



Agilent AN 1310

Mobile Communications Device Testing

Application Note

Considerations when selecting a System Power Supply for Mobile Communications Device Testing

Abstract

Pulsed battery drain currents, regulated charge currents, and remote DUT (Device Under Test) fixtures, dictate the need for specialized power sourcing, loading, and measurement capabilities for testing mobile communications devices. Many of these capabilities are not available in general-purpose system power supplies.

This guide will assist the test system designer in selecting a system power supply by properly evaluating test system and power supply needs that are unique to the application and not immediately obvious. In this way, many problems likely to arise in production can be avoided.



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Overview

Mobile Communications System Power Supplies

The growth of the mobile communications market is clearly in the newer digital wireless products. The consumer advantages are significant—improved transmission quality, accessibility, security, and operating time.

Digital mobile communications devices transmit in short bursts which conserves power between transmissions, thus extending talk time of the battery. Likewise, during standby, some digital devices also “wake up” and listen for incoming calls in short bursts, again extending battery life. The resulting battery drain is pulsed current, ranging from milliamperes to amperes. Accurate current drain measurements are important to assure proper battery life for these different operating modes.

Mobile communications devices incorporate a wide variety of battery charging schemes. Constant and pulsed charge currents ranging from milliamperes to amperes are characteristic of rapid, slow, and trickle battery charge modes of these devices. There are a variety of charge termination methods all primarily determined by battery voltage.

In the production testing of mobile communications products, a system power supply replaces the battery. High volume manufacturing often dictates that the DUT fixture is remotely located from the test system, introducing significant impedance due to long wiring length. This, in combination with pulsed current drain, makes it challenging to maintain a stable, transient-free voltage at the fixture just as if the DUT were operating directly from a battery. In addition to emulating the battery, the power supply can also provide current and voltage measurements required for testing and calibrating the DUT.

All of these things dictate the need for a system power supply with power sourcing, loading, and measurement capabilities specially tailored for this application. By properly evaluating these unique needs of the test system and power supply, the test system designer can avoid production test problems by selecting a power supply suited for the application.

Considerations when Selecting a System Power Supply

There are several unique needs to consider in the system current supply selection, specific to mobile communications device testing.

These needs can be categorized as sourcing power, battery charger loading, and current measurement. This guide is organized accordingly, as follows:

Section One Considerations when Sourcing Power to the DUT

- A. Transient Voltage Drop at the DUT Fixture
- B. Pulsed Current Sourcing for DUT Transmit Burst Current Drain

Section Two Considerations when Loading the DUT Battery Charger

- A. Constant Voltage Loading Capability

Section Three Considerations when Making DUT Current Measurements

- A. Talk-mode Current Drain Measurements
- B. Standby-mode Current Drain Measurements
- C. Off-mode Current Leakage Measurement
- D. Battery Charger Current Measurement

The following references are useful in the selection of any system power supply:

- *Power Supply Testing*, Application Note 372-1, pub. # 5952-4190
- *DC Power Supply Handbook*, Application Note 90B, pub. # 5952-4020

Section One

Considerations when Sourcing Power to the DUT

There are important factors the designer needs to consider in sourcing power to the DUT:

A. Transient Voltage Drop at the DUT Fixture

B. Pulsed Current Sourcing for DUT Transmit Burst Current Drain

A stable DC voltage at the test fixture is necessary in mobile communication device test. Transient voltage drop can be a particular problem due to the DUT transmit burst current drain and the impedance of long wiring connecting the test system to a remote test fixture. If the transient voltage drop is large enough, it will activate the DUT low voltage shutdown circuit and disrupt the test, impairing test throughput and yield.

Since digital mobile communications products draw current in pulses, the average current is low compared to the pulsed current. Being able to specify the power supply based on pulsed instead of average current capability can result in a smaller and less costly unit.

Careful evaluation of these current sourcing capabilities will assure optimum performance at the remote DUT test fixture. More details on determining specific requirements on each factor are provided in the following sections.

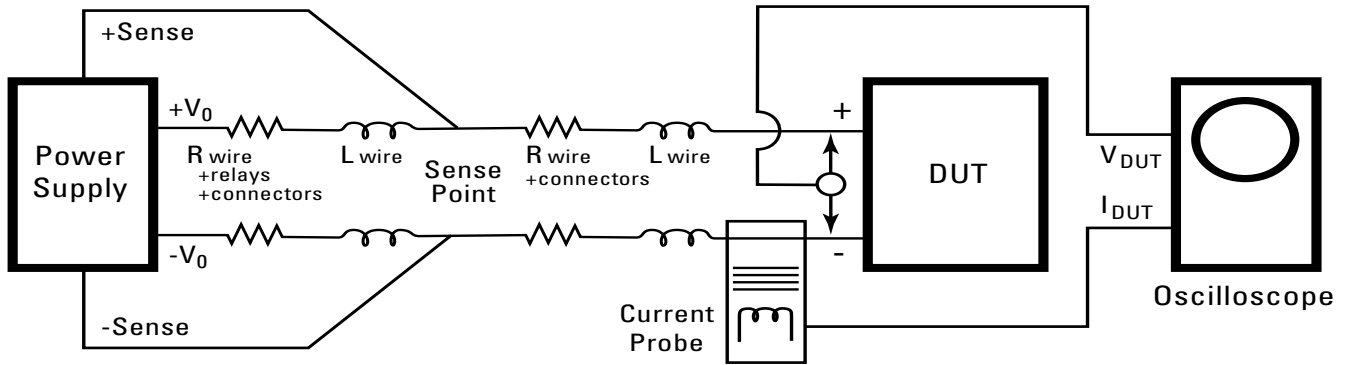
A. Transient Voltage Drop at the DUT Fixture

The combination of a device's pulsed current drain and the impedance of wiring to the test fixture make it difficult to maintain a stable DC voltage with low transient drop at the DUT. If the resulting transient voltage drop is large enough, it will activate the DUT's low voltage shutdown circuit, disrupting the test. This impairs production throughput and yield. The transient voltage drop should be kept below 150 mV for mobile communications devices operating at 3.6 volts.

The transient voltage response specification on typical power supplies is not adequate to assure proper performance in this application. It specifies the performance directly at the power supply output terminals operating in local voltage sense mode. It does not consider the wiring voltage drop that the power supply is attempting to compensate for when operating in remote voltage sense mode. Moreover, most power supplies do not have sufficient speed to match the fast rise and fall times of the DUT transmit burst current. As a result, the actual transient voltage drop may be significant at the DUT even when the power supply is operating in remote voltage sense mode.

A suitably fast-responding power supply can provide an order of magnitude reduction of the transient voltage drop. However, at this fast response speed, the test set wiring, relays, connector resistance, wiring inductance, and the DUT's characteristics, all influence transient voltage drop performance. A fast-responding power supply typically provides optimum performance only over a specific range of operating conditions.

Figure 1: Test System Configuration Modeling



Test System Parasitic Elements

The parasitic elements in the test system are wiring, relay and connector resistance, and wiring inductance, modeled in Figure 1. To evaluate transient voltage drop, one must test over the range of expected parasitic values. The variety of test platforms in production, R&D, service, and repair benches should also be considered in determining the range of parasitic values to be expected.

Typical parasitic values for the test system wiring are as follows:

- Wiring inductance;
 - 1.5 to 2 uH/meter untwisted,
 - 0.5 to 1 uH/meter twisted
- Wiring resistance; depends on diameter, add 50% for twisted
- Connector or relay resistance; initial: 0.01 to 0.05 ohms
- Connector or relay resistance; end of life: 0.1 to 0.5 ohms

These values are for illustrative purposes. It is important to estimate the parasitic values over the anticipated test system life. Otherwise an increasing frequency of unexplainable intermittent problems could occur as the test system connectors and relays wear.

Always try to minimize these test system parasitic values as much as practical.

Simulating the Test System Parasitic Elements

The best final proof of performance is with the actual test system. When using the test system, it is important to ascertain the condition of the relays and connectors. To properly test at initial conditions, replace any worn components.

In many cases the actual test system may not exist yet. The test system wiring parasitic values can be simulated using appropriate lengths and diameters of actual wire pairs as called for in the design. Untwisted wire pairs should be kept closely spaced to minimize loop area and resulting inductance and noise pick up. Connector and relay initial and end of life resistance can be simulated using appropriate non-inductive resistors.

It may be useful to set up a matrix for the range of parameters and conditions to conduct the evaluation, similar to Table 1.

Table 1: Test System Parasitic Elements Matrix

Test system	Wiring before voltage sense point				Wiring after voltage sense point			
	Length	L wire	R initial	R final	Length	L wire	R initial	R final
Auto test set 1	6 m	4 uH	0.5 ohm	3 ohm	0.5 m	0.7 uH	0.2 ohm	0.4 ohm
Auto test set 2	4 m	6 uH	0.7 ohm	1.4 ohm	0.2 m	0.3 uH	0.1 ohm	0.3 ohm
Bench test set 1	1 m	2 uH	0.1 ohm	0.1 ohm	0.2 m	0.3 uH	0.1 ohm	0.1 ohm

The DUT Characteristics

The range of various different models of DUT's likely to be tested need to be taken into consideration in the transient voltage drop evaluation testing. Typical ranges of DUT talk-mode operating values may be as follows.

- Operating voltage: 2.5 to 8.0 volts
- Talk-mode low level pulsed current drain: 75 to 300 milliamperes
- Talk-mode high level pulsed current drain: 0.8 to 2 amperes
- Talk-mode initial peak transient current drain: 1.2 to 3 amperes
- Pulsed current drain rise and fall times:
 TDMA: 25 microseconds or slower
 GSM: 17 microseconds or slower
 CDMA: 3 microseconds or slower

A mobile communications device's battery input port is very complex with regard to its impedance and actual pulse wave shape. It is important to conduct testing with actual DUTs to verify true transient voltage drop performance.

DUT Operating Conditions to Consider

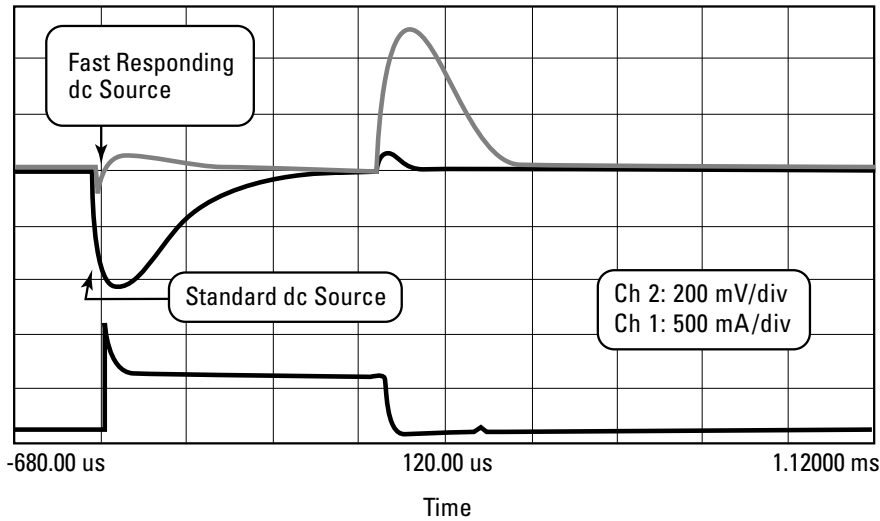
The DUT should be set to maximum transmit power and be operated at the lowest input voltage to get maximum current drain. This will usually give the largest transient voltage drop. System performance should also be verified at maximum DUT operating voltage to verify that the power supply still has adequate voltage reserve to compensate for peak voltage drop in the wiring. Check transient voltage drop performance with all DUTs to be tested on the system. It is worthwhile documenting the actual DUT characteristics used to conduct the evaluation for future reference.

Using an Electronic Load to Simulate the DUT

One should not depend on using a commercial electronic load or power transistor and pulse generator to simulate the DUT pulsed drain current to verify transient voltage drop performance. Their characteristics are very different in comparison to an actual DUT. The results will be approximate at best, so the final proof is to always use an actual DUT.

Transient Voltage Drop Evaluation Test Result Example

Figure 2: Transient Voltage Drop Measurement Results



The transient voltage drop performance and pulsed current drain are measured directly at the DUT with an oscilloscope and current probe, as shown in Figure 1. Typical values of these measurements are illustrated in Figure 2.

Table 2: Transient Voltage Drop Evaluation Results Matrix

	DUT1		DUT2		DUT3	
	V drop/R initial	V drop/R final	V drop/R initial	V drop/R final	V drop/R initial	V drop/R final
Auto test set 1	100 mV	135 mV	110 mV	145 mV	90 mV	125 mV
Auto test set 2	80 mV	105 mV	90 mV	115 mV	70 mV	95 mV
Bench test set 1	70 mV	70 mV	80 mV	80 mV	60 mV	60 mV

It may be useful to set up a matrix for the range of parameters and conditions to track the results of the evaluation, as illustrated in Table 2. Again, it is important to test the DUT at both low and high operating voltage limits.

For More Information

Additional useful information on reducing output voltage transient drop at the DUT fixture can be found in the following:

Minimizing Power Supply Transient Voltage at a Digital Wireless Telecommunications Products Test Fixture, Technical Paper (located at the Agilent Technologies Web site in applications/technologies section, www.agilent.com/find/power)

B. Pulsed Current Sourcing for DUT Transmit Burst Current Drain

Power supplies specifically developed for this application may offer pulsed current sourcing capability that exceed their DC average current sourcing capability. This effectively provides more power in a smaller package for digital mobile communications devices, which draw current in pulses.

The Pulsed Current Drain of Digital Mobile Communications Devices

Two common examples for transmit bursts are TDMA and GSM products.

- TDMA transmits in 6.67 millisecond bursts with a $\frac{2}{6}$ -duty cycle
- GSM transmits in 0.57 millisecond bursts on a $\frac{1}{8}$ -duty cycle

In application, the DUT operates at a specified voltage and draws current based on its power needs. The voltage is being controlled by the power supply while the levels of current are being determined by the DUT.

Simulating the DUT Pulsed Current Drain

The evaluation needs to reflect the application conditions, to correctly test the suitability of a power supply's pulsed current sourcing capability. In Figure 3, the power supply is set to the DUT operating voltage. An electronic load is set to alternate between two constant current levels to simulate the pulsed current drain of a DUT.

Both the DC average current and pulsed current levels need to be considered. A power supply that provides pulsed current sourcing capability has a fast current limit to protect from excess peak current drain and a slow current limit to protect from excess DC average current drain. These limits protect the power supply as well as the DUT.

Measuring the Power Supply's Pulsed Current Sourcing Capability

To measure the pulsed current sourcing capability, the electronic load pulse duration is increased while duty cycle is decreased to avoid exceeding the DC average current sourcing capability of the power supply. When the pulsed current sourcing capability is exceeded, the pulsed current limit takes over control of the source output collapsing the output voltage. The pulse current source duration is the time taken from the start of the current pulse to the collapse of the output voltage as observed by the oscilloscope trace example in Figure 4. This testing can be conducted at several pulse current levels to determine the duration for each as the duration may be a function of the pulse level.

Figure 3: Pulsed Current Source Capability Test Set Up

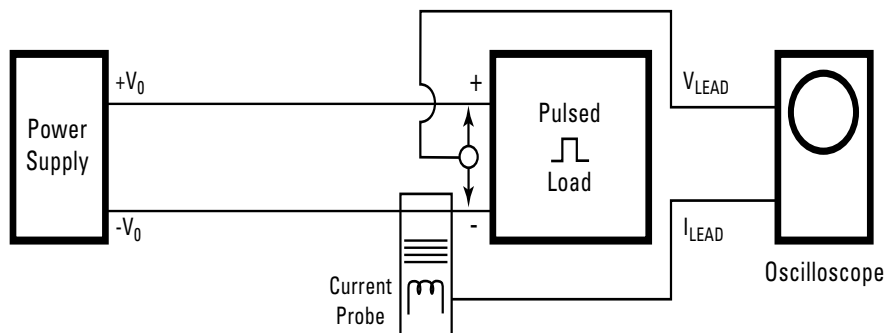


Figure 4: Pulsed Current Source Capability Measurement Results

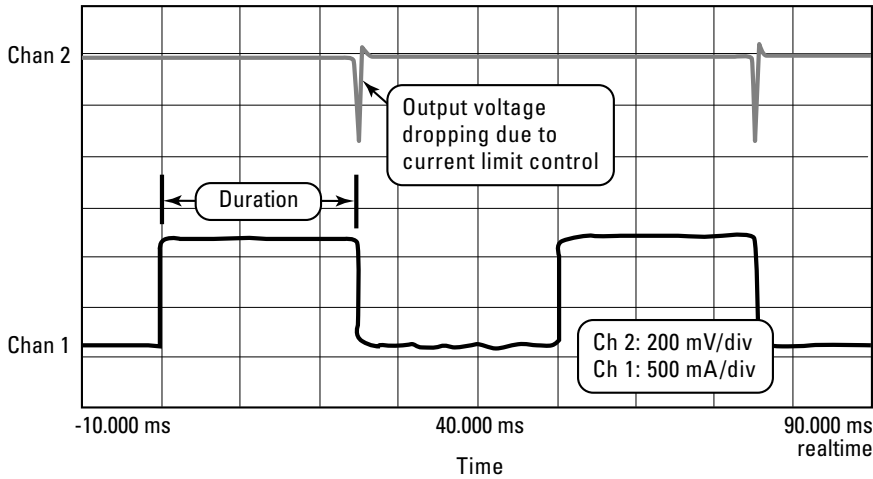


Table 3: Power Sourcing Considerations Summary

Summary of considerations when sourcing current to the DUT

Power sourcing factor	Considerations	Evaluation method
Output transient voltage drop at DUT fixture (Low-transient battery voltage)	Range of test systems and wiring parasitics Range of DUT's input characteristics	Oscilloscope AC-mV measurement Min. and max. wiring parasitics Min. and max. DUT voltages
Output pulsed current source capability (Transmit burst current drain)	Range of DUT's pulsed current load levels and duration	Oscilloscope DC voltage and current time measurement Adjustable pulsed load

Applying a Short Circuit to Measure the Pulsed Current Sourcing Capability

Applying a short circuit to the power supply output may not correctly measure the pulsed current source duration as required in the application. A short circuit instantly drives the power supply into current limit operation. This does not reflect the constant voltage operation and DUT's repetitive current pulse drain of the application.

Minimizing the transient voltage drop at the DUT fixture is a primary concern as it impacts production throughput and yield. A fast responding power supply can significantly reduce transient voltage drop. Output pulsed current source capability is beneficial by reducing the size and cost of the power supply in the test system.

The Agilent 66111A, 66311B/D and 66309B/D dc sources feature fast response and pulsed current source capability.

Section Two

Considerations when Loading the DUT Battery Charger

Mobile communications devices incorporate a wide variety of battery charging schemes. In production test the DUT charger is typically calibrated at high and low current levels for accurate full and trickle charge rates. There are a variety of charge termination methods, all primarily determined by battery voltage. The DUT's battery voltage sense needs to be calibrated to assure proper battery charging termination. Improper charger calibration can lead to exploding batteries when the device is in use.

To calibrate and test a mobile communications device's battery charging system, the current needs to be drawn in *reverse*, out of the device's battery port. The need for a separate load can be eliminated if the power supply can provide this function.

To emulate a charging battery, the system power supply needs to operate as a constant voltage electronic load by maintaining a stable positive voltage while sinking the charge current. The voltage needs to be regulated at the remote test fixture. The power supply now needs to compensate for the *reverse* voltage drop in the wiring to the fixture. Considerations for constant voltage load operation are examined in detail in the following section.

A. Constant Voltage Loading Capability

Mobile Communications Device Battery Charger Operation

In battery charge mode, the mobile communications device must regulate the battery charge current and monitor the battery voltage to terminate when the battery is fully charged. Usually an external battery charger connected to the charger-input port on the device provides the power.

It is important that the DUT's battery charging current and voltage circuits be tested and calibrated. Improper calibration can result in under- or over-charging, or worse, exploding batteries, when the mobile communications device is in charge mode.

The Power Supply Emulating a Charging Battery

In contrast to the more usual situation of sourcing current, the power supply now needs to *absorb*, or *sink* the battery charging current from the DUT, while also maintaining an accurate, remotely sensed, positive voltage at the DUT. The power supply is operating as a CV (Constant Voltage) electronic load.

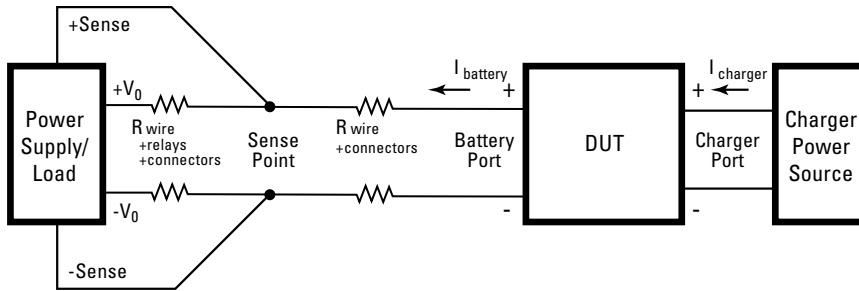
Power Supply Considerations for CV Load Operation

CV load operation is needed to calibrate the DUT's internal battery voltmeter so that the DUT can accurately sense the battery voltage low, high, and charge termination points. The CV load voltage should be within 0.5% (20 mV for a 3.6 V battery) to calibrate the DUT charge circuit accurately. This allows margin for DUT inaccuracies and still has the necessary accuracy for proper battery charge-voltage termination.

The power supply's current sinking and power dissipating capabilities and ability to maintain an accurate, remotely-sensed, positive voltage at the DUT are important features to check in the evaluation. Many system power supplies do not offer the capability of operating as a true CV load. To evaluate CV load capability refer to Figure 5. With an appropriate external battery-charging source connected to the DUT (an external battery charger or another DC source) the DUT can be placed into battery charge mode.

Because the main test system power supply is now sinking current, its remote sense must compensate for a *reverse* wiring voltage drop. The voltage at the power supply output terminals will be *less* than the remote sense voltage at the DUT fixture. As a result, the power supply's output will be operating over a wide range of voltage. At the upper extreme it may be nearly 8 volts to emulate a fully charged 7.2V battery pack under trickle charge. At the lower extreme it may need to operate near zero volts to emulate a discharged 3.6V battery back under rapid charge, while compensating for the wiring *reverse* voltage drop.

Figure 5: Test System Configuration during CV Load Operation



Test System Fault-mode Consideration during Battery Charger Calibration

For power supply remote sense operation, a separate pair of leads remotely sense the voltage to accurately measure and regulate the voltage at the DUT. Over time, the remote sense connections can become intermittent or open. Under these conditions most system power supplies revert to local sense operation, measuring and regulating the voltage at the output terminals. The power supply will appear to continue to function properly as the measured voltage will be the expected value set. However, the voltage at the remote DUT will be in error. This will cause incorrect calibration, which can result in under- or over-charging, or worse, exploding batteries, when the mobile communications device is in use.

The test system designer should assess the power supply’s behavior for this fault mode and take necessary precautions to prevent this from occurring.

Summary of Important Items for Validating Constant Voltage Load Capability

- Maximum current sinking capability in CV load operation
- Maximum power dissipation capability at high voltage
- Over-power/temperature and reverse current limit protection
- Output voltage-programming accuracy (< 0.5%)
- Maintains voltage regulation, especially at low voltage, end of relay and connector life, and maximum charge current, operating conditions
- Broken voltage sense lead fault-mode behavior

Validating these capabilities by reviewing specifications and making some performance verifications against specific application requirements, will assure proper CV load performance for accurate and repeatable battery charger test and calibration.

The Agilent 66111A, 66311B/D, and 66309B/D dc sources feature CV load operation and uniquely provide open sense lead fault detection. The 66309B/D dc sources have a second output to provide power to the DUT battery charger input port.

Section Three

Considerations when Making DUT Power Measurements

The current measurement considerations when selecting a system power supply for mobile communications device testing are:

A. Talk-mode Current Drain Measurements

B. Standby-mode Current Drain Measurements

C. Off-mode Current Leakage Measurement

D. Battery Charger Current Measurement

Digital mobile communications devices transmit in short bursts which conserves power between transmissions thus extending talk time of the battery. Likewise, some digital devices also “wake up” and listen for incoming calls in short bursts, again extending battery life. The resulting battery drain is continuous or pulsed current, ranging from milliamperes to amperes.

Longer talk and standby operating times are of primary importance to the user. Accurate current drain measurements are fundamental to assure proper battery life and operating time. The wide range and pulsed current drain characteristics can be challenging to measure accurately.

If off-mode leakage current is high, it can quickly drain the battery leading to user dissatisfaction. Microampere level measurement is needed to test leakage current.

The DUT battery charger is typically calibrated at high and low current levels for accurate full and trickle charge rates. Milliampere to ampere-level, negative current measurements are needed to calibrate the device’s battery charge circuit.

A DMM is often added, along with a general-purpose power supply, to supplement the test system’s current measurement capabilities. This does not adequately address all these specialized requirements. Ideally, the system power supply alone would adequately address DUT battery current and voltage measurement requirements, eliminating the need for additional equipment. For this, the power supply must have several advanced measurement capabilities, specifically developed for the application. Considerations for these measurement capabilities are explored in detail in the following sections.

A. Talk-mode Current Drain Measurements

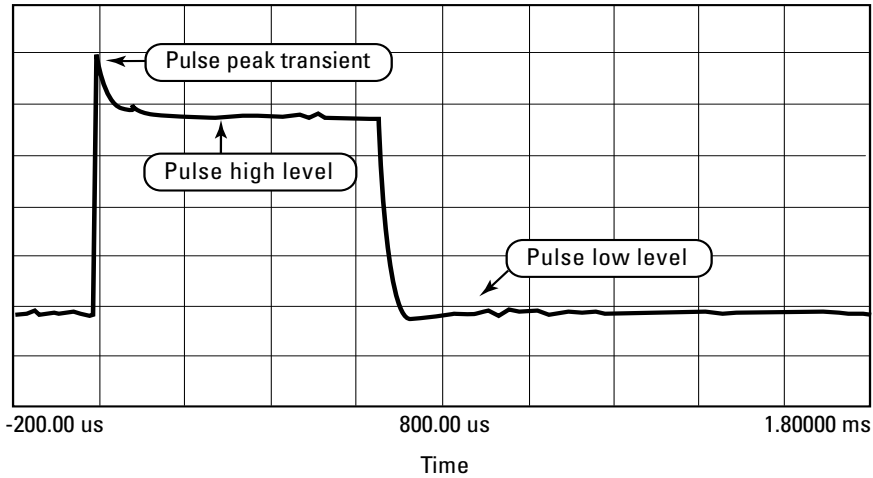
Talk-mode current drain is the most fundamental current measurement, to assure the mobile communications device will provide adequate battery talk time. The pulsed current drain characteristic of digital devices can be challenging to measure accurately.

Pulsed Current Drain Characteristics

The pulsed current drain characteristics are typically within the following ranges:

- Pulse periods from 5 to 100 milliseconds
- Crest factors exceeding ten
- Duty cycles from 10% to 50%
- The pulse may have a high peak transient value to consider.

Figure 6: Typical Talk-mode Pulsed Current Drain Example.



DC Average Current Measurement Considerations

Many times the DC average current drain measurement is in error, or erratic, because the pulse characteristics are not taken into consideration:

- The high crest factor may exceed the instrument’s capability. Usually the measurement is erroneously low, allowing defective product to be passed.
- The high pulse level but low average value dictates milliampere measurement accuracy over a full 2 to 3 ampere range.
- The relationship of pulse rate to the test equipment’s measurement window capability is overlooked. This most often results in jittering or erratic measurements.

For good accuracy and speed, a few factors need to be considered when selecting a product for making DC average current measurements:

- The measurement system handles high crest factors.
- The measurement window can be set to measure exactly one or more pulse periods when the pulse rate is known precisely.
- The measurement system can alternately provide accurate measurement when the pulse rate is not known precisely.
- Measurement accuracy is 1-3 milliamperes over a full 2 to 3 ampere range.

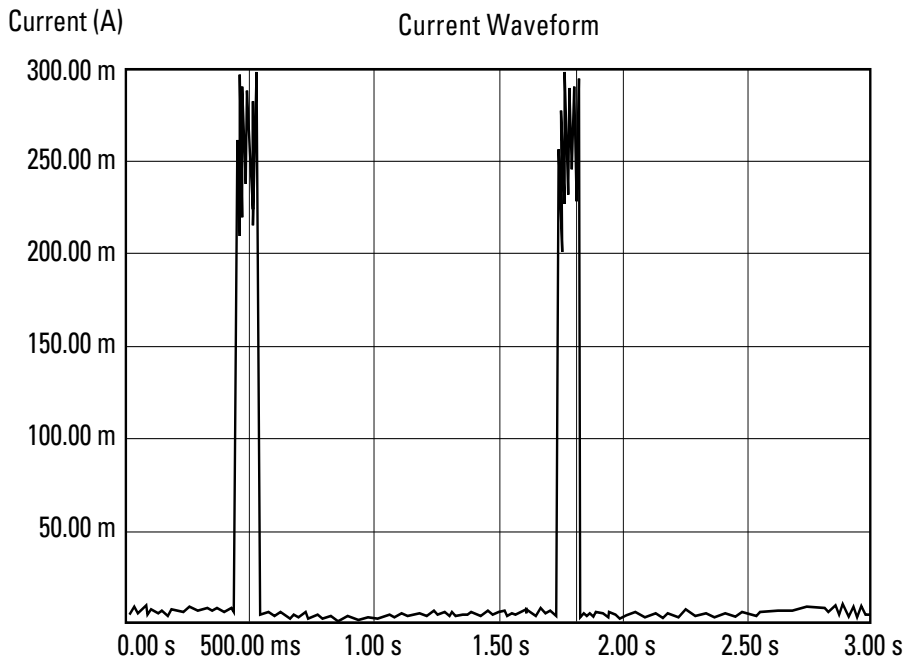
Most general-purpose power supplies cannot provide adequate accuracy due to the low DC average value relative to the large full-scale capability. Second, the short and fixed measurement window they have is not well suited for pulsed current drain measurements.

High Level and Peak Transient Current Drain Measurements

Testing the pulsed current drain’s high level and peak transient values augments qualitative screening of the DUT. Checking the high level ascertains transmitter power efficiency and quality. Checking the peak overshoot current enhances talk time test screening. A large peak current causes a corresponding large momentary battery voltage drop. Low battery voltage shutdown occurs sooner, reducing talk time.

It is unlikely to find these measurement capabilities on any general-purpose power supplies or most basic system DMMs. If they are featured, it should be verified that the capabilities are specifically suited for this application. This is easily done using a wide band AC/DC current probe and oscilloscope.

Figure 7: Slotted-mode Operation Pulsed Current Drain



B. Standby-mode Current Drain Measurements

Long standby-mode operation is extremely desirable, allowing the mobile device to receive incoming calls for many days before recharging the battery. Accurate current measurements down to milliamperes current levels are required to assure adequate standby-mode operating time. Standby current may either be continuous or pulsed.

Continuous Standby Current Measurement

Continuous standby current drain is typically tens of milliamperes, providing about two days-standby mode operating time. The equipment should be able to measure the standby current drain at a few percent or better accuracy (<1 mA) to assure adequate DUT standby time performance.

Most general-purpose power supplies do not have adequate accuracy for standby current drain measurement due to its low value relative to the large full-scale capability.

Slotted-mode Standby Operation and Pulsed Current Drain Measurement

Some cellular phones enter a “wake up” state every few seconds for a short period to check for any incoming calls, drawing an active-mode current level.

Between these periods the cellular phone drops back into a “sleep” state, drawing only millamperes of current. This uses less average current than continuous standby operation, providing longer operating time. This is referred to as slotted-mode, which is standard for narrow band CDMA format. Slotted-mode current drain is illustrated in Figure 7.

Considerations are the same as for talk-mode current drain. However, standby-mode pulsed current drain presents more of a challenge due to the longer periods, lower duty cycles, higher crest factors, and lower levels of current involved. Factors to consider in addition to those of talk-mode are:

- Sub-milliamperes measurement accuracy in presence of high pulsed currents.
- Extended measurement window time and resolution of window time setting suited for slow pulse rates with very low duty cycles

General-purpose system power supplies and basic system DMMs are not suited for directly measuring slotted-mode standby current, because of these factors.

C. Off-mode Current Leakage Measurement

If off-mode leakage current is high, it can quickly and unexpectedly drain the battery, leading to user dissatisfaction as well as being systematic of a potential latent failure mechanism. Production testing off-mode leakage current catches random manufacturing and component defects. The off-mode current drain is usually under 100 microamperes.

The low-level accuracy needs to be considered when making off-mode current drain measurements. A separate, low current measurement range with better than 10 microamperes accuracy is adequate for this measurement.

Microampere level measurement is not a feature of general-purpose power supplies.

D. Battery Charger Current Measurement

In most designs, the battery charger current is monitored and controlled by the mobile device itself. The DUT is usually calibrated at high and low current levels for accurate rapid and trickle charge rates.

Rapid charge rate current is typically under one ampere. Trickle charge rate current is tens of milliamperes. Measurement accuracy of 1% (< 3 milliamperes) should be sufficient for accurate battery charging calibration.

Providing the power supply has the ability to sink current and emulate a battery under charge conditions (see “Considerations when Loading the DUT Battery Charger,” part II). It should then be verified that the power supply measures high and low charge rate *negative* currents to the required accuracy to properly calibrate the DUT. The accuracy required at the low level, relative to the full-scale capability needs to be considered.

Summary of Considerations when Making DUT Power Measurements

Measurement factor	Target accuracy	Considerations
Talk-mode, DC average current	< 3 mA or 1%	The measurement system handles high crest factors. The measurement window can be set to measure exactly one or more pulse periods, when the pulse rate is known precisely. The measurement system can alternately provide accurate measurement, when the pulse rate is not known precisely. Measurement accuracy is over a full 2 to 3 ampere range.
Talk-mode, peak and high level currents	< 20 mA or 3%	Peak and high-level measurement capability is actually suited for the application.
Continuous standby-mode DC Ave. current	< 1 mA or 1 to 3%	Demanding accuracy requirement relative to full-scale current capability
Slotted standby-mode DC average current	< 0.5 mA or 1 to 3%	As per talk- and continuous standby-modes Sub-milliampere measurement accuracy in presence of high pulsed currents Low pulse rate and duty cycle requires long measurement period and precise resolution.
Off-mode DC average current	< 10 uA or 5 to 10%	Accuracy requirement at microamperes current level
Charge-mode DC average current	< 3 mA or 0.5%	Demanding negative polarity current measurement relative to full-scale current capability

The wide range and pulsed current characteristics are challenging to measure accurately, even when using multiple pieces of equipment. Accurate current measurements during production test are fundamental in assuring proper battery life, calibration, and quality of the mobile communications device.

The Agilent 66311B/D and 66309B/D dc sources feature a measurement system specifically for addressing all these specialized requirements without the need of additional equipment. The 66311D and 66309D also have a separate DVM input channel for independent voltage measurements at the DUT fixture.

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