Keysight Technologies
Enhance the Battery Life of Your Mobile or Wireless Device

Get the tools you need to measure and analyze dynamic current drain from sub-microamps to amps to deliver exceptional battery life.

KEYSIGHT TECHNOLOGIES

Powering the wireless revolution

The success of the wireless revolution is visible in the number of devices we use every day: smartphones, tablets, e-readers, GPS units, wearable patient monitors, heart-rate monitors, and many more. Some attribute this success to the long-awaited convergence of highly integrated technology, wide bandwidths, application rich content, and attractive pricing.

Of course, the insatiable demand for anytime, anywhere access leads to end-user expectations that increase the pressure on product designers. As an example, visit any product-review page and one of the biggest issues—or opportunities—becomes clear: battery life.

The power challenge stems from two shared issues. One is the need to use power from a battery or low-power DC bus. The other is long periods of standby operation between bursts of intense RF activity. The resulting current drain is pulsed with extremely high peak current, low duty cycle and low average values. Accurately measuring the profile of dynamic current drain can be difficult and challenging with many of today's existing tools.

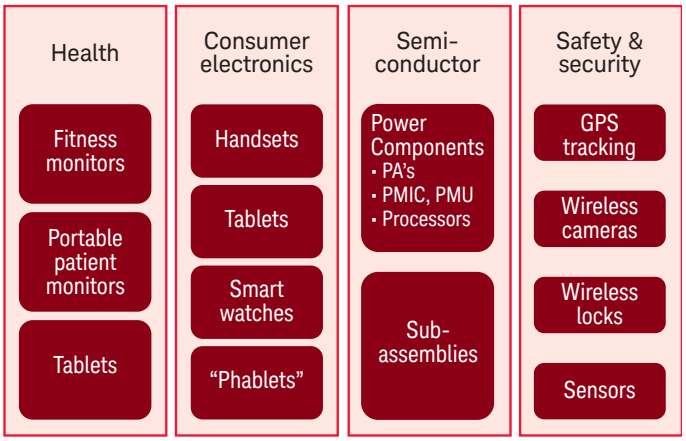

Figure 1. Example markets and devices

Battery Life is Critical to End Users

We can all relate to the anxiety caused when our mobile phone's battery is low. Battery run-time is one of the easiest product characteristics for an end user to recognize.

"*The smartphone spec that matters most – Battery Life*" -Boy Genius Report (May 2014)

"Battery life is the biggest single issue for consumers when choosing a handset" -IDC Survey (May 2014)

"Battery Life is the Only Spec That Matters" -Gizmodo (April 2013)

Scaling the measurement challenge

To maximize battery life, you may use a variety of advanced power-management techniques. For example, subcircuits can be rapidly turned on and off to help reduce overall power consumption. As the device transitions between different operating states, this creates dynamic current consumption that ranges from sub-microamperes to amperes.

Measuring these dynamic changes is essential to understanding power consumption and battery life. However, handling a 1,000,000-to-1 ratio between minimum and maximum current levels is not possible with typical tools: digital multimeters (DMMs), oscilloscopes, current probes, conventional source/measure units (SMUs), or multiple shunt resistors. Using these tools can result in poor results, inaccurate understanding and daily frustration.

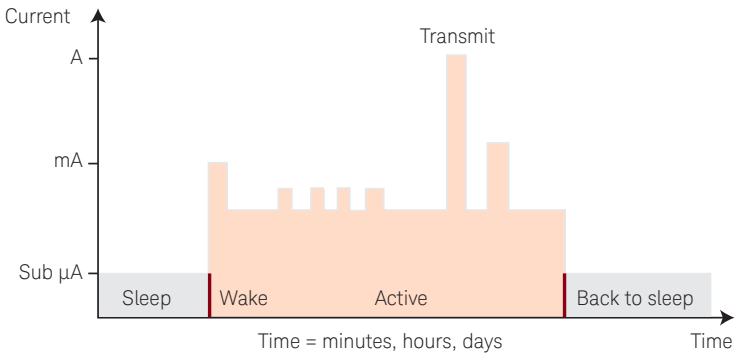

Figure 2. Example current drain profile

Solving the challenge

The old way: Falling short

With today's million-to-one dynamic current ratios, typical solutions fall short in many ways, whether the tool-of-choice is a current probe and oscilloscope, a DMM, a shunt, or an SMU.

Current probe and scope

This is the simplest way to measure dynamic current waveforms. It offers good measurement range, wide bandwidth and time-correlation of events. However, there are three key problems: accuracy depends on the scope's resolution, dynamic range reaches down to just a few milliamps, and periodic zero compensation is needed. Also, this approach isn't suitable for long-term data collection because acquisition is not gap-free.

DMM with autoranging

The methods used in most DMMs can measure a wide range of current levels. However, because most DMMs are designed for low frequencies, they can't handle the pulsed currents found in battery-powered devices. Also, because ranging can take several milliseconds, the DMM may miss part of the current waveform. Worse yet, the input impedance may change during autoranging —and this can make the device-under-test (DUT) lock up, reset or shut down.

Precision shunts with a DMM

These offer good accuracy at any level and can be used to get milliamp-level readings. However, different shunts are required to measure different levels: resistance must be high for low currents and low for high-currents. Further, shunts can add a burden voltage that may affect the measurement results.

Conventional SMUs

With measurements into the picoamp range, these are perhaps the most accurate way to measure steady currents. However, coupling between the output source and measurement subsystem may cause changes in the output current limit—and glitches or voltage drops—during range changes that can interrupt test and damage DUTs.

Custom shunt/digitizer solutions

Long-term current-drain profiles can provide a full picture of device performance under varying operating conditions. This can be achieved by putting a shunt in series between the DUT and a power source, and then connecting the shunt to a digitizer that transfers data to a PC for logging. This works well down to milliamp levels but measurement offset errors and the large shunt resistance make it unusable when standby currents fall well below 1 µA.

The new way: The Keysight N6781A and N6785A

To help you overcome these issues, Keysight Technologies, Inc. has created a purpose-built solution that provides high accuracy and flexible measurement capabilities. The N6781A and N6785A is a two-quadrant SMU module that plugs into the N6705B DC power analyzer mainframe (see page 4).

Serving as both a source (power supply) and measurement device, the N6781A and N6785A provides stable DC output voltage, programmable output resistance and an auxiliary digital voltage meter (DVM). Coupling these features with those listed below, the N6781A and N6785A are today's ideal solution.

Seamless measurement ranging

This patented capability lets you measure and visualize current drain in new and informative ways. A single sweep provides accurate measurements that range from sub-microamps to amps. See page 4 for more.

Current-only measurements (ammeter mode)

This mode lets you connect a battery to the DUT and then simultaneously log the current drain profile along with battery voltage values with no shunt burden voltage.

Fast response DC source

The N6781A and N6785A provides fast recovery times and glitch-free operation when powering dynamic loads. The absence of unexpected output glitches helps ensure proper operation of the DUT.

Battery emulator mode

The source is programmable in terms of DC level and output resistance. This is another capability that helps to more accurately emulate a battery.

Precision constant current or constant voltage load

The ability to operate as a CC or CV load can be used to create battery charge and discharge profiles. This mode includes static and dynamic operation.

Arbitrary waveform generation

For stress testing, user-defined tests, and more, the N6781A and N6785A let you create custom DC power waveforms such as DC bias supply transients and disturbances. See page 8 for more.

READ ON — The capabilities of the N6781A, N6785A, N6705B and the associated 14585A software are described in more detail on the pages that follow.

Presenting the Keysight dynamic current drain solution

The Keysight solution contains three main elements: the N6705B DC Power Analyzer, the N6781A and N6785A 2-quadrant SMU and the 14585A Control and Analysis Software.

Deliver exceptional battery life

Only Keysight's N6780 Series SMUs let you visualize current drain from nA to A in one pass and one picture unlocking insights to deliver exceptional battery life.

- Exceptional sourcing: accurately emulate a battery
- Exceptional measurement: make measurements you didn't think were possible
- Exceptional analysis: see your device's power consumption like never before

Figure 3. N6705B

N6705B DC Power Analyzer

With the ability to accept up to four DC power modules, the N6705B provides unrivalled productivity gains in the sourcing and measuring of DC voltage and current to and from a DUT. It does this by integrating advanced power supplies with DMM, scope, arb, and data logger features. As a result, the N6705B eliminates the need to first gather multiple pieces of test equipment and then create complex test setups—including current probes and shunts—before measuring current into your DUT.

N6781A and N6785A 2-quadrant SMUs for Battery-Drain Analysis

Adding the N6781A or N6785A to the N6705B creates a totally integrated solution that includes DC sourcing and built-in measurement capabilities that simplify the process of battery-drain analysis. Key features include seamless measurement ranging, programmable output resistance and an auxiliary DVM.

Figure 4. N6705B and SMU

14585A Control and Analysis Software

When used with the 14585A software, the N6781A and N6785A becomes an even more powerful solution for battery-drain analysis. Through a familiar PC interface, the 14585A software lets you control the advanced capabilities of the N6705B and the N6781A and N6785A. It also helps you analyze data acquired with the N6705B/N6781A and N6785A: Capabilities include waveform capture, long-term data logging, CCDF statistical analysis, and creation of arbitrary waveforms that range from basic to complex.[1]

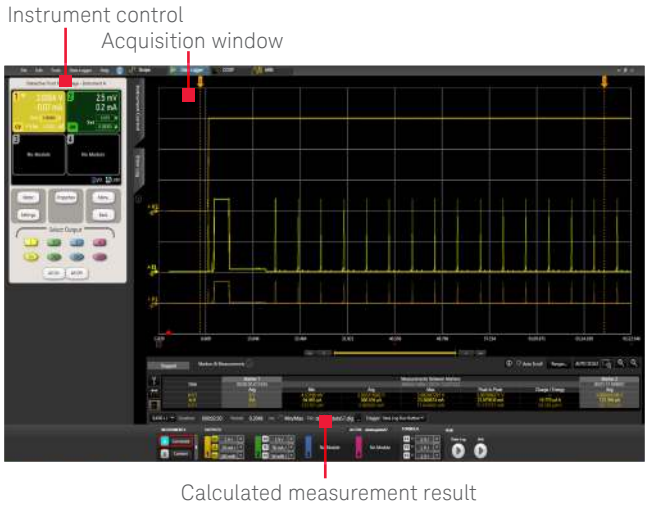

Figure 5. 14585A control and analysis software

1. The 14585A software is available as a free download with a built-in 30-day trial license (www.keysight.com/find/14585); however, a license is required when connecting the software to an N6705B mainframe.

Utilizing seamless measurement ranging

The N6781A and N6785A two-qµAdrant SMU is designed specifically for battery current-drain analysis. These modules have two distinct capabilities:

- A precise, fast-response programmable DC power source
- An innovative seamless measurement system

You can now make measurements you did not think were possible. Using the patented "Seamless Current Ranging" feature in one gapless measurement sweep you can measure:

- Sub µA up to 3A (N6781A)
- Sub µA up to 8A (N6785A)

Now you can very easily measure deep sleep, wake-up, active, transmit pulses, and back to sleep in the all in the same measurement sweep.

In terms of raw numbers, the N6781A and N6785A input ranges provide the following accuracy levels:

Current Range	N6781A	N6785A
8 A	N/A	0.04% + 1.5 mA
3 A	0.03% + 250 µA	N/A
100 mA	0.025% + 10 µA	0.025% + 10 µA
1 mA	0.025% + 100 nA	0.025% + 100 µA
10 µA [2]	0.025% + 8 nA	N/A

For current measurements, the ranging process seamlessly changes between the 8-A, 3-A, 100-mA and 1-mA ranges while maintaining a 200 kSa/s sample rate and measuring each range with an 18-bit digitizer.2 The net effect is eqµAl to a 3-A range with 28-bit resolution and an offset error as low as 100 nA. This level of precision provides the amplitude accuracy and time resolution needed for detailed characterization of current drain.

Long term data logging

Long term datalogging coupled with the "Seamless Measurement Ranging" capability you get the benefit of gapless data log, simultaneously voltage and current measurements with:

- Up to 200 kSa/s
- 20 uSec integration period (underlying 5 uSec samples)
- Log current drain from minutes, hours, days up to 1000 hours
- Enable Markers for current drain profile analysis
- Energy consumption measurements (Ah, Wh, Joules, Coulombs)

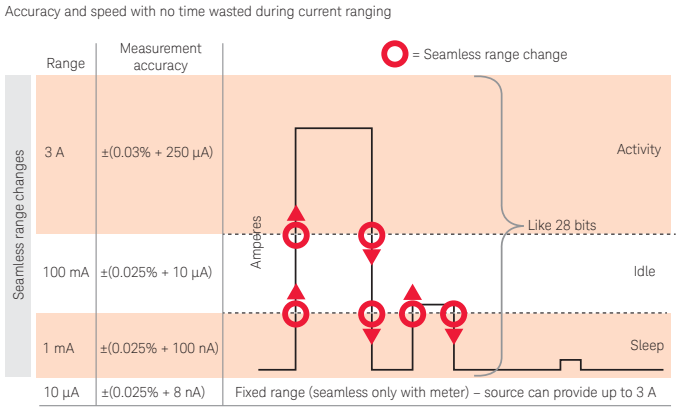

Figure 6a. N6781A/82A SMUs – seamless ranging

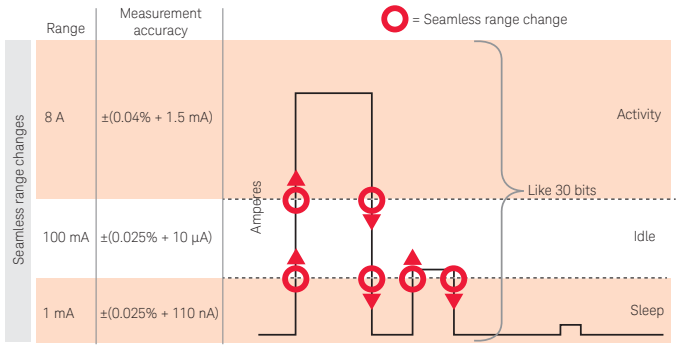

Figure 6b. N6785A/86A SMUs – seamless ranging

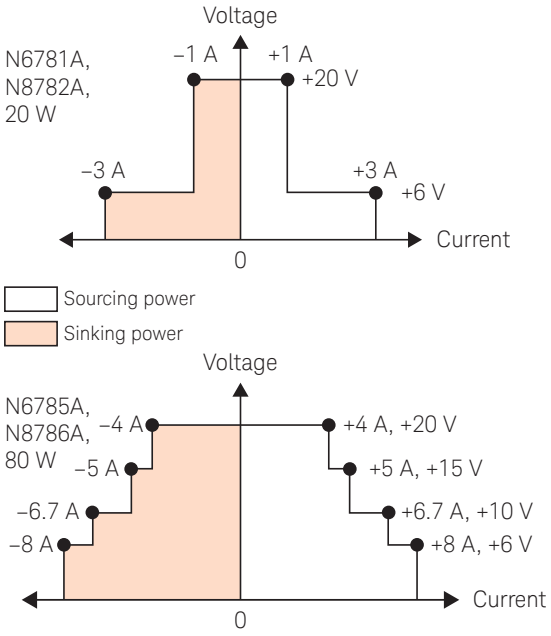

Figure 7. Two-quadrant capability covers a wide range of possible operating points.

2. The seamless-ranging process does not use the 10 µA range.

Exploring the Keysight Solution

The N6705B, N6781A, N6785A and 14585A can be easily configured through a variety of operating modes. This helps you quickly set up the system for specific operating conditions.

N6781A and N6785A battery emulation mode

In this mode the module is set up to act and perform like a battery. You can specify the battery voltage and range as well as the positive and negative current limits.

- N6781A output, voltage and current, +20 V ±1 A or +6 V ±3 A
- N6785A output, voltage and current, +20 V ±4 A or +6 V ±8 A
- Output resistance: programmable from – 40 mΩ -1 Ω

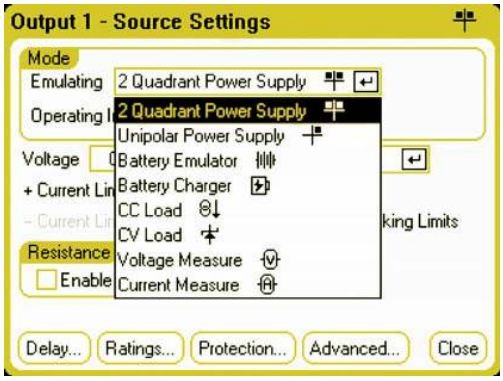

Figure 8. The N6781A and N6785A provides a variety of emulation selections.

N6705B meter view

Each of the N6700 Series DC power modules has its own measurement capability. When the meter view is displayed, the measurement system continuously measures the output voltage and current.

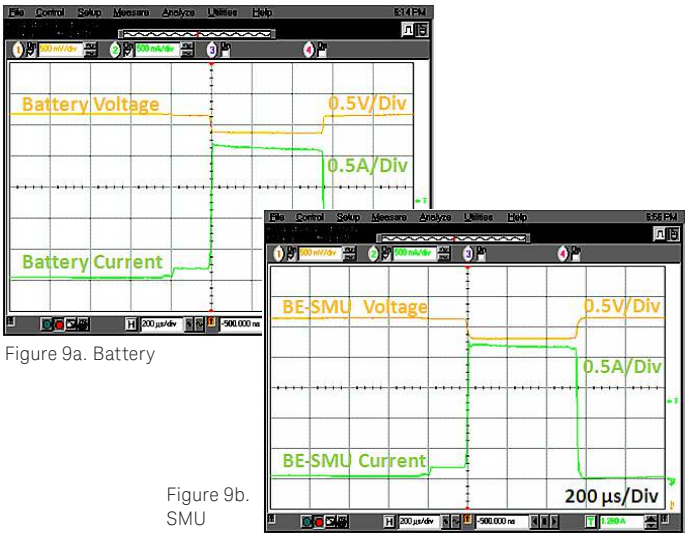

Figure 9a. Battery

Figure 9b. SMU

Figure 9A & Figure 9B. The trace on the left shows an actual GSM current pulse (lower waveform) on a real battery with an internal resistance of 150 mΩ (upper trace is voltage). The trace on the right shows N6781A emulation of the same waveforms with a programmed output resistance of 150 mΩ.

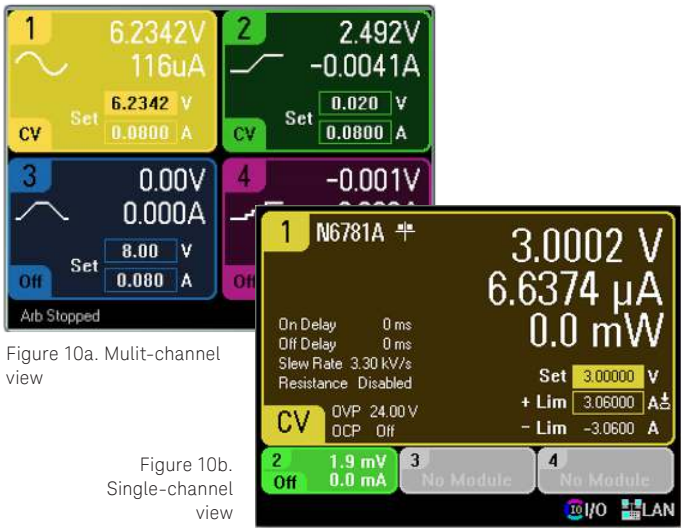

Figure 10a. Mulit-channel view

Figure 10b. Single-channel view

Figure 10a. The meter view shows a summary of all installed DC power modules. Figure 10b. Each summary can be expanded to show more detail.

N6705B scope view

Within the DC power analyzer, this function resembles the capabilities of a benchtop oscilloscope and displays output voltage and current as a function of time. This mode provides scope-like controls: choices of which outputs and functions to display, front panel knobs for adjusting gain and offset, and configurable trigger settings.

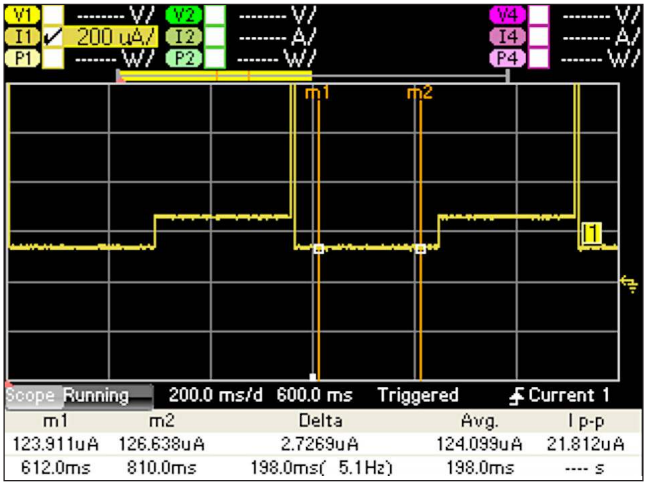

Figure 11. The N6705B scope mode provides familiar controls, displays and marker capabilities.

N6705B data logger view

Using this capability, hours of measurements with a maximum time resolution of 20 µs can be logged to internal memory or an external USB memory stick. Because data-logger measurements integrate multiple samples at 5-µs intervals, there is no risk of losing peak values.

Figure 12. The N6705B data log view makes it easy to scroll through captured signals and zoom in on the details.

14585A CCDF view

To help you analyze distribution profiles, the 14585A software includes a complementary cumulative distribution function (CCDF).[3] This function provides a concise way to display long-term dynamic random current drain. It is also an effective way to quantify the impact of design changes—hardware, firmware or software—on current flows in your device.

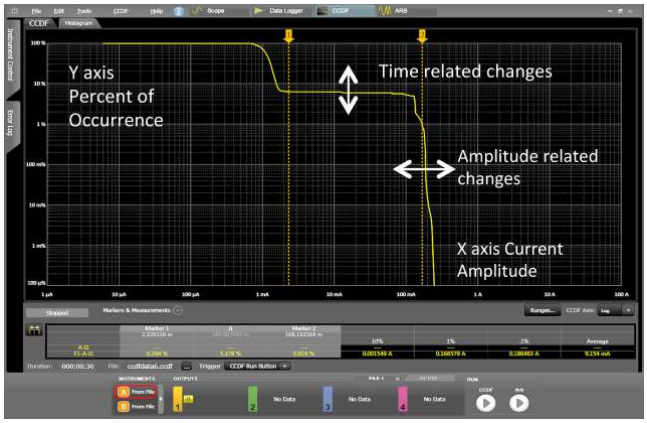

Figure 13. This CCDF measurement reveals the key attributes of standby current in a smartphone.

3. The CCDF value equals (1 – CDF) and the CDF is the area under the probability density function (PDF) curve. Because the CDF ranges from 0 to 100 percent probability, the CCDF ranges from 100 to 0 percent probability.

N6781A and N6785A ARB capability

The arb function can generate voltage or current waveforms based on user-controlled settings such as dwell time, repeat count or continuous output. The AWG has the following characteristics:

- Maximum size of 64,000 waveform points
- Maximum bandwidth of 100 kHz into a resistive load
- 200 kHz digitizer (5 µs sampling)
- Two-quadrant operation

You can also generate arbitrary waveforms using the 14585A software. As shown in Figure 13, the lower part of the screen includes a variety of built-in wave shapes and formula-based arbs. You can also create user-defined waveforms: the wave shape is drawn automatically (lower right) as you enter the waveform parameters (lower center).

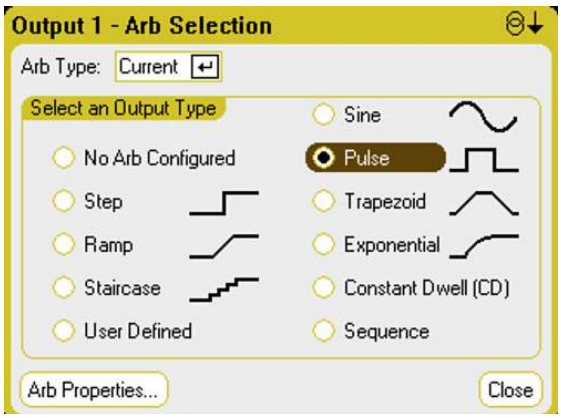

Figure 14. To help you save time, the arb selection screen provides a variety of preconfigured output types.

Figure 15. The 14585A software provides an interactive environment for creation of arbitrary waveforms.

14585A control and analysis software

- Compliments N6705B front panel by controlling instrument through PC
- Supports all N6700 family of power modules
- Extends N6705B features
  - Larger scope and data logger display
  - More traces and user can select trace names and colors
  - Easily access built-in Arbitrary waveform generation
- Adds new capabilities
  - Data log direct to disk
  - Import N6705B data log at fastest rate (20 usec integration period)
  - Record waveform and then playback
  - Battery run down test, energy consumption measurements
  - CCDF view (statistical analysis of complex current drain profiles)

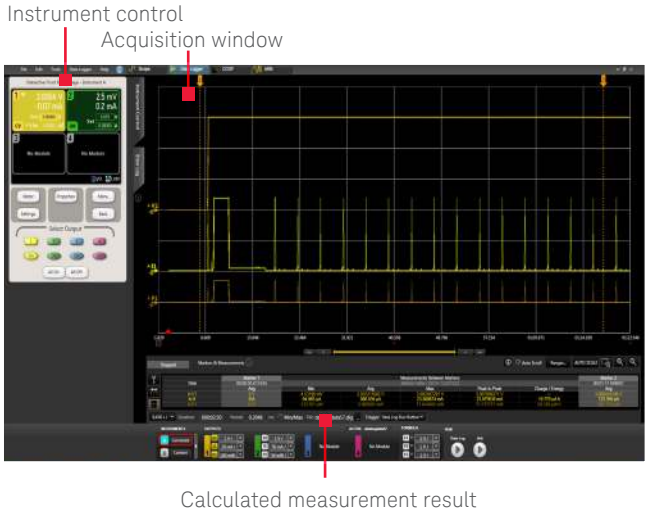

Figure 16. 14585A control and analysis software

Exploring applications

A few examples will illustrate the types of measurements that are possible with an N6781A or an N6785A-based solution.

The examples use the following test configuration:

- N6705B DC power analyzer
- N6781A two-quadrant SMU power module
- Twisted-pair cables for source and sense leads (four-wire operation)

Once the DUT is connected, you can configure the N6781A settings and start using the built-in measurement capabilities: meter, scope, data logger, and so on. It really is that easy.

Figure 17

Application: BATTERY RUN-DOWN TESTING

Using a real battery will help reveal how a device behaves as a system—and if it operates as expected in terms of low-voltage conditions, battery life and more. In the figure, a battery powers the DUT and the N6781A or N6785A are connected in series to make the current-drain measurement. This uses the ammeter emulation mode in which the N6781A and N6785A serve as a measurement-only device.

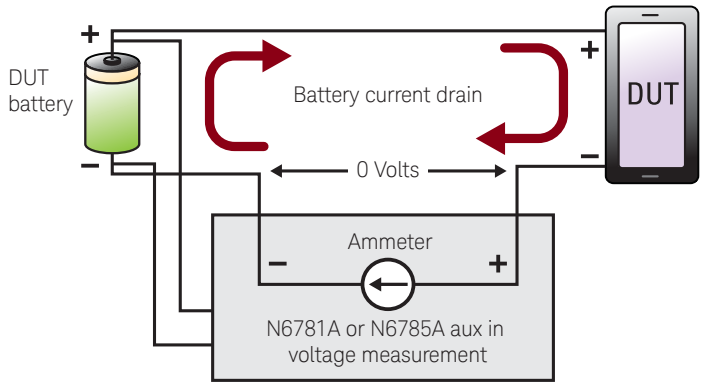

Figure 18

By automatically regulating a zero-volt drop across the module, this mode turns the N6781A/N6785A into a zero-burden ammeter and eliminates the problems that typically occur with shunt resistors in traditional setups. The N6781A and N6785A also offer an auxiliary DVM that can be connected across the battery to analyze voltage fluctuation.

As shown in Figure 19, you can place markers on the current drain profile. To help you achieve useful insights into DUT behavior, readouts are presented as minimum, average and maximum volts, amps and watts. This example produced the following results:

- I_{avg} = 233 mA
- V_{avg} = 3.82 V
- Charge = 843 mA-h
- Energy = 3.19 W-h
- Run time = 3 hr 38 min
- $V_{shutdown}$ = 3.44 V

Figure 19. Battery run down test result

Key points

- Gapless 3 hour 38 minute data log
- Simultaneously V & I measurements
- All calculations based on marker positions
- User can define trace names and trace colors

applications *continued*

Application:
BATTERY DISCHARGE OPERATION

You can configure the N6781A or N6785A SMU to operate as an advanced electronic load that ensures the DUT will draw a steady-state DC current. You can also set the current level to be drawn from a battery and the module will sink that current from the battery.

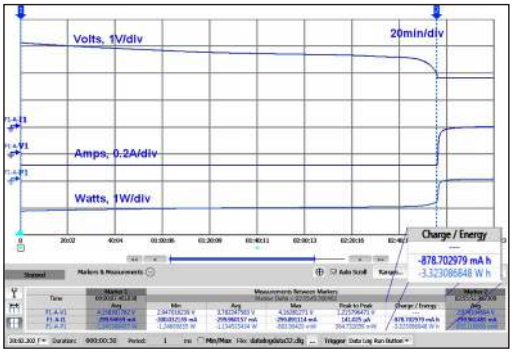

Figure 20. The 14585A software presents battery-discharge results in an easy-to-read format.

Application:
BATTERY CHARGER CIRCUIT TESTING

This mode lets you specify the charge voltage and range as well as the positive current limit. Note: Because the charger can only source current, the voltage and current settings are limited to positive values.

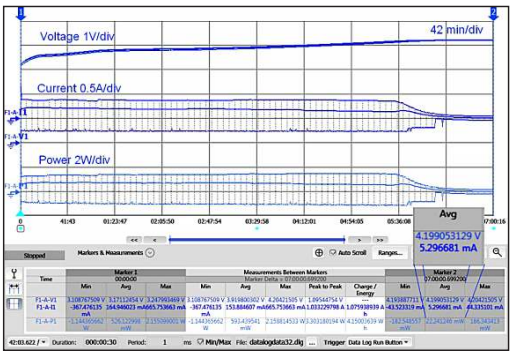

Figure 21. The 14585A software includes a variety of useful information with battery-charger test results.

Application:
PULSED CURRENT LOADING

With the built-in ARB capability, you can generate pulse-load patterns to simulate real-world pulses that would be drawn from a battery. For example, you could use a specific pulsed current pattern to ensure consistent testing during qualification of batteries from different vendors. The example here shows a continuous -30 mA to -300 mA pulse with a 5 percent duty cycle.

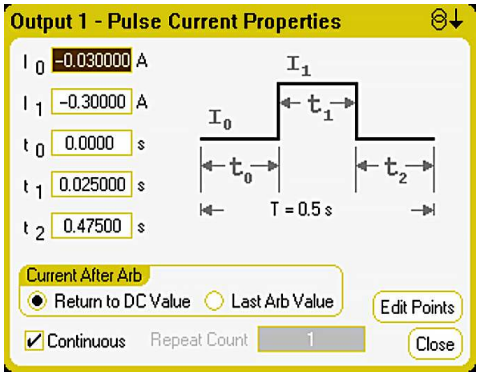

Figure 22. The N6705B makes it easy to enter pulse-load properties.

Application:
DC-DC CONVERTER TEST

Designers need to validate and characterize their DC-DC converter and regulator designs. Typical measurements include, power efficiency vs load current vrs input voltage, line and load regulation, start-up and shut down times

The Keysight one box solution provides:

- Precision source and precision sink capability
- Integrated voltage and current measurements
- Ammeter does not influence the circuit impedance
- Voltage and current ARB functionality
- Better accuracy and faster than collection of instruments

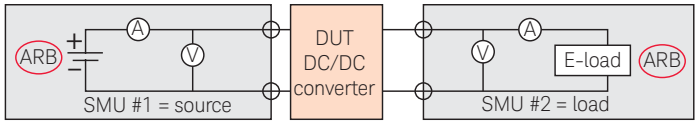

Figure 23. DC-DC converter test block diagram

applications *continued*

Application: MEASURING SUBCIRCUIT CURRENT DRAIN

A typical wireless device has several subcircuits that may be powered by a power-management integrated circuit (PMIC) or power-management unit (PMU). In this example, a PMU provided bias voltages—independent and regulated—to each subcircuit. This made it possible to adjust the power to each subcircuit, and turn each one on or off, as needed.

As shown in the diagram, the test configuration used two N6781A SMU modules within an N6705B mainframe. Channel 1 was the battery emulator, which also measured total current drain. Channel 2 was configured in "current measure only" mode and recorded the subcircuit current drain.

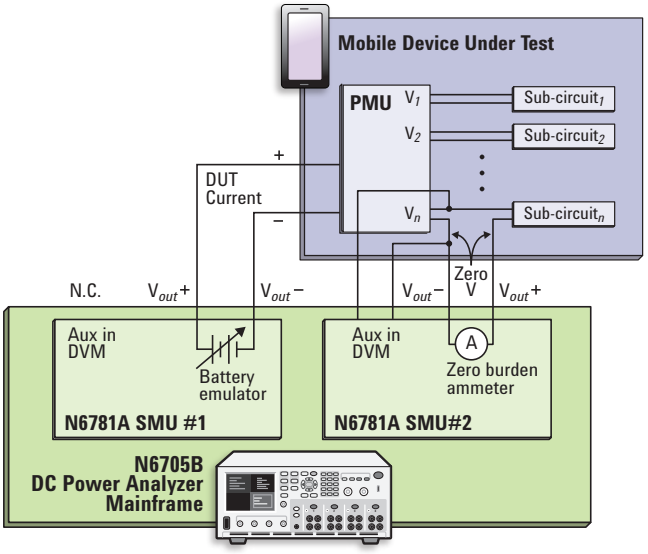

Figure 24. This test configuration can be used to measure current drain from multiple subcircuits within a single DUT.

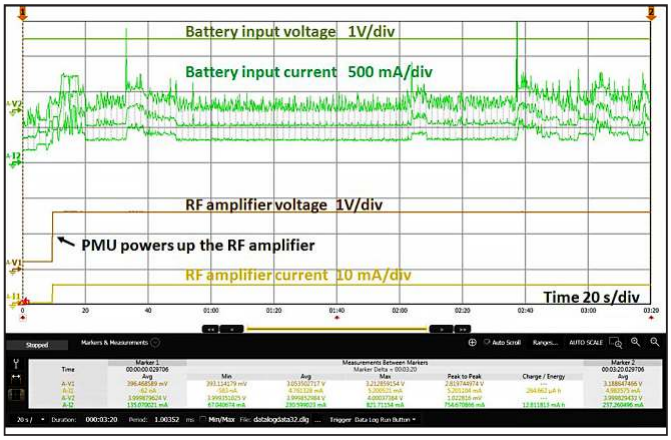

Figure 25. This trace from the 14585A software shows the types of measurement results that are possible with the example configuration.

Application: FUNCTIONAL TEST OF POWER COMPONENTS AND MODULES

Functional test of RF PA's, RF Chipsets, BT/WLAN/GPS modules, and DC-DC converters can be fully automated by selecting the N6700B Modular Power System mainframe and the N6782A or N6786A SMU modules. Modern I/O consisting of LAN/USB/GPIB, 1U high 4 slot mainframe, and fast programming make for a very compact and functional test system.

More information

N6781A specifications
www.keysight.com/find/N6781A

N6782A specifications
www.keysight.com/find/N6782

N6785A specifications
www.keysight.com/find/N6785A

N6786A specifications
www.keysight.com/find/N6786A

N6705B Users guide
www.keysight.com/find/N6705B

14585A Control and Analysis sw
www.keysight.com/find/14585A

N6700B Family Specifications Guide
http://literature.cdn.keysight.com/litweb/pdf/N6700-90001.pdf

10 Tips to Optimize a Mobile Device's Battery Life
http://literature.cdn.keysight.com/litweb/pdf/5991-0160EN.pdf

N6700 Family Brochure
http://literature.cdn.keysight.com/litweb/pdf/5990-9555EN.pdf

For Functional Test applications consider the Keysight N6700 low-profile mainframes with similar capabilities in a small 1U footprint.

N6700 modular power system

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