PRODUCT BROCHURE

Enhance the Battery Life

Of Your Mobile or Wireless Devices

KEYSIGHT

Introduction

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

As a growing number of electronic devices are designed to be portable and integrated with various features, battery runtime has emerged as a crucial differentiator between products and a critical factor in ensuring customer satisfaction.

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

Powering the Wireless Revolution

The success of the wireless revolution is visible in the number of devices we use daily: 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 any time anywhere access leads to end-user expectations that increase pressure on product designers. For example, visit any product-review page, and one of the most significant issues—or opportunities—becomes apparent: battery life.

The power challenge stems from two shared issues. One is to use power from a battery or a low-power DC bus, and 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 complex and challenging with many of today's existing tools.

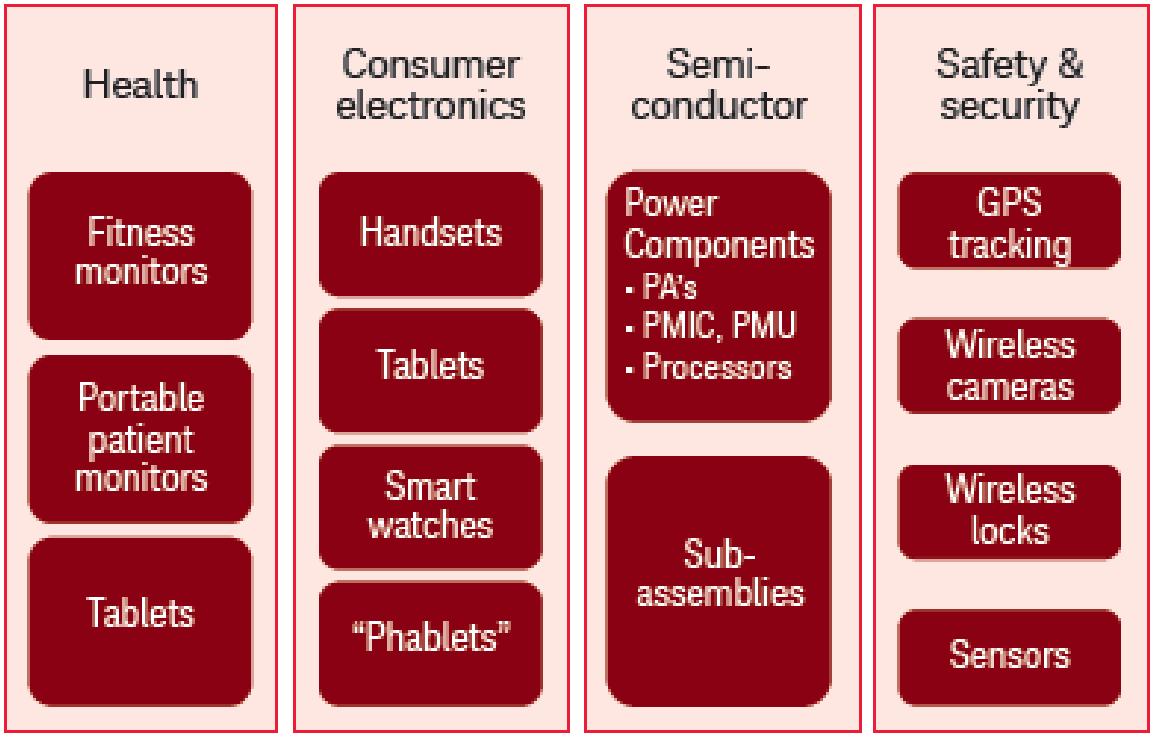

Figure 1. Example markets and devices

Battery life is critical to end users

We can all relate to the anxiety caused by our mobile phones when the battery is low. Battery runtime 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 various advanced power-management techniques. For example, you can rapidly turn on and off the subcircuits to 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 impossible with standard 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 frustration.

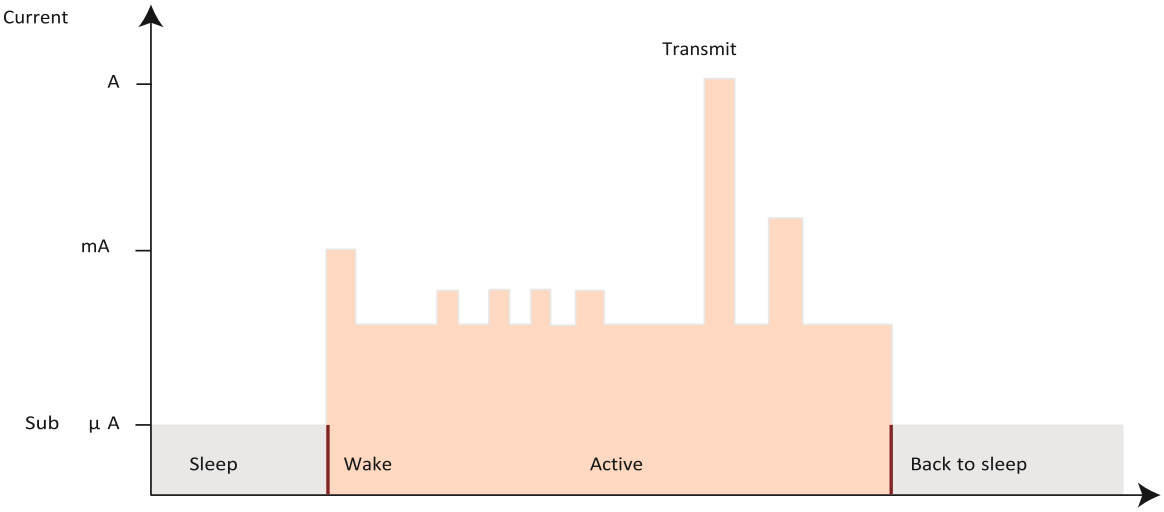

Figure 2. Example current drain profile

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 a good measurement range, wide bandwidth, and time-correlation of events. However, there are three significant drawbacks: 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 auto-ranging

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 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 auto-ranging —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. Furthermore, shunts can add a burden voltage that may affect the measurement results.

Conventional SMUs

These measurements into the picoamp range 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 tests and damage DUTs.

Custom shunt/digitizer solutions

Long-term current-drain profiles can provide a complete 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 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 are two-quadrant SMU modules that plug into the N6705C DC power analyzer mainframe (see page 8).

Serving as both a source (power supply) and measurement device, the N6781A and N6785A provide 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 solutions.

Seamless measurement ranging

This patented capability lets you measure and visualize the current drain in new and informative ways. A single sweep provides accurate measurements that range from sub-microamps to amps. See page 6 for more info.

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 provide fast recovery times and glitch-free operation when powering dynamic loads. The absence of unexpected output glitches helps ensure the 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 emulate a battery more accurately.

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 operations.

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 14 for more info.

Presenting the Keysight Dynamic Current Drain Solution

The Keysight solution contains four elements: the N6705C DC Power Analyzer, N6781A, N6785A 2-quadrant SMU, and Pathwave BenchVue BV9200B and BV9210B.

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

N6705C DC power analyzer

With the ability to accept up to four DC power modules, the N6705 provides unrivaled productivity gains in sourcing and measuring DC voltage and current to and from a DUT. It integrates advanced power supplies with DMM, Scope, arb, and data logger features. As a result, the N6705 eliminates the need to gather multiple pieces of test equipment first and then create complex test setups—including current probes and shunts— before measuring current into your DUT.

Figure 3. N6705C DC power analyzer

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

Adding the N6781A or N6785A to the N6705 creates an 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

Pathwave BenchVue BV9200B and BV9201B

When used with the Pathwave BenchVue BV9200B and BV9201B software, the N6781A and N6785A become even more powerful battery-drain analysis solutions. Through a familiar PC interface, the BV9200B/ BV9201B software lets you control the advanced capabilities of the N6705, the N6781A, and N6785A. It also helps you analyze data acquired with the N6705/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.

Figure 4a. Pathwave BenchVue BV9200B/ BV9201B software

Pathwave BenchVue BV9210B and BV9211B

The Keysight BV9210B Pathwave BenchVue Advanced Battery Test and Emulation application software provides critical functions for testing battery performance. It generates battery models that the software can use for battery emulation utilizing one or more Keysight two-quadrant power supplies. The BV9210B/BV9211B is compatible with power supply models N6705C, N6781A, N6785A, and several others.

Figure 4b. Pathwave BenchVue BV9210B / BV9211B software

For more information

For more information about the Pathwave BenchVue BV9210B, go to www.keysight.com/us/en/product/BV9210B/advanced-battery-test-and-emulation-software-for-multiple-instru.html

For more information about the Pathwave BenchVue BV9211B, go to www.keysight.com/us/en/product/BV9211B/advanced-battery-test-and-emulation-software-for-a-single-instrument.html

Utilizing Seamless Measurement Ranging

The N6781A and N6785A two-quadrant SMU are explicitly designed 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)

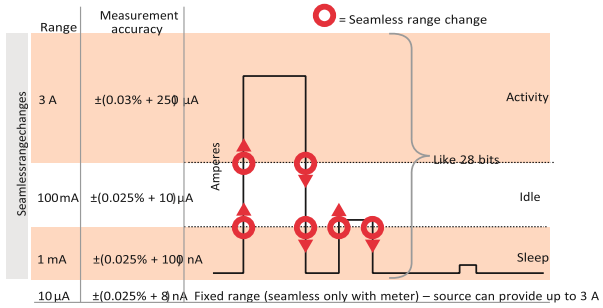

Figure 5a. N6781A/82A SMUs – seamless ranging

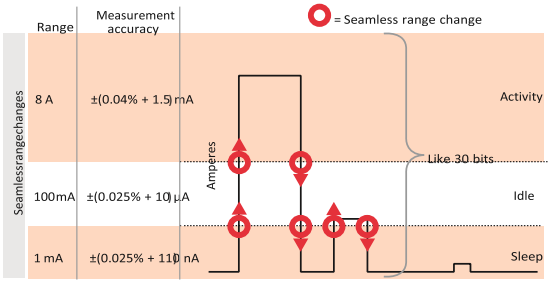

Figure 5b. N6785A/86A SMUs – seamless ranging

You can now quickly measure deep sleep, wake-up, active, transmit pulses, and back to sleep, 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[1]	0.025% + 8 nA	N/A

Note:
1. The seamless-ranging process does not use the 10 µA range

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 equal 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 the current drain.

Long-term data logging

Long-term data logging 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, and days up to 1000 hours
- Enable Markers for current drain profile analysis
- Energy consumption measurements (Ah, Wh, Joules, Coulombs)

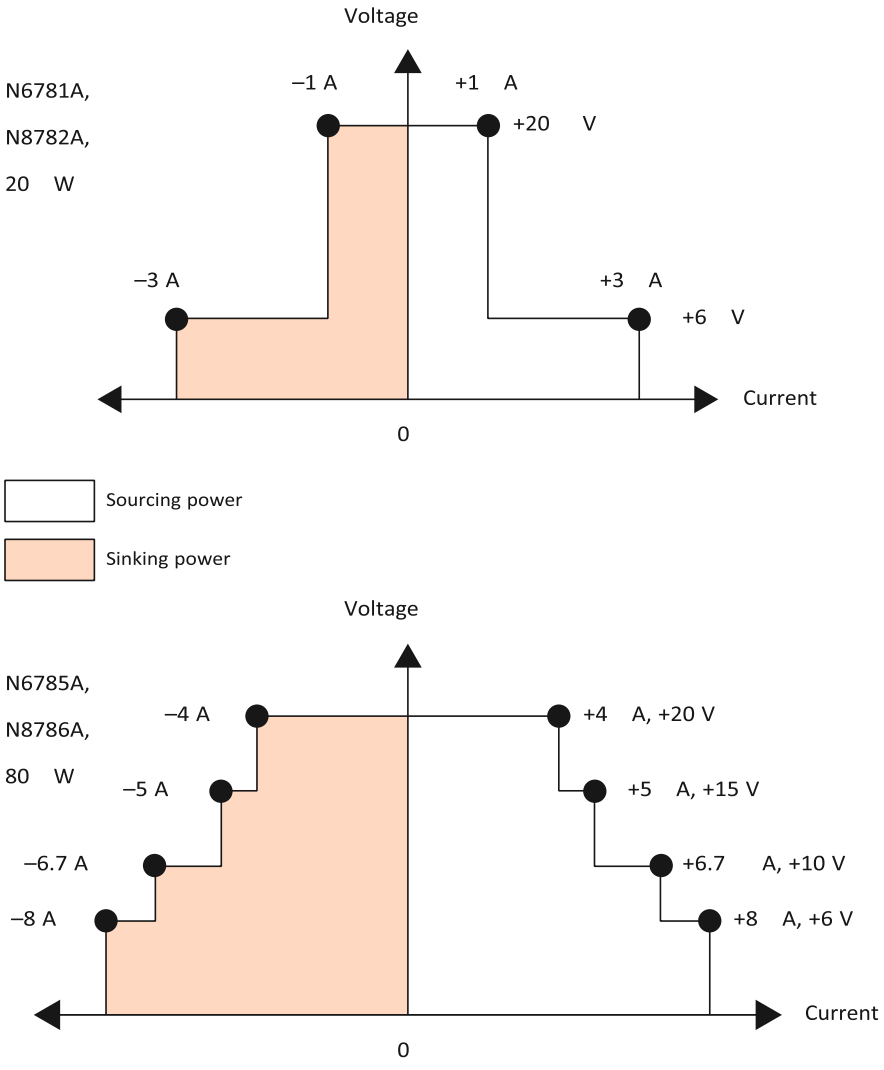

Figure 6. Two-quadrant capability covers a wide range of possible operating points

Exploring the Keysight Solution

You can easily configure the N6705, N6781A, N6785A, BV9200B, and BV9210B through various operating modes to help you to easily and quickly set up the system for specific operating conditions.

N6781A and N6785A battery emulation mode

The module is set up in this mode 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

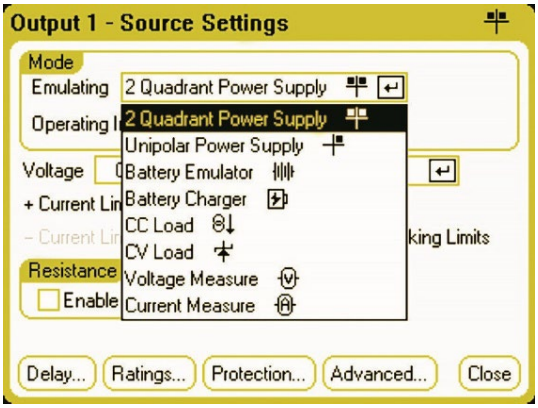

Figure 7. The N6781A and N6785A provide a variety of emulation selections

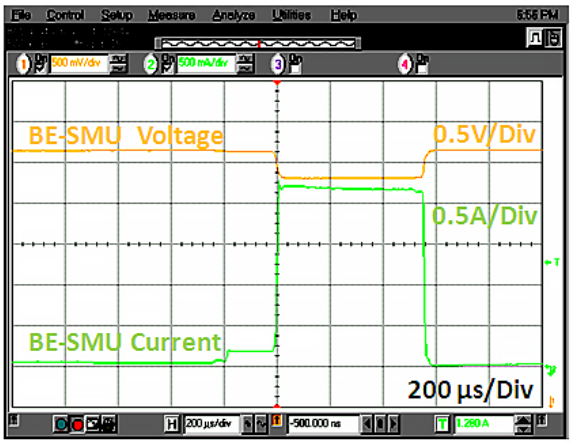

Figure 8a. Battery

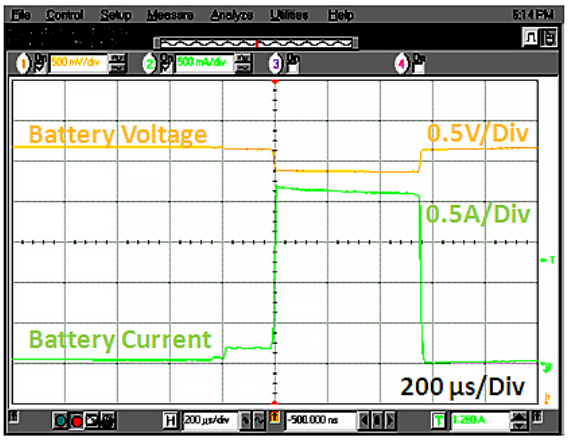

Figure 8b. SMU

Figure 8A & **Figure 8B**. 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.

N6705 meter view

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

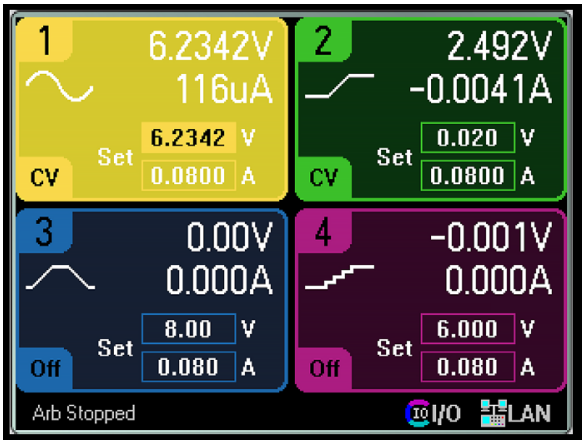

Figure 9a. The meter view shows a summary of all installed DC power modules.

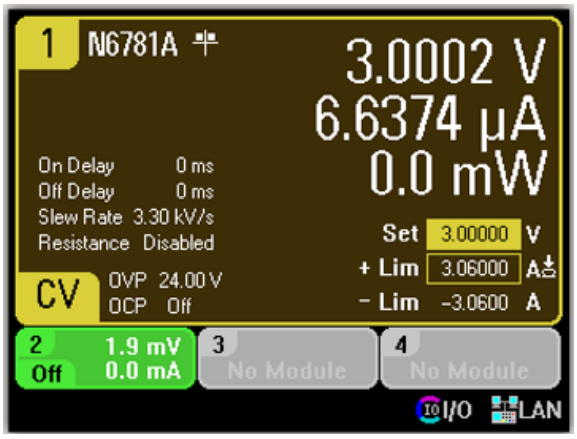

Figure 9b. Expand each summary to show more detail.

N6705 scope view

Within the DC power analyzer, this function resembles the capabilities of a benchtop oscilloscope. It 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.

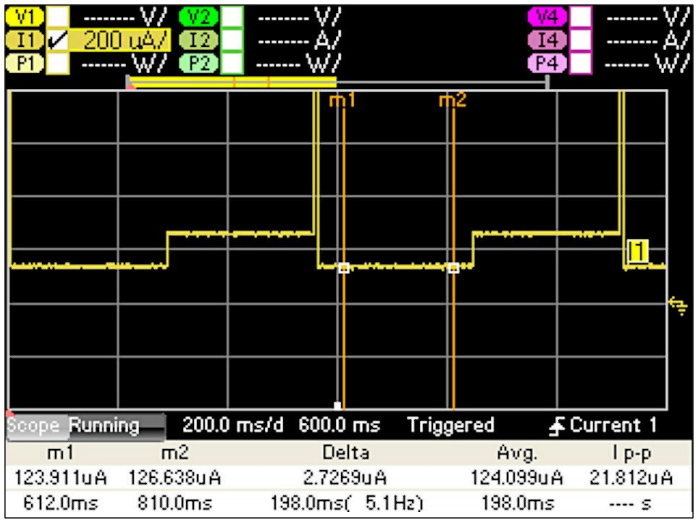

Figure 10. The N6705 scope mode provides familiar controls, displays, and marker capabilities

N6705 data logger view

N6705 data logger view lets you log hours of measurements with a maximum time resolution of 20 µs 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.

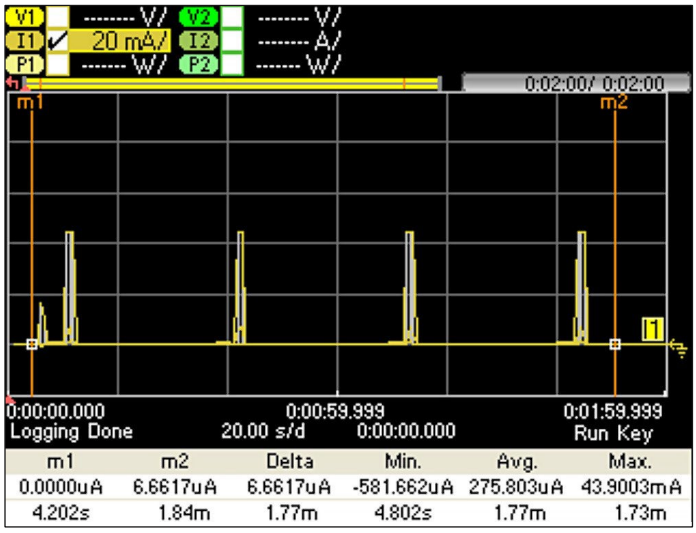

Figure 11. The data log view makes it easy to scroll through captured signals and zoom in on the details

BV9200B and BV9201B CCDF view

In order to help you analyze distribution profiles, the Pathwave BenchVue BV9200B software includes a complementary cumulative distribution function (CCDF)[1]. 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 12. This CCDF measurement reveals the key attributes of standby current in a smartphone.

[1] 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 Pathwave BenchVue BV9200B software. As shown in Figure 14, the screen's lower part includes various 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).

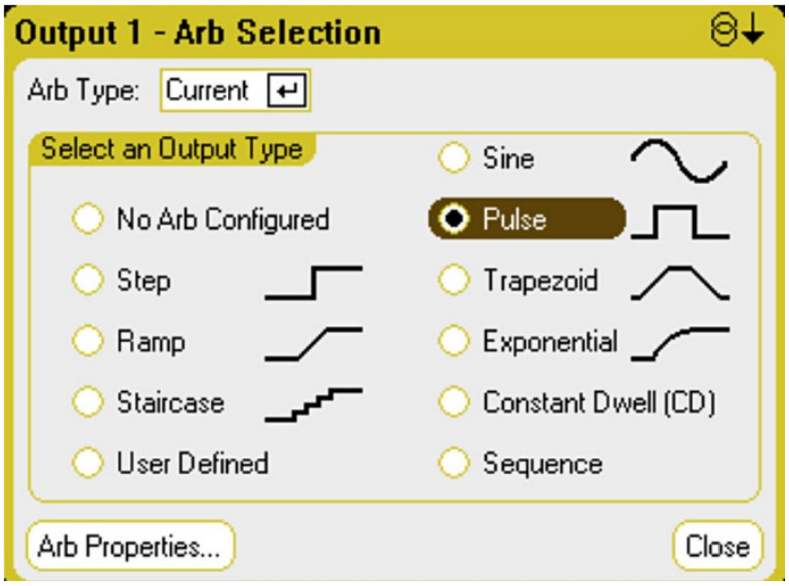

Figure 13. The arb selection screen provides a variety of preconfigured output types to help you save time.

Pathwave BenchVue BV9200B and BV9201B

- The BV9201B will allow the user to control a single instrument. In contrast, the BV9200B will allow users to control up to four instruments simultaneously.
- Compliments N6705 front panel by controlling instrument through PC
- Supports all N6700 family of power modules
- Extends N6705 features
  - Larger scope and data logger display
  - More traces and users can select trace names and colors
  - Easily access built-in Arbitrary waveform generation
- Adds new capabilities
  - Datalog measurements directly to a PC
  - Import N6705 data log at the fastest rate (20 usec integration period)
  - Record waveform and then playback
  - Battery run-down test, energy consumption measurements
  - Apply mathematic functions to waveforms
  - Perform statistical analysis (CCDF) of current consumption
  - API call functionality

Figure 14. Pathwave BenchVue B9200B and B9201B control and analysis software

Exploring Applications

A few examples will illustrate the types of measurements that are possible with an N6781A or N6785A coupled with BV9200B and BV9210B-based solution

The examples use the following test configuration:

- N6705C DC power analyzer
- N6781A or N6785A two-quadrant SMU power module
- Pathwave BenchVue BV9200B or BV9210B
- Twisted-pair cables for source and sense leads (four-wire operation)

After connecting the DUT, you can configure the N6781A/N6785A settings and begin using the built-in measurement capabilities, such as the meter, scope, and data logger, among other things. It is as simple as that.

Figure 15.N6705C DC power analyzer, N6781A Two-quadrant SMU power module, Pathwave BenchVue BV9200B, and BV9210B

In the following few pages, we will explore some of the applications that make use of the above-mentioned software and hardware.

- Battery run-down testing
- Battery emulation with BV9210B/BV9211B
- Pulsed current loading
- DC-DC converter test
- Measuring subcircuit current drain
- Functional test of power components and modules

Application: battery run-down testing

Using an actual 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. The figure below shows that the 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 measurement-only devices.

This mode automatically regulates a zero-volt drop across the module, turning the N6781A/N6785A into a zero-burden ammeter. It 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.

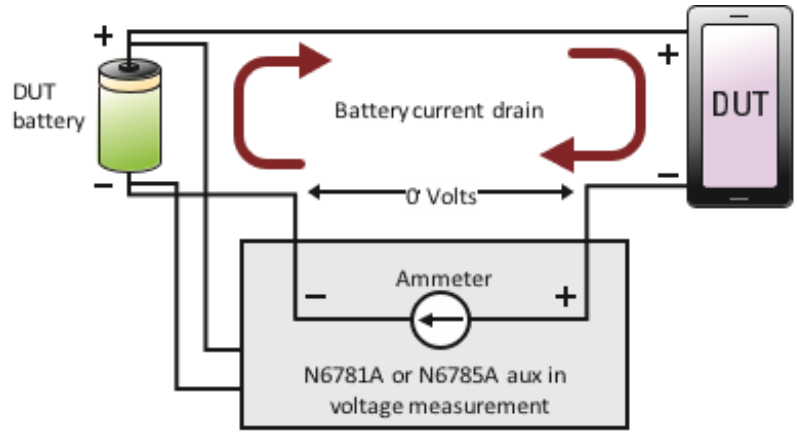

Figure 16. Battery run-down application diagram

Key Points

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

Alternatively, a detailed characterization of battery current drain offers more profound insights into the device's operation. It can be done with BV9200B software in conjunction with the N6781/5A source and measure unit. The N6781A/5A are specialized battery emulator DC sources designed for powering a device and measuring its current drain from µA to A at a digitization rate of over 195 KSample/sec. With a wide dynamic measurement range and high-speed digitizing, it quickly provides deeper insights for optimizing battery run time.

For more information

Refer to this technical overview to learn more www.keysight.com/us/en/assets/7018-03184/technical-overviews/5990-9261.pdf

Application: battery emulation with BV9210B/BV9211B

Using an actual battery can help you understand how a device works as a whole. However, we must continue testing the battery under various operating conditions to cover a wide range of test scenarios, and using an actual battery for this purpose would be highly inefficient. The BV9210/11B allows you to emulate the battery in various operating conditions using one or more Keysight N6780 series two-quadrant power supplies. This method eliminates the need to wait for an actual battery to be charged or discharged before conducting various tests.

To emulate battery characteristics, start by loading a battery model into BV9210B/11B software, and the software algorithm will then follow the battery model in real-time and emulate the battery's behavior. The software allows two methods for battery models—open profiles generated by the software or importing external battery models with Voc, SoC, and Ri parameters in a CSV file. For simplicity, you will only need to enter four parameters to emulate a battery – capacity rating, current limit, initial SoC, and a cut-off condition.

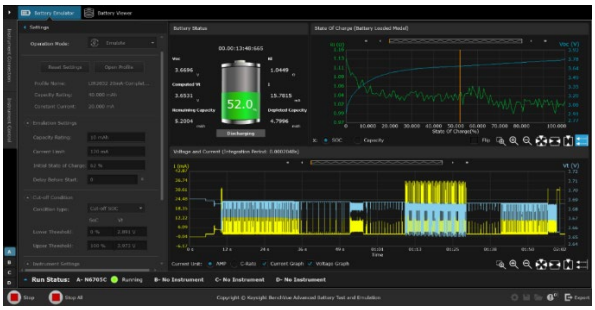

Figure 17. BV9210B emulating lithium battery powering a low-power device.

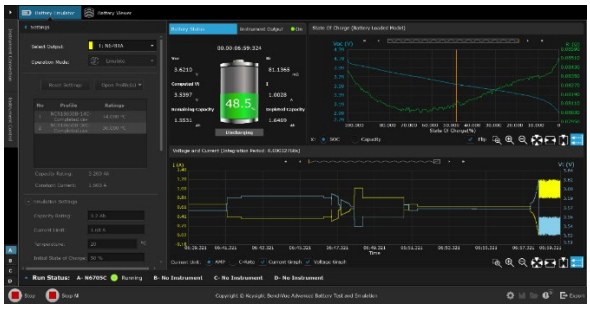

Figure 18. BV9210B emulating multiple battery models at different temperatures.

The BV9210B/11B can continuously measure voltage and current while emulating a battery and store the measurement results. Additionally, the software allows you to load multiple battery models created at different temperatures.

For more information

For more information about the Keysight BV9210/11B Pathwave BenchVue Advanced Battery Test and Emulation, visit:

www.keysight.com/us/en/assets/3121-1066/data-sheets/BV9210B-PathWave-BenchVue-Advanced-Battery-Test-and-Emulation-Software.pdf

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 the qualification of batteries from different vendors. The example here shows a continuous -30 mA to -300 mA pulse with a 5 percent duty cycle.

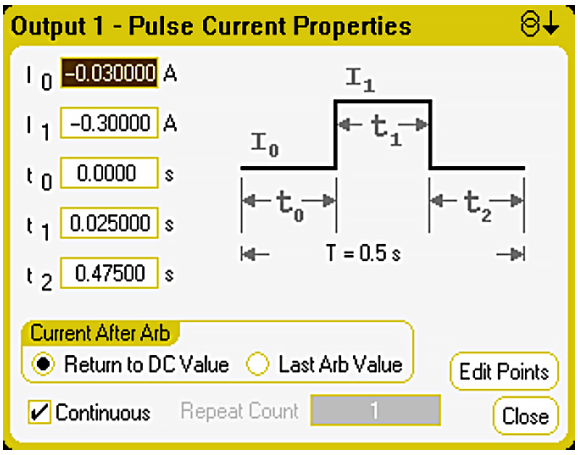

Figure 19. The N6705 makes it easy to enter pulse-load properties

Application: DC-DC converter test

Designers need to validate and characterize their DC-DC converter and regulator designs. Typical measurements include power efficiency, load current, input voltage, line and load regulation, start-up, and shutdown 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 a collection of instruments

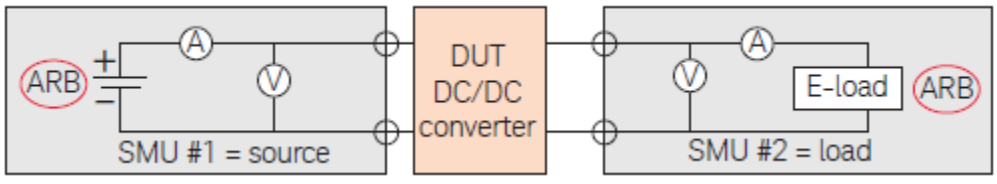

Figure 20. DC-DC converter test block diagram

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. The diagram shows that the test configuration used two N6781A SMU modules within an N6705 mainframe. Channel 1 was the battery emulator, measuring the total current drain. Channel 2 was configured in "current measure only" mode and recorded the subcircuit current drain.

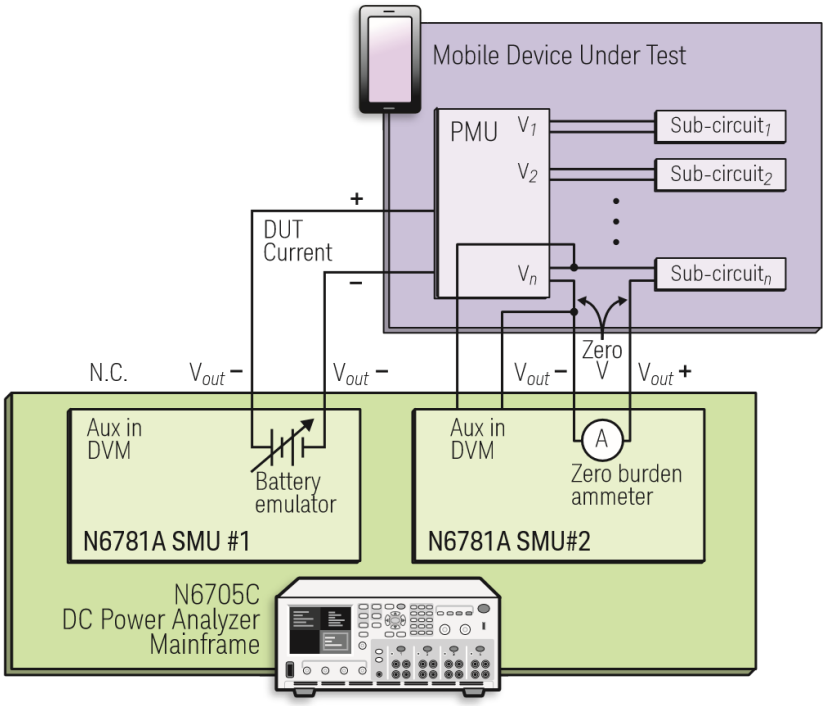

Figure 21. This test configuration can measure current drain from multiple subcircuits within a single DUT

Application: functional test of power components and modules

You can fully automate the functional tests of RF PA's, RF Chipsets, BT/WLAN/GPS modules, and DC-DC converters by selecting the N6700C 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 makes for a very compact and functional test system.

For more information

N6781A specifications - www.keysight.com/us/en/product/N6781A/2-quadrant-smu-battery-drain-analysis-20v-1a-6v-3a-20w.html

N6782A specifications - www.keysight.com/us/en/product/N6782A/2-quadrant-source-measure-unit-functional-test-20v-1a-6v-3a-20w.html

N6785A specifications - www.keysight.com/us/en/product/N6785A/smu-battery-drain-analysis-multiple-ranges-80w-double-wide.html

N6786A specifications - www.keysight.com/us/en/product/N6786A/smu-functional-test-multiple-ranges-80w-double-wide.html

N6705C Users guide - www.keysight.com/us/en/product/N6705C/dc-power-analyzer-modular-600-w-4-slots.html

Pathwave BenchVue BV9200B - www.keysight.com/us/en/product/BV9200B/benchvue-advanced-power-control-analysis-for-multiple-instrument-connections.html

Pathwave BenchVue BV9201B - www.keysight.com/us/en/product/BV9201B/benchvue-advanced-power-control-analysis-single-instrument-connection.html

Pathwave BenchVue BV9210B - www.keysight.com/us/en/product/BV9210B/advanced-battery-test-and-emulation-software-for-multiple-instru.html

Pathwave BenchVue BV9211B - www.keysight.com/us/en/product/BV9211B/advanced-battery-test-and-emulation-software-for-a-single-instrument.html

N6700C 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

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