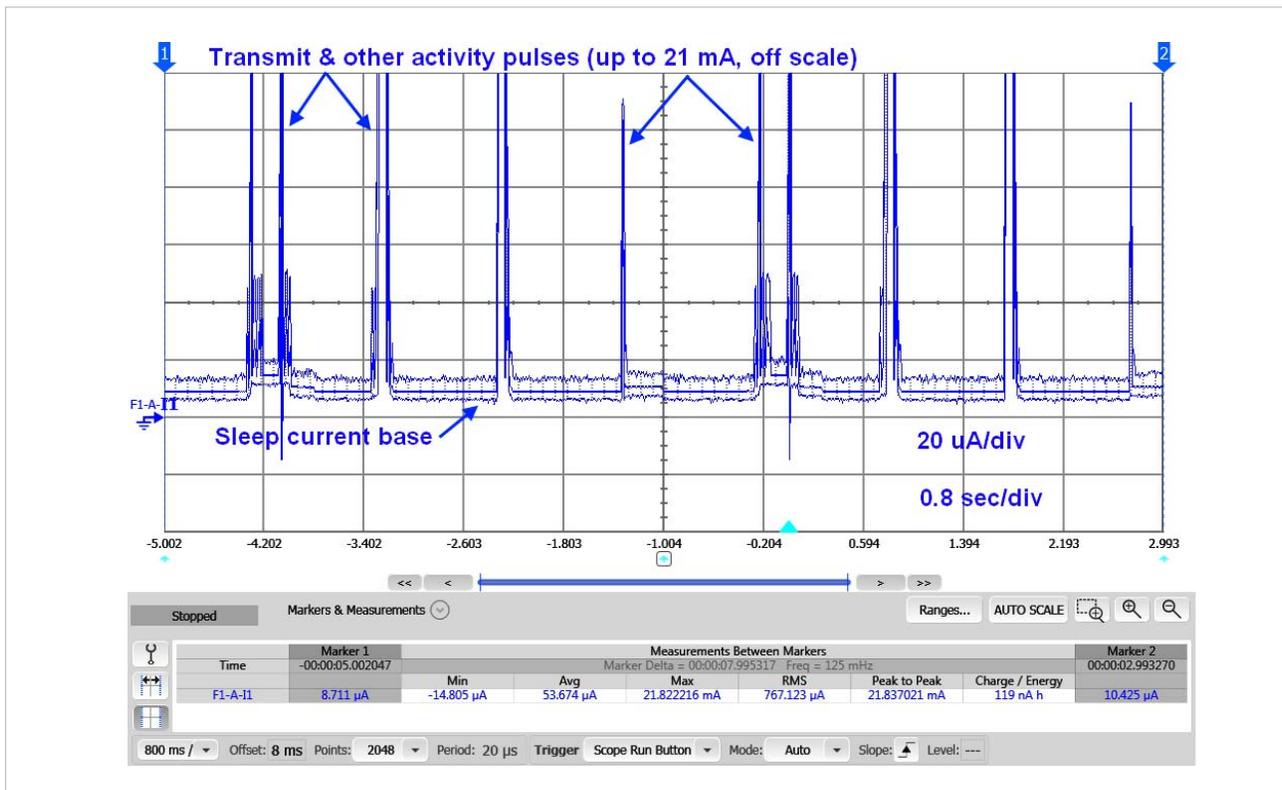


Figure 2: Wireless temperature transmitter current drain, seamless ranging measurement

TIP

3

Analyze Distribution Profiles to Quickly Optimize Battery Run Time

Technical Overview

When optimizing battery run time, you need a way to quickly and easily visualize and quantify impact of design changes on a wireless mobile device's long-term current drain.

The activities of various sub circuits in a mobile device are by nature random over time, depending on user behavior, the network environment it operates in and complexity of the device itself. The battery current drain associated with these sub circuits and activities is correspondingly random over time as a result. Validating improvements from design changes for optimizing battery run time requires you to log the current

drain over a sufficiently long timeframe to average out random behavior. The difference in average current before and after design changes, is the net impact of the changes. However, you need more detail about the impact of design changes when you are optimizing battery run time. Did you get the expected improvement? How do you determine which sub circuits and activities within the device were impacted? One approach you can take is to manually scroll through the data logs to estimate levels and durations of current bursts relating to various sub circuits and associated activities.

While useful, this approach has several drawbacks:

- It is extremely time consuming.
- Many values are estimates at best, due to the long-term random nature.
- It is easy to reach incorrect conclusions because of the difficulty of examining and quantifying countless millisecond-duration activities in up to hours-long data logs.

While long-term logging of a mobile device's current drain is necessary, direct visual inspection to quantify the data log's details is problematic. You need to resort to alternate methods to quickly and effectively analyze long-term current drain logs when optimizing battery run time.

Analyzing probability distribution function profiles quickly and concisely visualizes and quantifies detail differences in long-term current drain resulting from design changes.

An effective method you can use to quickly and concisely visualize and quantify the impact of design changes on a mobile device is to analyze probability distribution function (PDF) profiles of the long-term current drain. PDFs are plots of the current drain sampled over time, plotted against the relative frequency of occurrence of the given current level, the total adding up to 100%. Histograms are the most widely recognized form of PDFs. However, complementary cumulative distribution functions (CCDFs) in particular work well for quickly visualizing and analyzing long-term current drain and quantifying the impact of design changes.

What is a CCDF?

- Cumulative distribution function (CDF) = \int PDF (area under curve = 1 or 100%).
- Complementary cumulative distribution function (CCDF) = 1-CDF.

A CDF profile goes from 0% to 100% probability, while a CCDF profile goes from 100% to 0% probability. Note how the CCDF profile in Figure 1 concisely displays the long-term current drain logged on a mobile phone during standby operation, measured and displayed using the Agilent N6781A DC source/measure unit and 14585A

control and analysis software. The X-axis is the current drain's amplitude and the Y-axis is its relative frequency of occurrence. Horizontal shifts in the profile are amplitude-related changes, while vertical shifts are time-related changes. You can use these shifts to quickly analyze and quantify detail differences of long-term current drain resulting from design changes, for optimizing battery run time.

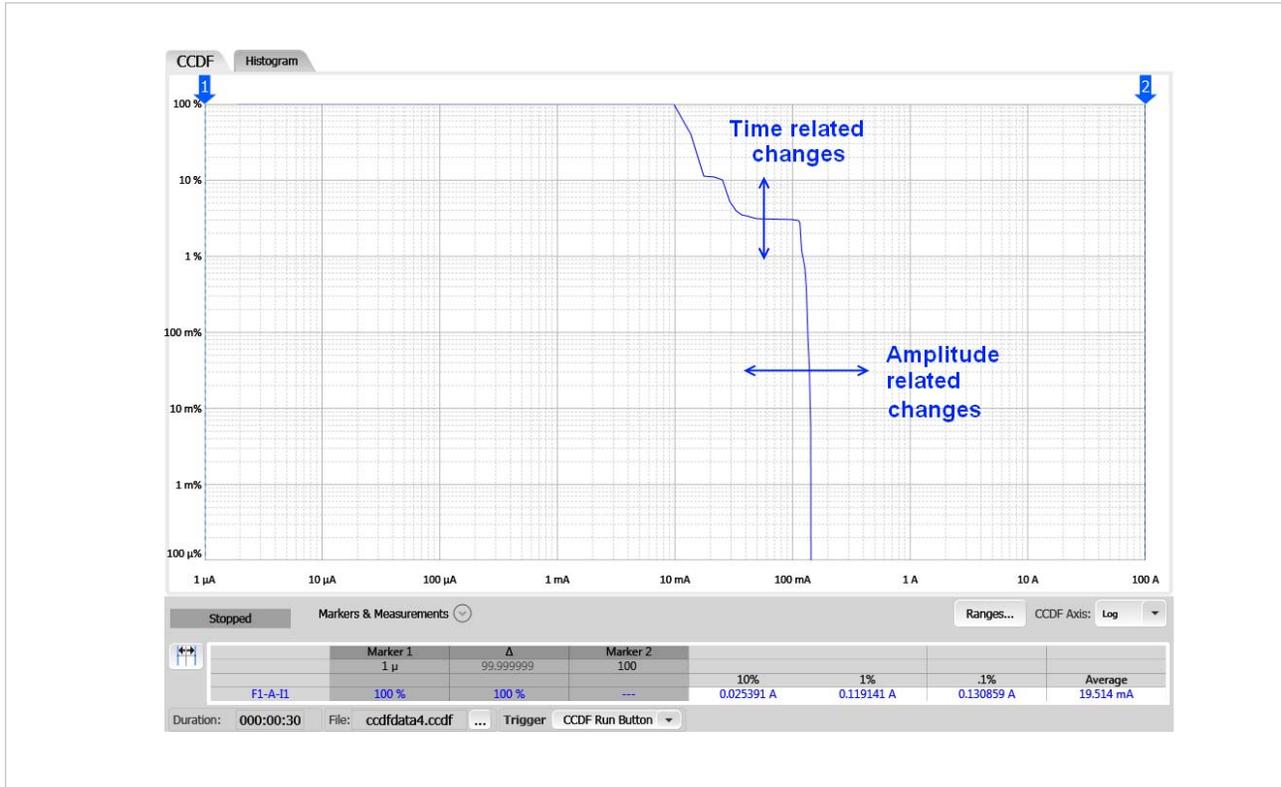


Figure1: CCDF profile of a mobile phone's standby current drain

Example of evaluating CCDF profiles to analyze power savings for a mobile phone's standby operation.

To extend battery run time for standby, mobile phones often employ discontinuous receive (DRX) operation. Compared to using continuous receive, the amount of power savings realized depends on, among other things, the level of sleep current you can achieve during inactive periods and how much you can minimize the receive activity time, in the design of the mobile phone.

To evaluate its effectiveness on power savings, we used the N6781A DC source/measure unit and 14585A software to log long-term current drain on a mobile phone for both continuous and discontinuous RX standby operation. As shown in Figure 2, we used the 14585A software to display and compare CCDF profiles of the two current drains to quickly and easily identify and analyze details of the power savings.

By quantifying the vertical and horizontal shifts between the two profiles we found:

- A (vertical) change of 2.8% of RX activity at 128 mA returned 18% power savings
- A (horizontal) change of 11.9 mA in idle current returned 55% power savings
- The remaining 27% power savings came from reduced baseband activity
- The total power savings was 85.5%

As you can see, by using distribution profiles you can quickly and easily visualize, identify, and quantify detailed impact of design changes on sub circuits and associated activities, when optimizing battery run time, a task that would otherwise be time consuming and difficult using traditional approaches.

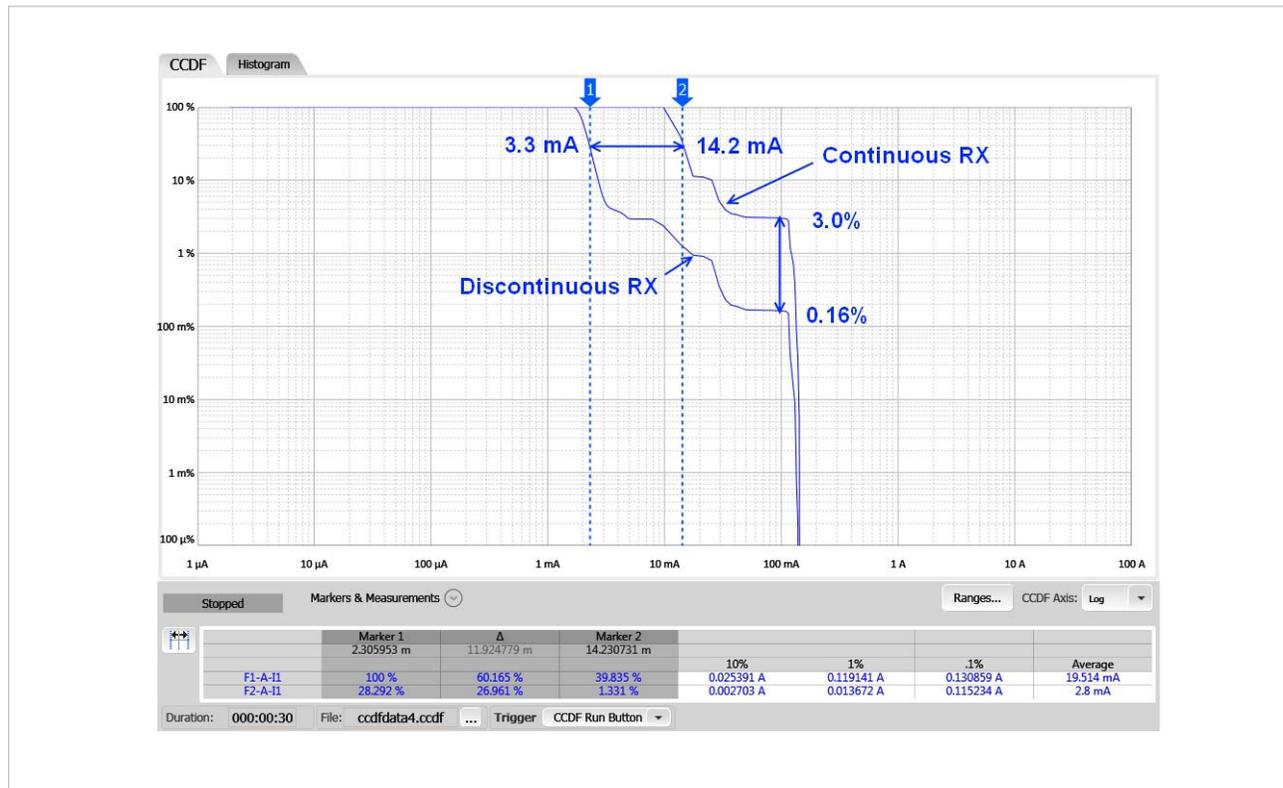


Figure 2: Analyzing a mobile phone's standby power savings details using CCDF profiles

TIP

4

Emulate the Battery for More Realistic Mobile Device Test Results

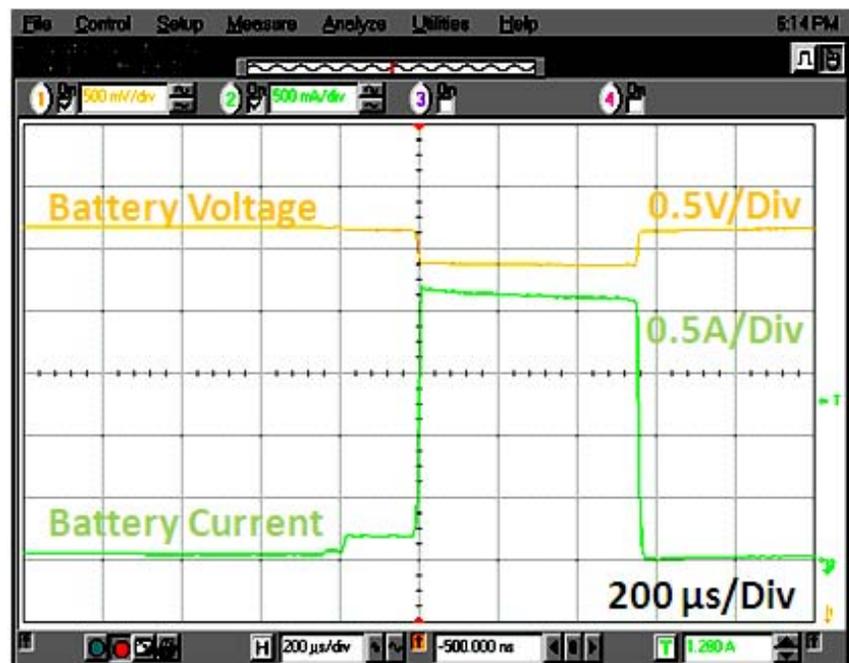
Technical Overview

A key consideration when powering a mobile device with a DC source is getting current drain test results comparable to that of using a battery, when optimizing battery run-time.

Batteries are very non-ideal energy sources. A battery's characteristics interact with a mobile device, influencing its resultant current drain. Accurate current drain results are essential when you optimize your mobile device's battery run-time. You need to take the battery's characteristics into consideration when powering your mobile device by a DC source, in order to assure your current drain results are comparable to that of using a battery.

When powered by a general purpose DC source, a mobile device's current drain is often not comparable to that of using an actual battery.

Figure 1 show the pulsed current drain and voltage response on a GSM mobile phone powered by its battery. As can be seen, a battery has substantial series output impedance, causing its output voltage to drop in direct proportion to the mobile device's current drain. Many mobile wireless devices adapt and adjust accordingly to compensate for the battery's characteristics.

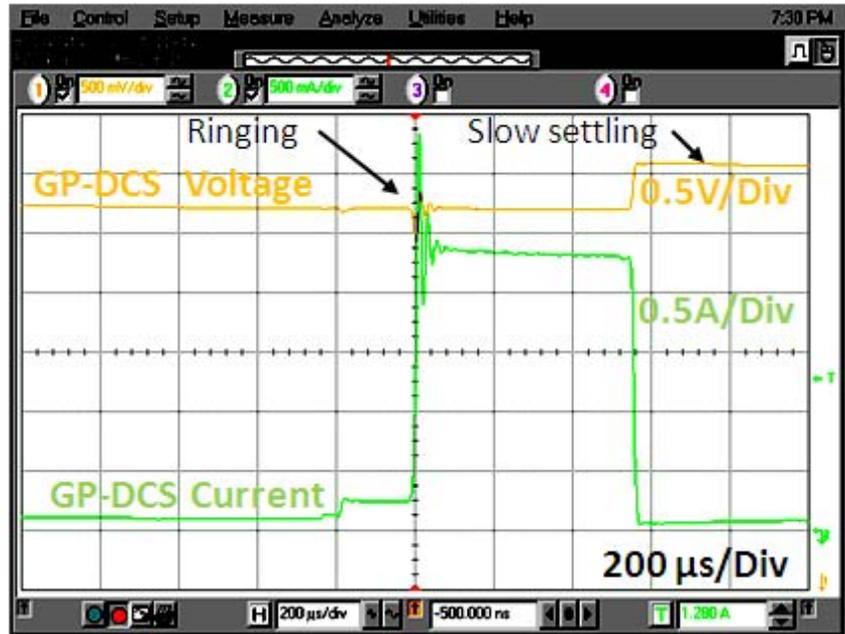


Battery response characteristics

- Battery voltage drops proportionally with current
- Battery resistance is 150 mΩ

Figure 1. Battery powering a GSM mobile phone

A general purpose DC source strives to be an ideal voltage source with zero output impedance by using feedback to regulate its output to a fixed voltage setting. Unlike a battery, its voltage does not drop proportionally with load current. Also, feedback regulation has finite response time. This leads to transient voltage drop and overshoot during loading and unloading transitions. If a transient voltage drop is large enough it can even trigger a mobile device's low battery voltage shutdown. The net result is a general purpose DC source does not behave like a battery. Figure 2 show the same measurements made in Figure 1 using a general purpose DC source in place of the battery. The voltage response is very different and the resultant current drain ended up being 10% higher than when using the battery.



General purpose DC source response characteristics

- Voltage response is not like battery
- Resultant current is 10% higher than the battery

Figure 2. General purpose DC source powering a GSM mobile phone

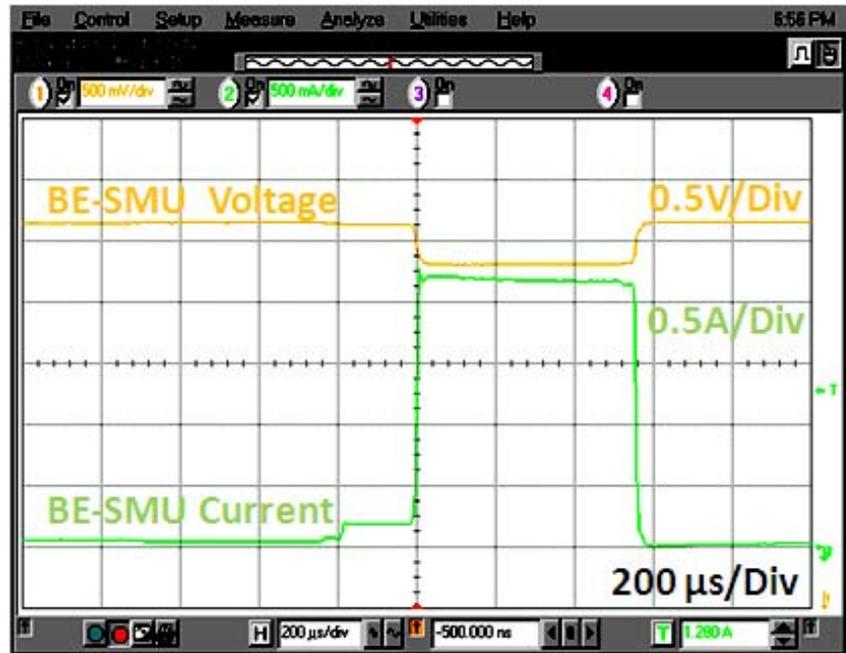
When powered by a battery emulator DC source, a mobile device's current drain is comparable to that of when using an actual battery.

DC sources tailored for powering mobile devices have capabilities for emulating batteries, including:

- Current sinking in addition to sourcing, to emulate a battery's charging current capabilities
- Programmable series output resistance to emulate a battery's impedance
- Extremely fast load transient response to minimize voltage drops and overshoots, and accurately emulate a battery's dynamic voltage response

Figure 3 shows the same measurements made in Figure 1 using an Agilent N6781A SMU with battery emulation capabilities, in place of the battery. The N6781A's series output resistance was set to match the battery's 150 mΩ value. Both the voltage response and resultant current drain ended up being comparable to that of when using the battery, respectively.

When powering your mobile device with a DC source do not ignore the battery's characteristics when evaluating its current drain. Your current drain results must be comparable to that of using a battery when optimizing your device's battery run-time. A general purpose DC source does not behave like a battery, often providing very different current drain results. Using a DC source with battery emulation capabilities helps assure you achieve more accurate results, comparable to that of when using a battery..



Battery emulator SMU response characteristics

- Battery emulator SMU set to 150 mΩ
- Voltage and current comparable to the battery

Figure 3. Agilent N6781A battery emulator SMU powering a GSM mobile phone

TIP

5

Simplify Validating a Battery's Capacity and Energy Ratings

Technical Overview

A key part of determining a mobile device's run time is validating the battery's capacity and energy ratings.

If you determine a device's run time based solely on a manufacturer's data sheet without validating the battery's capacity and energy ratings, your results are bound to be inaccurate. The stated capacity is often based on ideal conditions and represents the maximum charge you might obtain from the battery.

Actual capacity will usually end up being less when you verify it in your application.

Battery capacity is the amount of charge in ampere-hours (Ah) or milliamp-hours (mAh) the battery is specified to hold. This is different from the battery's energy rating, which is in watt-hours (Wh). You can determine the energy rating by taking the product of the battery's capacity (Ah) times its stated nominal voltage (V). As the battery's actual energy content can be more a factor in a mobile device's run time than the battery's capacity, it is important to validate both of these values.

Temperature and battery age also affect how much charge might be obtained from the battery, so you also need to consider these factors when you determine the run time that can be expected for the mobile device.

Validating a battery's stated capacity and energy ratings requires accurate voltage and current logging under precisely controlled conditions.

Very small differences in charging (for rechargeable batteries) and discharging conditions can lead to large differences in the capacity and energy obtained from a battery. That is why it is paramount to precisely replicate and control all conditions for achieving good results. One key condition is the discharge rate, usually stated as a constant current discharge at some ratio of the AH capacity rating, referred to as the C rate. A manufacturer may specify a discharge C rate of 0.3, for example, as higher discharge rates lead to lower capacity and energy delivered from the battery. A C rate of 0.3 would theoretically fully discharge the battery in 3.33 hours. For a 2-Ah

battery, a C rate of 0.3 would be 0.6 A constant current discharge. It is also worth noting that the measured energy rating can differ from that based on the stated nominal voltage, as the actual battery run down voltage profile may lead to a slightly different result. Precisely controlling test conditions while accurately logging both the battery's current and voltage assures accurate and consistent results when determining the battery's capacity and energy ratings.

Constant Current Load Operation for Battery Discharge

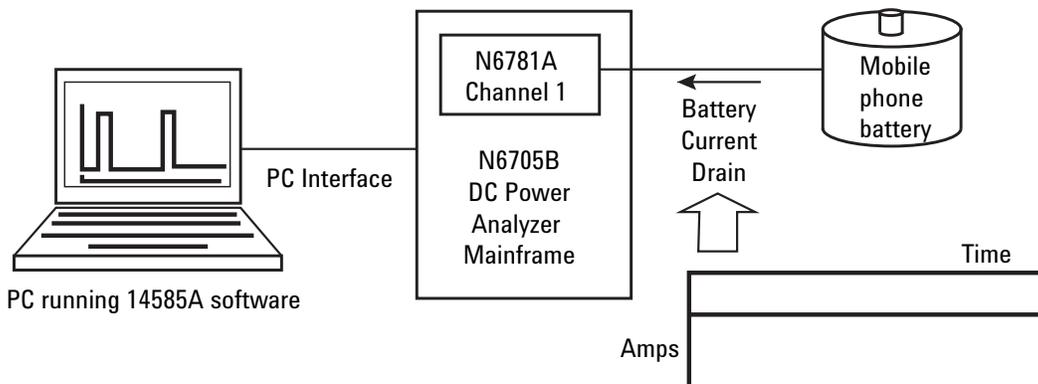


Figure1: Using a constant current load to discharge a battery at a fixed C rate.

Example of validating a battery's capacity and energy ratings:

We used the setup depicted in figure 1 to discharge a rechargeable mobile phone lithium ion battery at a fixed C rate. The full 2-quadrant capability on the Agilent N6781A source/measure unit makes it well suited for use as a precision high-performance electronic load as well as a precision DC source. A constant current discharge of 0.3 A with 3.0-V cutoff voltage and long-term data logging for validating the capacity and energy ratings were quickly set up and displayed using the companion

Agilent 14585A software. The results of validating the capacity and energy ratings the battery are shown in Figure 2. Placing measurement markers at the start and cutoff voltage points on the data log revealed the battery delivered 879 mAh and 3.32 Wh. Both of these values were notably lower than 1 Ah and 3.6 Wh ratings obtained from the battery's data sheet. The next steps are to identify what factors lead to the difference and then assess if additional capacity can be extracted from the battery or not. As can be seen, it is best not to assume the battery's rated capacity and energy are what you will get, making it important to validate them as part of determining run time for your product.

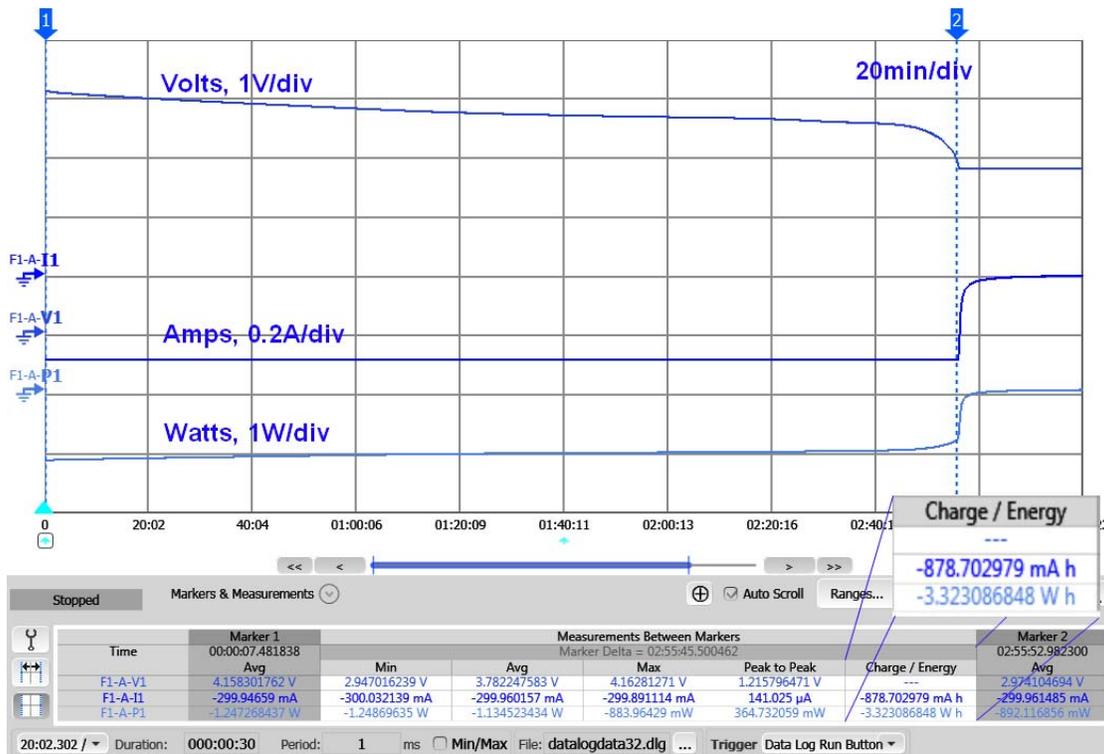


Figure2: Measuring a battery's capacity and energy using the 14585A software.

TIP

6

Simplify Validating a Battery's Capacity and Energy for End-Use Loading Conditions

Technical Overview

A key part of determining a mobile device's battery run time is validating the battery's capacity and energy under dynamic end-use loading conditions.

Once you have validated a battery's stated capacity and energy ratings based on data sheet conditions, you also need to validate them under dynamic loading conditions that reflect the actual end-use. Just as higher constant current discharge rates lead to reduced capacity and energy obtained from a battery, high peak pulsed dynamic discharge currents also yield lower capacity and energy

compared to an equivalent constant current discharge having the same average value. The amount of peak pulsed discharge that can be tolerated is highly dependent on the battery's design. Because of this, you must validate the capacity of the battery under consideration under dynamic loading conditions reflecting the actual end-use as part of optimizing the battery run time of a mobile wireless device.

Validating a battery's capacity and energy for end-use loading conditions requires you to accurately log voltage and current while reliably recreating the dynamic end-user loading conditions.

Just as with static charging and discharging, small differences in dynamic loading conditions for discharging can lead to large differences in the capacity and energy obtained from the battery. Non-linear time-variant battery behaviors will yield different capacity and energy results, which are caused by differences in dynamic loading. Consequently, you need an accurate dynamic load profile for discharge. Using the actual mobile device provides the most realistic dynamic loading profile but has some drawbacks. Often it is difficult to reliably create the necessary conditions

for the device to have it operate in the desired fashion, and usually there can be significant variance when doing this on a repeated basis. A solution for doing this on a repeatable basis is to capture the device's dynamic current drain over an appropriate period and then play it back with an electronic load that will support this type of operation, to discharge the battery.

Example of validating a battery's capacity and energy ratings by recording and playing back end-use load conditions.

We used the setup depicted in Figure 1 to first power and capture an active-mode current drain profile on a GPRS smart phone and then play the captured profile back as a dynamic current load over an extended period to discharge a battery. We used the Agilent N6781A source/measure unit as it features full 2-quadrant operation making it useful as both a high-performance DC source and electronic load, addressing both steps of this application. Its biggest benefit, however, comes from being able to

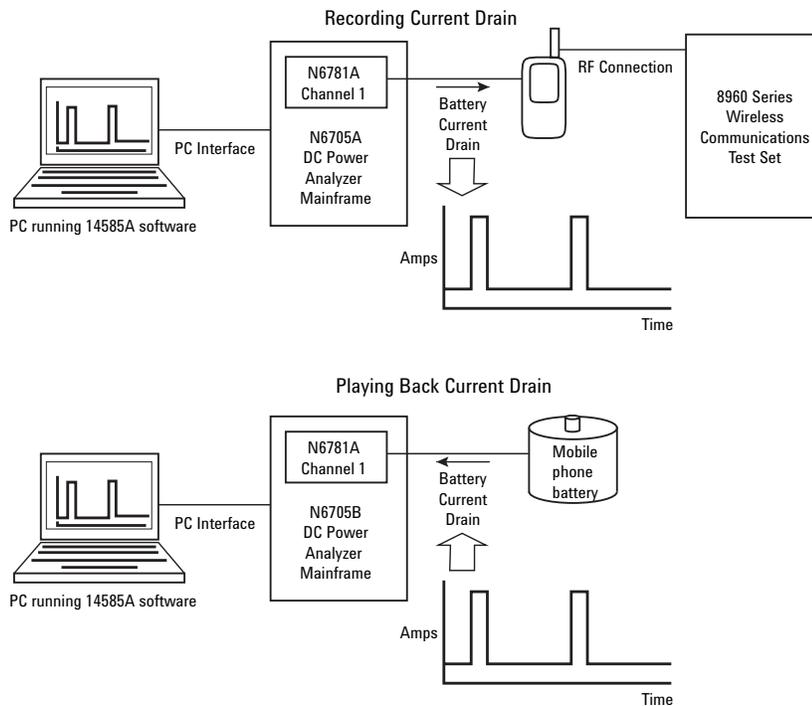


Figure 1. Recording and playing back a device's current drain to discharge a battery.

digitize its output current profile when sourcing power and then use this same profile as a dynamic arbitrary waveform input when it is operated as a load. Utilities in the N6705B DC Power Analyzer mainframe and 14585A software further simplify and streamline this task.

We then validated a rechargeable Lilon battery rated for 1-Ah and 3.6-Wh. You can see the results in Figure 2. The resultant 0.856-Ah capacity and 3.22-Wh energy values obtained by playing back the 2-A peak, 0.3-A average current drain profile captured on the mobile phone were slightly lower than the 0.879-Ah and 3.32-Wh values obtained using an equivalent

0.3-A constant current discharge. The battery's pulsed capability is well matched to its intended end-use. The impact becomes much more prominent with higher peak discharge rates and with many high-energy-density primary (non-rechargeable) batteries. As you can see validating the battery under end-use loading conditions is a key part of determining the run time of a mobile device.

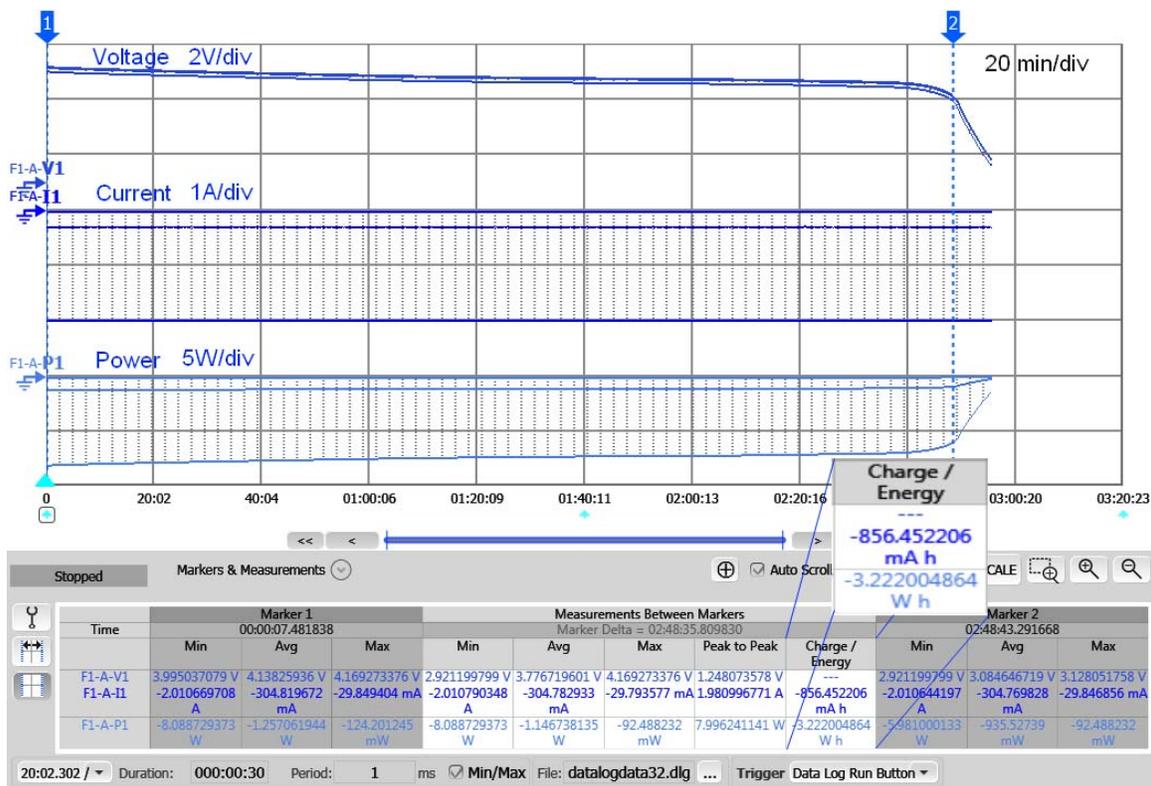


Figure2. Measuring battery capacity under end-use pulsed loading condition.



Mobile Device Run-down Testing Provides Realistic Assessment of Battery Performance

Technical Overview

Conducting a run-down test on a mobile device with its battery yields unique and useful insights for optimizing battery run time.

It is important to test the mobile device and battery individually when determining and optimizing run-time. However, a battery is not an ideal voltage source; its characteristics interact with and influence the host mobile devices' power consumption. Because of this interdependency, a number of unique and useful insights are obtained only when you perform a run-down test on a device with its battery, together as a system. These insights include:

- Obtaining the most realistic performance and run-time to serve as a baseline to compare and correlate against results you get from other methods
- Assess the battery capacity and energy achieved in actual use against the battery manufacturer's ratings to determine reasons for differences, if any
- Verify low-battery shutdown and full-battery charge termination (when batteries are rechargeable) thresholds on the mobile device to ascertain if it is making full use of the battery

As you can see, performing a run-down test with the device and its battery is key and complementary to a suite of methodologies for optimizing battery run time.

Conducting a battery run-down test requires accurate high-speed voltage and current logging with minimal influence from instrumentation on the measurement.

Figure 1 depicts a conventional set up for conducting a battery run-down test. In particular, high-speed digitization of the current is essential, as it provides many detailed insights. A 50-KSa/sec sampling rate is a good starting point when you log pulsed battery current drain signals of wireless devices. It is also a recommended rate for some mobile phone test standards.

Accurate measurement over an extended dynamic range is also essential for obtaining meaningful results due to the high peak, low duty cycle and low average values typical of pulsed current drain of wireless mobile

devices. Depending on the operating mode of the device under test, the crest factor can be several hundredfold. The span in current is even greater if there are multiple operating modes of different power levels during the test. High crest factors consume the instrumentation's dynamic measurement range, limiting achievable accuracy. This is even more problematic when you consider the current shunt peak voltage drop should be below 50 mV so it does not unduly influence test results. It is imperative the instrumentation has sufficient gain, dynamic range and accuracy for good results. Conventional instrumentation usually falls short of meeting these requirements.

A second independent measurement channel is also needed to log the battery voltage simultaneously with the current. Together they provide the key insights necessary from a battery run-down test for analyzing and optimizing the run time of the device.

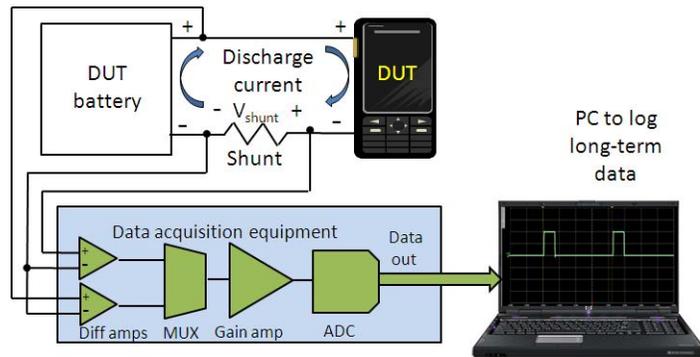


Figure 1. Conventional battery run-down test setup

Battery run-down test example:

We conducted a battery run-down test on a GPRS smart phone using an Agilent N6781A 2-quadrant source/measure unit to log the battery run-down voltage and current, as depicted in Figure 2. The N6781A has a number of unique features and advantages that provide improved accuracy and greater insights specifically when you conduct a battery run-down test:

- It offers an independent DVM input for logging the battery voltage.
- It is a true “zero burden” shunt, eliminating the voltage drop problem of conventional shunts.
- Seamless measurement ranging provides accurate current measurement of signals spanning from nA to A in one continuous logging measurement, eliminating the dynamic range and accuracy limitations of conventional, fixed-range instrumentation.
- A logging resolution of up to 20.48 μsec (and underlying sampling resolution of 5.12 μsec) assures accurate measurement for most any pulsed signals you are likely to encounter.

The battery run-down test results, captured and displayed using the Agilent 14585A control and analysis software, is shown in Figure 3.

Placing measurement markers at the start and shut-down points yields:

- Average and peak currents of 0.233 A and 1.29 A respectively
- Charge and energy delivered by the battery were 843 mAh and 3.19 Wh respectively
- The mobile phone ran for 3 h 38 min before shutting down at 3.44 V low battery

Based on these results findings include:

- The delivered charge was 16% less than the capacity stated for the battery
- The battery discharge termination voltage was higher than the target value

As you can see by this example, performing battery run-down test yields unique and useful insights that complement the other test methods in optimizing battery run time on mobile wireless devices.

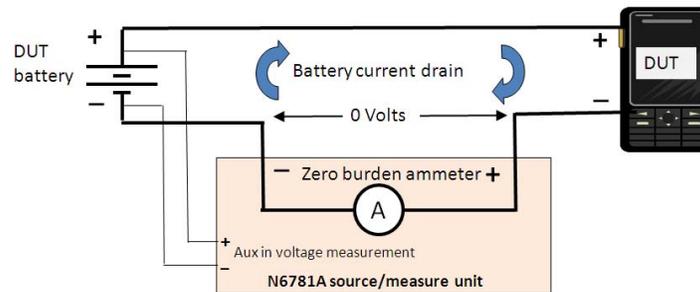


Figure 2. Battery run-down test setup using the Agilent N6781A source/measure unit

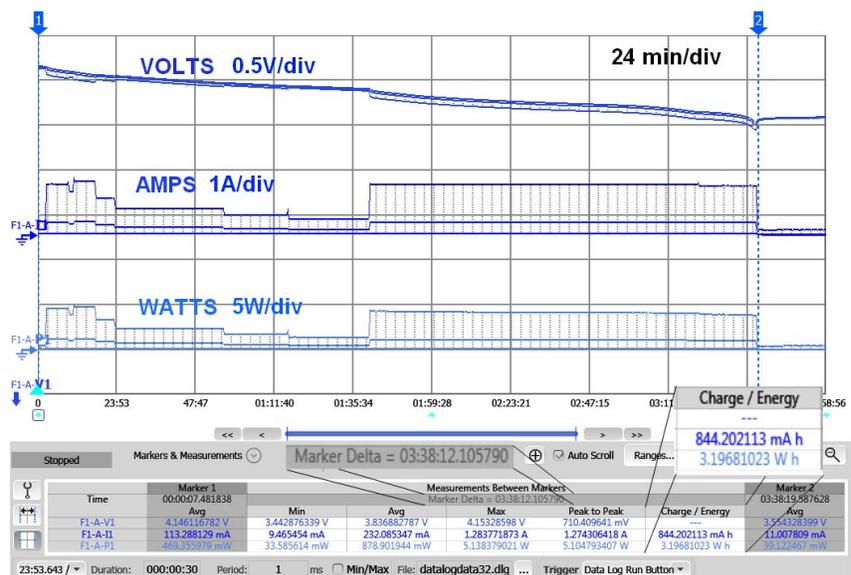
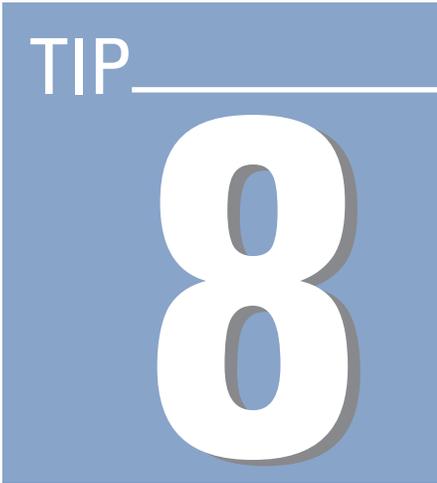


Figure 3. Battery run-down test results



Validate Charge Management for Optimum Battery Performance and Reliability

Technical Overview

Validating a mobile device's battery charge management function is paramount for assuring overall battery performance is collectively optimized.

For devices using rechargeable batteries, the charge management function impacts both short- and long-term battery performance. Validating the battery charging profile and termination is a vital task to assure several battery performance attributes are collectively optimized to meet design goals, including:

- Charging time
- Battery longevity and safety
- Warranty claims due to battery performance
- Run time
- Managing fault conditions

While all of these factors are important, there is often some difference in emphasis placed on each depending on the particular device. For example, you may place greater emphasis on battery longevity in tablets, MP3 players, and wireless headsets when the battery is built in and not readily replaceable.

Validating a mobile device's battery charge management function requires accurate, high-speed voltage and current logging with equipment that has negligible influence on the measurements.

Figure 1 depicts a setup for evaluating the battery charging profile on a device, based on general-purpose equipment. You need two simultaneous measurement channels. One channel is for logging the charging current while the second channel is for logging the battery voltage. Together they provide key insights on validating the charge profile and management.

Lithium ion batteries are the favored choice for most all mobile devices needing rechargeable batteries due to their superior size, weight and energy density. The voltage level they are

charged to, or the float voltage needs to be extremely precise; just 10 mV or about 0.25% difference in float voltage can yield up to ten times that percent difference in stored charge. Errors of 50 to 100 mV can lead to safety issues from overcharging. Thus it's imperative that the impedance and resulting voltage drop of the current shunt as well as the voltage measurement error of the data acquisition equipment be negligible so it doesn't influence charging performance. Also, more sophisticated charge management techniques are increasingly being adopted, many applying various dynamic stimuli to determine attributes of the battery while charging.

You need good dynamic measurement performance and accurate DC measurement. These requirements challenge the performance limits in currently available commercial data acquisition equipment.

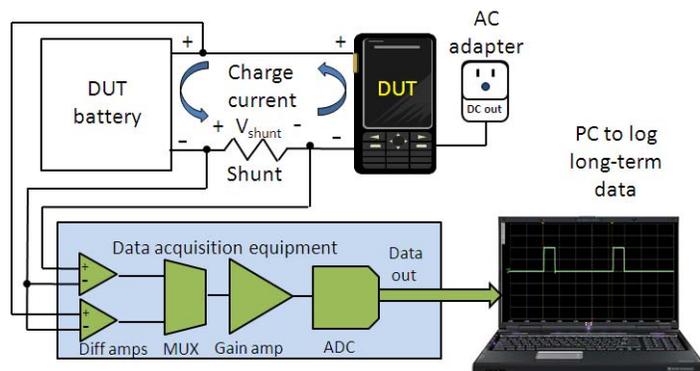


Figure 1. Traditional battery charge profile measurement test setup

Battery charge profile test example:

We measured the battery charge profile on a GPRS smart phone using a setup illustrated in Figure 2, based on the Agilent N6781A source/measure unit. The N6781A has specialized features for evaluating battery-powered products and provides a number of unique benefits:

- Zero-burden ammeter operation has no voltage drop, assuring accurate results.
- Built-in auxiliary voltage measurement simultaneously logs battery charge voltage.
- Seamless measurement ranging provides accurate measurement results over a wider dynamic range.
- Wide measurement bandwidth and high-speed digitizing capture dynamic activity details.
- Data logging mode allows high-speed digitizing over extended time periods.

The battery charge profile measurement results, captured and displayed using the Agilent 14585A software, are shown in Figure 3.

Observations include:

- Charging took place over a 7 hour period.
- Charging current is high-speed pulsing, not DC, as delineated by the min and max envelope traces (visualization realized by the underlying fast measurement digitizing).
- Rather than use a fixed constant current (CC)/constant voltage (CV) charge profile traditionally employed for lithium ion batteries, a tapered current brings the battery to full charge at the point the battery reaches the target float voltage level of 4.199 V.

Based on these results, findings include:

- Fast charging was not a priority. Rather, the slow charging is suited to fully charging the battery on an overnight basis.
- The final charging float voltage of 4.199 volts is considered near optimum for balancing long-term cycle life and amount of charge stored.

As you can see by this example, validating the battery charge profile test yields unique and useful insights that complement the other test methods in optimizing battery life on mobile wireless devices.

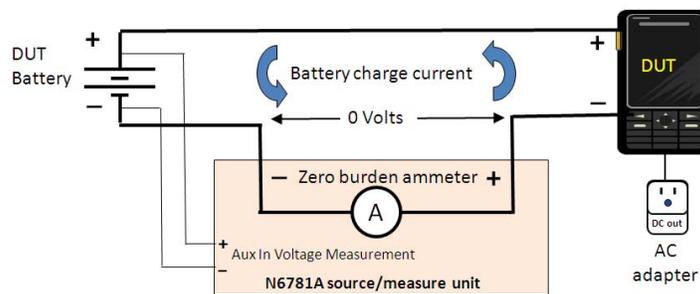


Figure 2. Battery charge profile test setup using the N6781A source/measure unit.

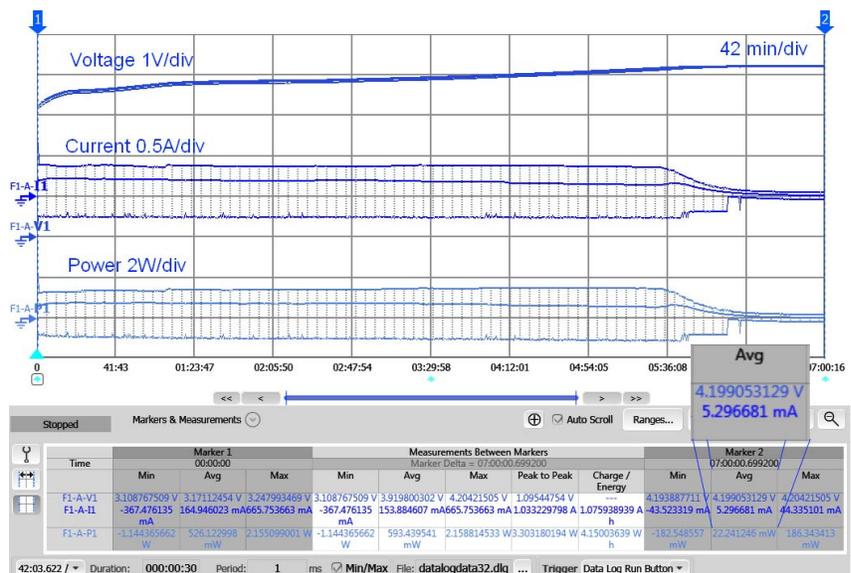


Figure 3. Battery charge profile measurement test results.

TIP

9

Optimize Your Mobile Device's Subcircuits for Battery Run Time

Technical Overview

Measure and analyze power consumption and control of subcircuits to gain greater insights for optimizing your mobile device's battery run time.

Just as it is necessary to measure and analyze your mobile device's overall power consumption for optimizing battery run time, you also need to measure and analyze your device's subcircuits. Often, you will want to do this in conjunction with the overall power consumption to gain further insight on their relationship.

Examples of measuring and analyzing a mobile device's subcircuits include:

- Display illumination power in relation to the contrast and color controls
- Baseband microcontroller voltage and current in relation to its operating state and clock rate when voltage-frequency scaling is used
- RF power amplifier current and voltage in relation to RF transmit power, with additional consideration when dynamic voltage control is used
- Powering on individual subcircuits at the appropriate time for specified operations

All the various subcircuits are most always powered by the power management unit (PMU). The PMU provides independent, regulated bias voltages to each of the subcircuits so they can be individually turned on or off, or their power can be adjusted as needed for power management purposes. Because of this arrangement, it is usually necessary to measure the respective voltage and current powering a subcircuit instead of directly powering it with an external DC source during test.

Measuring subcircuit power consumption requires high-performance, non-invasive measurement logging.

Figure 1 depicts a representative setup for measuring battery input and a subcircuit voltage and current using conventional data acquisition equipment. High-speed digitization of the current is essential, as it provides many detailed insights about activities. Accurate measurement over an extended dynamic range is also essential for obtaining meaningful results because of the wide dynamic operating range and high peak pulse current drains typical of mobile devices and their subcircuits. Individual subcircuits often have much lower minimum currents and therefore may need even greater

dynamic measurement range than the overall device needs. The wide-ranging current drain consumes the instrumentation's dynamic measurement range, limiting achievable accuracy. This becomes even more problematic when you consider the current shunt peak voltage drop should be kept below 50 mV so it does not affect the subcircuit and test results. It is imperative the instrumentation has sufficient gain, dynamic range and accuracy for good results. Conventional data acquisition equipment usually falls short of meeting these requirements.

Additional independent measurement channels are also needed to log the battery and subcircuit voltages simultaneously with their currents. Together they provide the key insights necessary for measuring and analyzing the battery input and subcircuits and PMU control activities of your device.

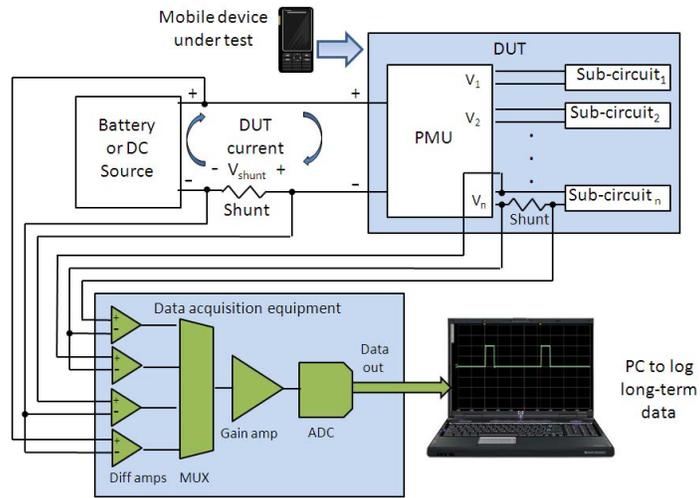


Figure 1. Conventional battery input and subcircuit power test setup

Evaluating the battery input and RF amplifier power on a GPS device.

We evaluated the battery input and RF amplifier subcircuit voltages and currents on a GPS device using two Agilent N6781A 2-quadrant source/measure units, as depicted in Figure 2. The N6781A has a number of unique features and advantages that provide improved accuracy and greater insights for this testing:

- Battery emulation source characteristics provide realistic input power characteristics and more accurate results.
- A “zero burden” shunt operation mode eliminates the voltage drop problem of conventional shunts that are used to measure subcircuit currents powered by low bias voltages.
- An independent DVM input is provided for logging the subcircuit bias voltage.
- Seamless measurement ranging provides accurate current measurement of signals spanning from sub μA to A level in one continuous logging measurement, eliminating the dynamic range and accuracy limitations of conventional, fixed-range instrumentation.
- High-speed, high-resolution waveform capture and data logging capabilities assure accurate measurements for most any pulsed signals you are likely to encounter.

We wanted to validate the battery input power demands and turn-on timing of the RF amplifier of our GPS device. To conserve power, the PMU should power up subcircuits only as needed. The test results, captured and displayed using the Agilent 14585A control and analysis software, are shown in Figure 3. Findings include:

- The battery input drew average and peak currents of 0.290 A and 0.822 A respectively.
- The PMU powered up the RF amplifier at the desired point of operation, as required.

As you can see, evaluating the subcircuits in combination with the overall power consumption is a useful way to gain key insights for optimizing your mobile device’s battery run-time.

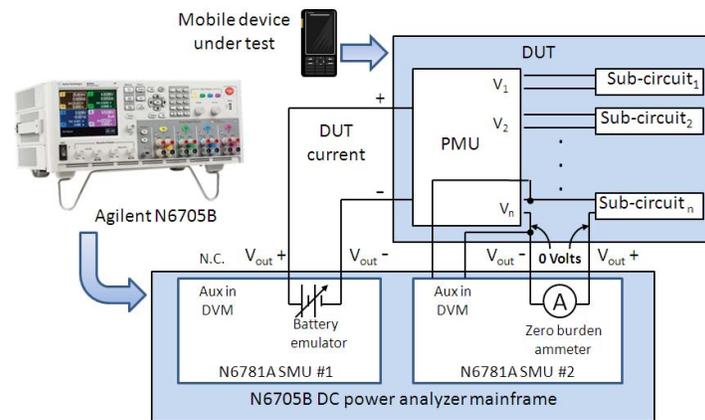


Figure 2. Battery input and subcircuit power test setup using Agilent N6781A source/measure units

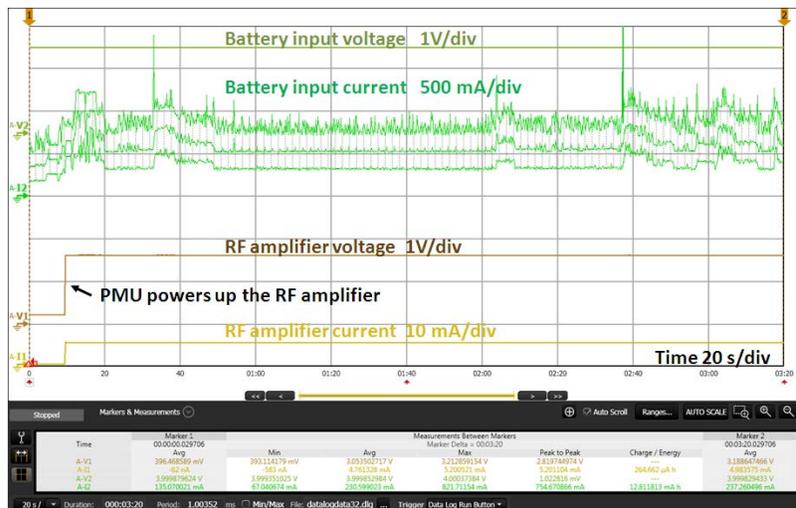


Figure 3. Battery input and subcircuit power test results on a GPS device

TIP 10

Validate Battery Run-time Under Real-world Conditions

Technical Overview

When you are validating battery run-time, conduct testing with realistic user profiles based on how your mobile device is really operated.

Basic talk- and standby-time tests no longer realistically validate battery run-time. Today's smart mobile devices provide a wide variety of innovative data-based applications. Many of these applications run simultaneously. A consequence of all this is battery run-time continues to worsen.

Battery run-time is better defined and validated by user profiles that reflect how mobile devices are realistically operated. Cellular service providers and industry-standard compliance tests are moving in this direction.

Employing realistic user profiles when validating battery run-time will assure your device performs to expectations. Table 1 shows examples of some realistic user profiles.

Table 1. Realistic user profile examples

	Teen	Soccer mom	PC data user	Business user	Grandparent
Data download	10%	10%	70%	20%	5%
Data upload	0%	0%	20%	5%	0%
Content type	http, UDP streaming	http	ftp, http, UDP, streaming	ftp, http,UDP, streaming	http
Voice usage	20%	80%	0%	40%	90%
Modem usage	0%	0%	100%	10%	0%
SMS usage	60%	20%	0%	20%	5%
MMS usage	10%	0%	0%	5%	0%
E-mail	5%	5%	10%	50%	0%
Cell mobility	Range: -95 to -30 dBm Occurrence: 50%	Range: -105 to -30 dBm Occurrence: 70%	Range: -85 to -30 dBm Occurrence: 15%	Range: -105 to -30 dBm Occurrence: 70%	Range: -95 to -30 dBm Occurrence: 50%
Handovers	40%	70%	15%	70%	50%
Back light	40%	70%	15%	70%	50%

Note: Simultaneous activities; not all user profiles are the same sequences of events

Validating battery run-time under real-world conditions requires realistic emulation of user activities and network conditions.

Battery drain is not simply a weighted sum of currents for individual activities. User activities and network conditions take place both simultaneously and sequentially. To achieve realistic results when you are validating battery run-time, the test system needs to emulate these user activities and network conditions in comparable fashion. It needs to log these activities and conditions in conjunction with the battery current drain over a suitable period of time to account for statistical variation. It needs to have sufficient automation to make tests as “turn-key” as possible to quickly and routinely run them when and where needed for reproducibility. It should have flexibility to let you easily modify tests to address new or updated requirements.

Creating such a test system requires a substantial amount of equipment, software, development work, and documentation. This task can be greatly simplified by pairing Agilent’s N5972A interactive functional test (IFT) software and the 8960 or E6621A wireless communications test set with either the 14585A control and analysis software and N6781A source/measure unit or the 14565B device characterization software and 66319D DC source. A representative setup is depicted in Figure 1. You can readily set up and run several activities and conditions, both simultaneously and sequentially,

with the N5972A software to emulate realistic user profiles. The N5972A sets up the 14565B or 14585A software and respective DC source to log your device’s battery drain together with its activities and network conditions. When using the N5972A in its interactive mode, you can automatically generate programming code and drop it into a script editor. The code can then be further enhanced for quickly developing automated tests.

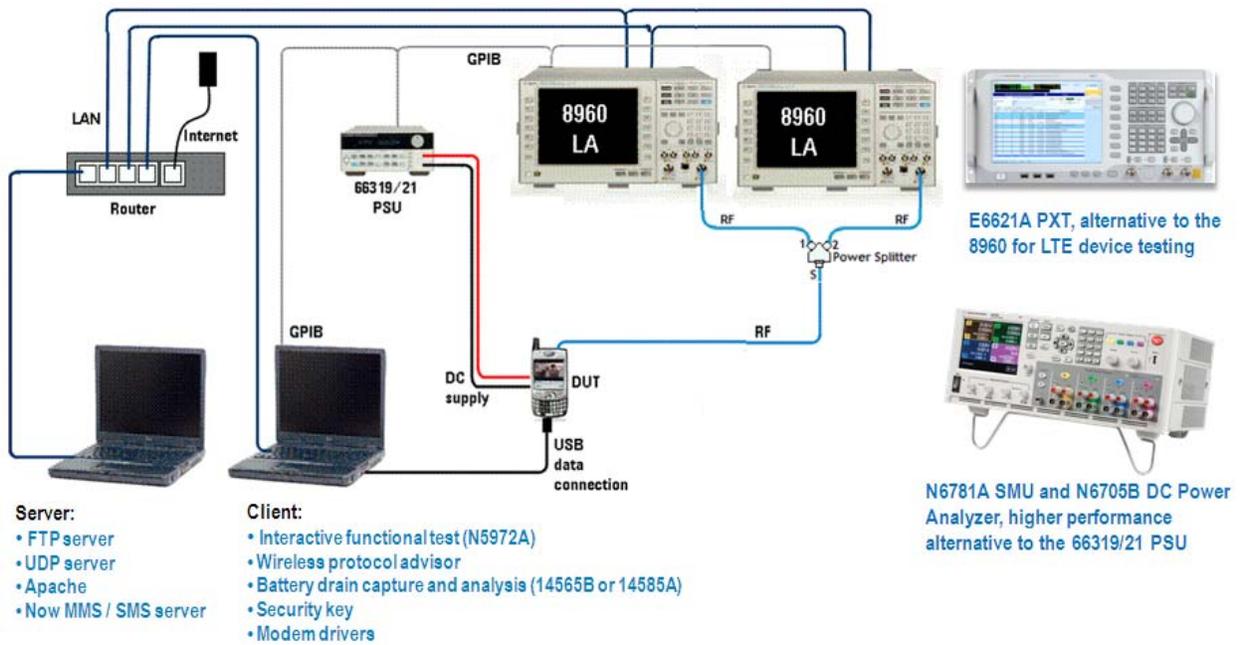


Figure 1. Agilent Technologies Interactive Functional Test (IFT) platform solution

Test results for representative realistic user-profile-based compliance tests.

Long-term battery current drain tests were set up and run on a mobile phone for the teen, soccer mom, and PC data user profiles shown in Table 1, using the test platform in Figure 1. Battery current drain was also taken for talk time and standby time for comparison. There is a considerable

difference in battery run time for the different user profiles, something you would not have been able to accurately estimate based only on the talk and standby battery current drain test results.

Table 2: Battery current drain

	Teen	Soccer mom	PC data user	Talk	Standby
Average current (ma)	389	318	238	343	55
Peak current (ma)	555	819	842	671	656
Peak current (ma)	2.57	3.14	4.20	2.92	18.2

Your smart mobile device is used for a variety of innovative applications that go well beyond just talk and standby operation. Battery run-time continues to worsen as a result. To assure your battery run-time is not a major dissatisfier, base your tests on realistic user profiles that you expect for your device.

Technical Overviews included in this compendium	Literature number
<i>Current Drain Waveforms Yield Deeper Insights on Optimizing Battery Run Time</i>	5990-9261EN
<i>Improving Measurement Accuracy Assures Longer Battery Run Time for Power-saving Modes</i>	5990-9262EN
<i>Analyze Distribution Profiles to Quickly Optimize Battery Run Time</i>	59909263EN
<i>Emulate the Battery for More Realistic Mobile Device Test Results</i>	5990-9651EN
<i>Simplify Validating a Battery’s Capacity and Energy Ratings</i>	5990-9264EN
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<i>Mobile Device Run-down Testing Provides Realistic Assessment of Battery Performance</i>	5990-9266EN
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<i>Validate Battery Run-time Under Real-world Conditions</i>	5990-9900EN



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Revised: January 6, 2012

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Published in USA, May 29, 2012
5991-0160EN



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