

Keysight Technologies

# 10 Practical Tips to Help Your Power Testing and Analysis

Application Note

Simple ways to improve  
your operation and  
measurement capabilities

# Introduction

Want to learn how to reduce noise from your power supply? How about simplifying your test setup? Read on!

Power supply is an integral part of any good test system. The capability to deliver clean and accurate power to your Device Under Test (DUT) removes doubts and gives you right results every time. Our practical tips will let you get more out of your power supply. If you ever need to get a new power supply, you can count on these tips to help you choose the right one. Remember, more power and features do not mean better a better power supply. It's about how you use your power supply.

Don't worry about your power supply. Let us do that for you. We want you to focus on what's important to you. We hope you enjoy our tips.

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## Tip 1: Use remote sensing to compensate for load-lead effects

When your power supply leaves the factory, its regulation sense terminals are usually connected to the output terminals. This limits the supply's voltage regulation abilities, even with very short leads. The longer the leads and the higher the wire gauge, the worse the regulation gets (Figure 1). Compare the output impedance of a well-regulated 10 A supply, which might have an output impedance of 0.2 m $\Omega$ , with the resistance of copper wire:

| AWG wire size                           | 22   | 20   | 18   | 16   | 14   | 12   | 10    |
|---|------|------|------|------|------|------|-------|
| Resistance in m $\Omega$ /ft (at 20° C) | 16.1 | 10.2 | 6.39 | 4.02 | 2.53 | 1.59 | 0.999 |

And regulation gets even worse if you use a relay to connect power to the load.

Remote sensing, in which you connect the sense terminals of the power supply's internal feedback amplifier directly to the load, lets the power supply regulate its output at the load terminals, rather than at its own output terminals (Figure 2). The supply voltage shifts as necessary to compensate for the resistance of the load leads, relays, or connectors, thereby keeping the voltage at the load constant.

To implement remote sensing, disconnect the local sense leads from the output terminals. Use twisted two-wire shielded cable to connect the power supply sensing terminals to the sense points on the load. (Don't use the shield as one of the sensing conductors.) Connect one end of the shield to ground and leave the other end unconnected.

Sensing currents are typically less than 10 mA, and as a general rule, you should keep the voltage drop in the sense leads to less than 20 times the power supply temperature coefficient (usually stated in mV/°C). This is easy to achieve with readily available shielded two-wire cable.

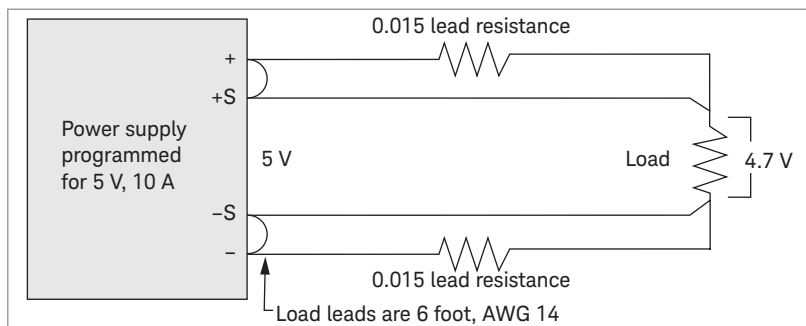


Figure 1: The effects of six feet of AWG 14-gauge leads without remote sensing

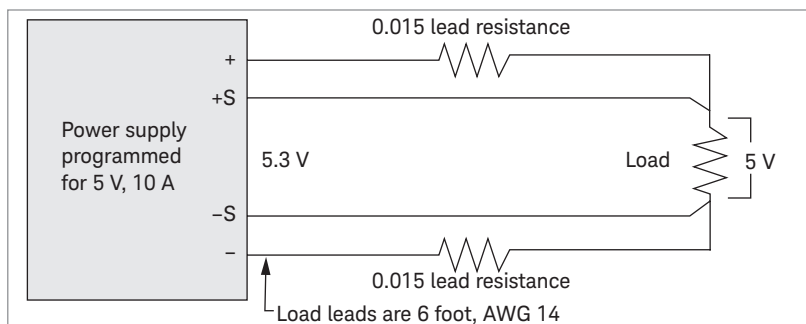


Figure 2: Using remote sensing to correct the lead-load problem

## Tip 2: Increase safety with remote disable feature

Remote disable offers a safe way to shut down a power supply to respond to some particular operating condition or to protect system operators (in response to a cabinet door being opened unexpectedly or someone pushing a panic button, for instance).

Remote inhibit (RI) is an input to the power supply that disables the output when the RI terminal is pulled low (Figure 1). Shorting the normally open switch turns off the supply's output. You could also use a logic chip with an open collector transistor output instead of the switch. Figure 1 also shows a discrete fault indicator (DFI) that you can use to signal an operator or other components in the system when the power supply detects a user-defined fault.

Almost any operating condition can create a DFI signal. For example, to generate a DFI signal when the load draws excessive current, enable the over-current protection (OCP) mode, program the unit to generate a DFI signal when it enters constant current mode, then program the maximum current the load normally draws. If the load current exceeds the maximum, the DFI output goes low, disables the power supply, and informs the operator of the over-current condition (or performs another user-defined function), without tying up the system bus or interrupting the system controller.

You can daisy chain DFI and RI as shown in Figure 2. If one supply detects a fault, all supplies in the system are disabled. Using this approach, you can chain together an unlimited number of supplies.

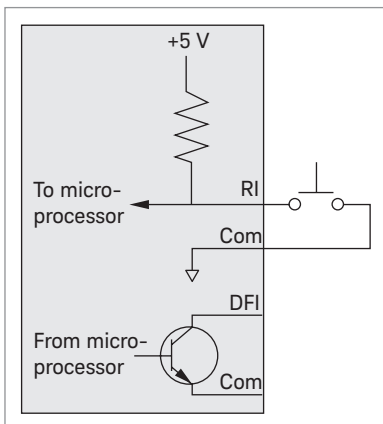


Figure 1. Remote inhibit and discrete fault indicator schematic

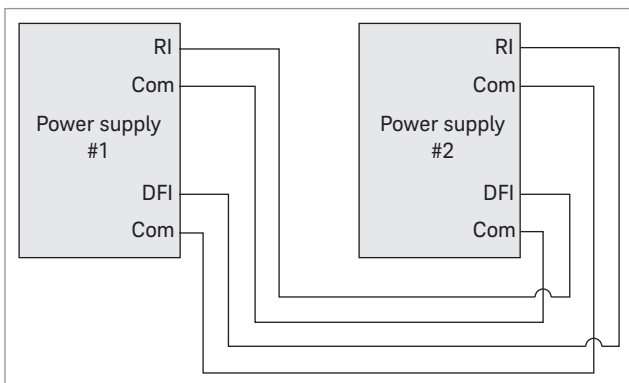


Figure 2. Daisy-chained DFI and RI

## Tip 3: Eliminate noise from low-level measurements

Noise in low-level measurements can come from a number of different sources, and it's easier to eliminate noise than to filter it. Check these noise sources:

### 1. Power supply

Starting with a low-noise supply is naturally a great way to keep noise out of your measurements. Linear power supplies have lower common-mode noise currents and generally operate at low frequency. However, you can use switch-mode supplies successfully if their specifications include a low common-mode current. As a rule of thumb, common-mode current over 20 to 30 mA is likely to cause trouble. Keep reading for hints on how to minimize the problem.

### 2. DUT to power supply connections

Minimize conducted noise by eliminating ground loops. Ideally, there should be only one connection to ground. In rack systems, where multiple ground points are inevitable, separate the DC distribution path from other conductive paths that carry ground currents. If necessary, float the power supply (don't connect either terminal directly to ground).

Minimize radiated pick-up (both electric and magnetic) by using twisted shielded conductors for the output and remote sense leads. To make sure the shield doesn't carry current, connect the shield to ground at one end only, preferably the single-point ground on the supply (Figure 1).

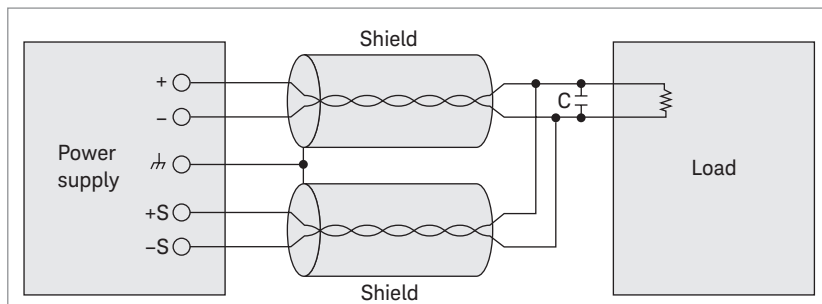


Figure 1: Minimizing radiated pick-up with twisted shield leads for both output and remote sense leads

Minimize the power supply's common-mode noise current by equalizing the impedance to ground from the plus and minus output terminals. Also equalize the DUT's impedance to ground from the plus and minus input terminals. Magnetic coupling or capacitive leakage provide a return path for noisy ground loop current at higher frequencies. To balance the DUT's impedance to ground for your test frequencies, use a common-mode choke in series with the output leads and a shunt capacitor from each lead to ground.

### 3. Current variations to the DUT

Rapid changes in the DUT's current demand cause voltage spikes. To prevent this, add a bypass capacitor close to the load. The capacitor should have a low impedance at the highest testing frequencies. Avoid imbalances in load lead inductance; direct connections to the DUT, such as twisted shielded pair, are your best bet.

## Tip 4: Use down programming to increase test speed

Under light or no load conditions, a power supply's output capacitor discharges slowly. If you're using the supply as a static voltage source, this is not problematic, but when you're making tests at varying voltage levels, slow discharge means slow tests.

Down programming circuits in power supplies rapidly decrease the output voltage, reducing discharge times by hundreds of milliseconds. Keysight Technologies, Inc. power supplies use two types of down programming circuits:

- In Figure 1, an FET is placed across the output terminals.
- Whenever the output voltage is higher than the programmed value, the FET activates and discharges the output capacitor.
- The FET can sink currents ranging from 10 percent to 20 percent of the supply's output current rating. The maximum load at low voltages is limited to the On resistance of the FET plus the series monitoring resistor, resulting in a slight degradation of the down programming current near zero volts.
- In Figure 2, the down programmer lies between the power supply's positive terminal and a negative source. This configuration pulls the output completely down with no degradation near zero.

Some power supplies, such as the Keysight 663xA series, can sink currents equal to their full output current rating. This sink current is programmable, so you can use the supply both as a programmable source and load.

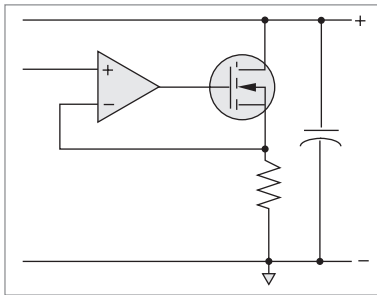


Figure 1: A down programming circuit with an FET across the output terminals

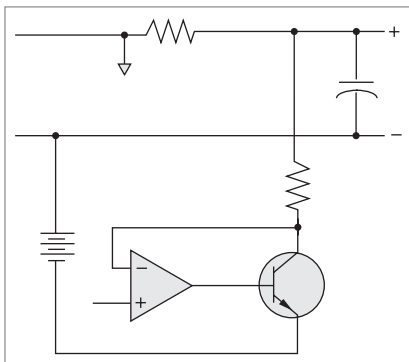


Figure 2: A down programmer situated between power supply's positive output and a negative source

## Tip 5: Simplify setup with autoranging power supplies

With bench and rack space at a premium, having the ability to produce a wide range of voltage and currents with one power supply is beneficial. Applications that require many voltage and current combinations require many power supplies or a very large power supply to span the largest voltage and current combination. For example, a DC/DC converter is tested under several voltage and current combinations at about the same power level.

A very basic DC power supply has a rectangular output (Figure 1). It has a maximum voltage setting ( $V_{max}$ ) and a maximum current setting ( $I_{max}$ ) with a single maximum power point ( $P_{max}$ ) which equals  $V_{max} * I_{max}$ . This creates a rectangular output characteristic.

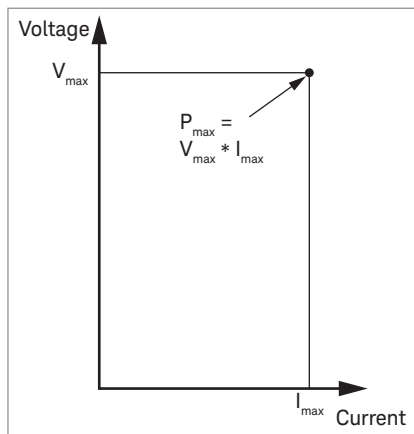


Figure 1: Rectangular output characteristic

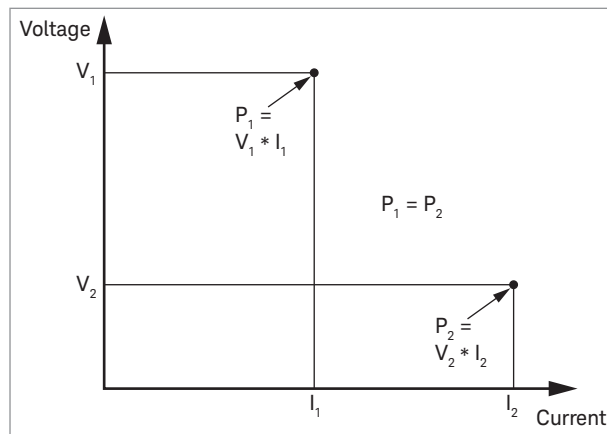


Figure 2: Dual-range output characteristic

More advanced power supplies have multi-range outputs. For example, a dual-range power supply (Figure 2) has two rectangular output characteristics, each having a different  $V_{max}$  and  $I_{max}$ . However, both output characteristics have the same  $P_{max}$  but at two different points. The power supply can switch between the different ranges to satisfy both rectangular output characteristics.

Autoranging outputs (Figure 3) satisfy many different voltage and current combinations that are limited by  $P_{max}$ . The output characteristic follows a constant  $P_{max}$  curve allowing for several different power curves rated at the same power level,  $P_{max}$ .

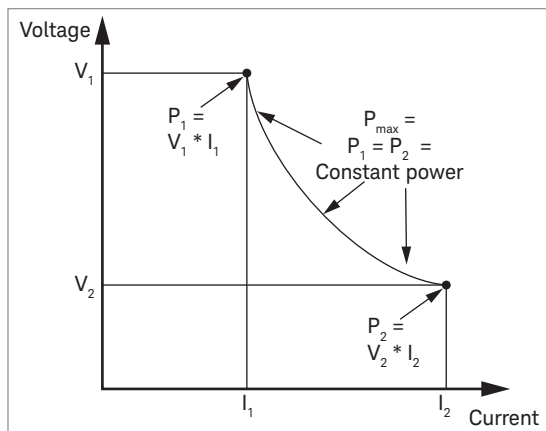


Figure 3. Autoranging output characteristic

Using autoranging outputs simplifies the test setup by eliminating the need for many power supplies. Supplies such as the Keysight N675xA and N676xA have autoranging outputs that help do this and drive the cost of test down.

## Tip 6: Connect power supplies in series or parallel for higher output

Connecting two or more power supplies in series (Figure 1) provides higher voltages, but observe these precautions:

- Never exceed the floating voltage rating of any of the supplies.
- Never subject any of the power supplies to negative voltages.

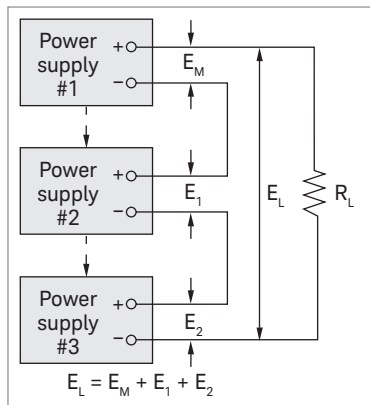


Figure 1: Connecting units in series

Program each power supply independently. If two supplies are used, program each one for 50% of the total output voltage. If three supplies are used, program each supply for about 33% of the total output voltage. Set the current limit of each supply to the maximum that the load can safely handle.

Connecting two or more power supplies in parallel (Figure 2) provides higher currents, but again, observe these precautions:

- One unit must operate in constant voltage (CV) mode and the other(s) in constant current (CC) mode.
- The output load must draw enough current to keep the CC unit(s) in CC mode.

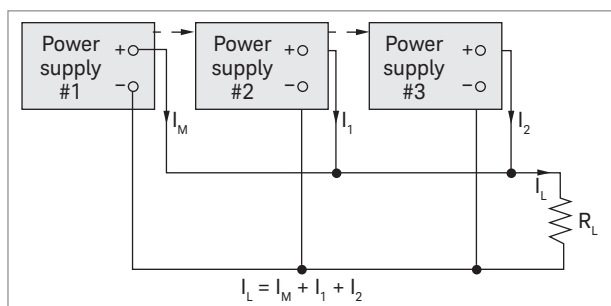


Figure 2: Connecting units in parallel

Program the current limit of each unit to its maximum value and program the output voltage of the CV unit to a value slightly lower than the CC unit(s). The CC units supply the maximum output current that they have been set to and drop their output voltage until it matches the voltage of the CV unit, which supplies only enough current to fulfill the total load demand.

The Keysight N6700 supplies have a grouping function that virtually parallels outputs. Output channels can be configured or “grouped” to create a single output with higher current and power capability.



## Tip 7: Simplify battery drain analysis with analysis tools

To adequately specify the power source for products that exhibit pulsed and dynamic current loading (such as digital cellular phone and hard drives), you need to evaluate both the peak and DC averages current draws.

You could use an oscilloscope to monitor a shunt or a current probe, but this approach raises issues with voltage drops, ground loops, common mode noise, space, and calibration.

As a simpler and cheaper alternative, use a power supply with built-in measurement capabilities. The Keysight 66300 mobile communications DC sources store up to 4,096 data points at sample intervals from 15  $\mu$ s to 31,200 s. Like an oscilloscope, they acquire pre- and post-trigger buffer data by crossing a user-set threshold.

The Keysight 14565B device characterization software is an automation tool compatible with the 66319/21B or D. These four sources have battery emulation capabilities and work with the software to accurately test today's communication devices as well as your next generation designs for cell phones, PDAs, Bluetooth™ enabled devices, and wireless LAN access devices. The software features dynamic current characterization (Figure 1), data logging and analysis (Figure 2), and CCDF measurements (Figure 3).

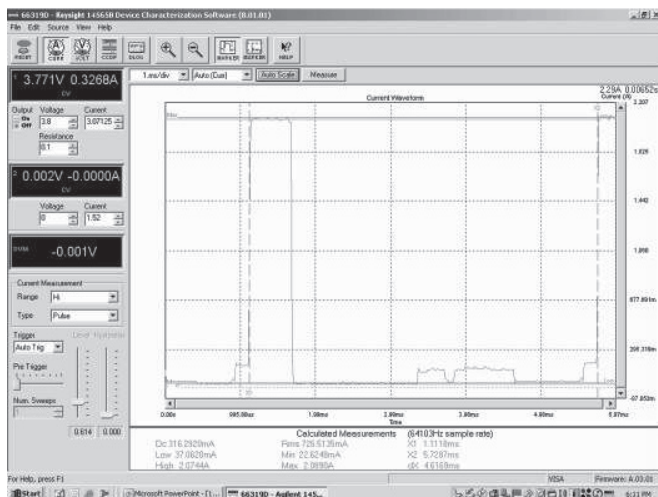


Figure 1. Waveform capture and analysis using the Keysight 14565B software.

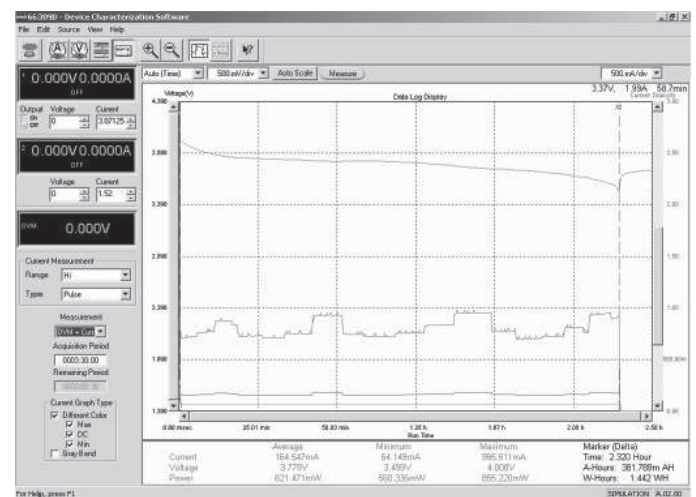


Figure 2. Data logging and analysis using the Keysight 14565B software.

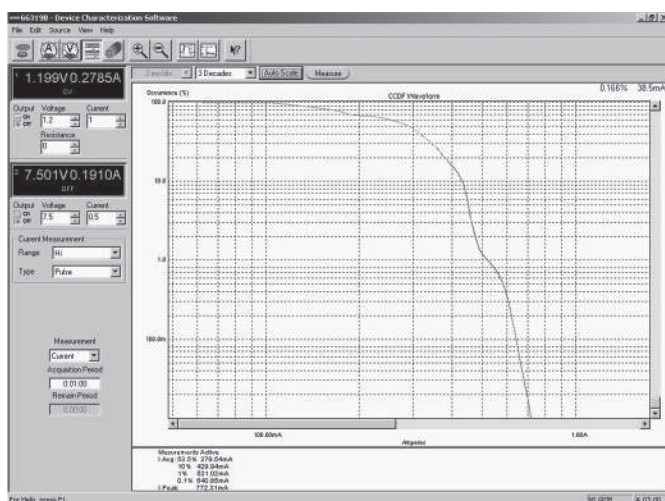


Figure 3. Complementary cumulative distribution function (CCDF) capture and analysis using the Keysight 14565B software.

## Tip 8: Characterize inrush current with an AC power source/analyzer

The inrush current characteristics of AC-DC switch mode power supplies vary with the turn-on phase of the voltage cycle. Usually, these power supplies have input capacitors that draw high peaks of inrush current as they charge from the rectified AC line at turn-on. Characterizing inrush current versus turn-on phase can provide some important design insights:

- Uncover component stresses
- Check to see if a product produces AC mains disturbances that interact with other products connected to the same branch circuit
- Select proper fuses and circuit breakers

However, this can be a challenging measurement because you have to synchronize the current digitization and peak current measurement with the startup phase of the voltage. Worst case inrush currents occur near the voltage cycle's peak and when the AC input capacitor of the DUT is fully discharged at startup.

Therefore, you must perform tests at incremental voltage startup phases from about 40° to 90° (Figure 1) and let the DUT's AC input capacitor discharge between tests.

A traditional test setup includes an AC source with programmable phase capability and an output trigger port, a digital oscilloscope, and a current probe. However, using an advanced AC power source/analyzer such as the Keysight 6800 series AC power source/analyzers is easier because they have built-in generation, current waveform digitization, peak current measurement, and synchronization capabilities that let you perform inrush current characterization without cabling and synchronizing separate instruments.

On the DC side, the Keysight N6705A DC power analyzer helps characterize the power of a device much like the AC power source/analyzer, except for DC power.

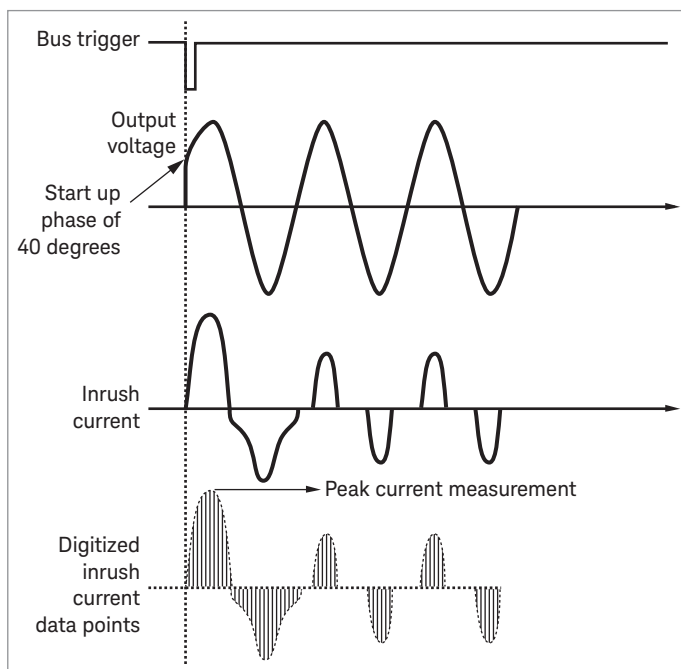


Figure 1: An inrush current measurement at 40° using Keysight 6800 series AC power source/analyzers

## Tip 9: Use a power supply to measure DUT supply current

Accurately measuring DUT supply currents above 10 A is beyond the range of the typical DMM in ammeter mode. You could use an external shunt and the DMM's voltage mode, but using the power supply itself is a better solution. Many supplies include an accurate measurement system, including a shunt. Current (with the internal shunt) or voltage measurements at the DUT can be as simple as sending a MEAS command to the power supply.

The following table shows the level of measurement accuracy you can expect with a good-quality supply:

| Output level       | Typical accuracy |
|--------------------|------------------|
| Full               | 0.1% to 0.5%     |
| 10% of full output | 0.5% to 1%       |
| 10% of full output | near 10%         |

While the advantages of using the power source to measure high currents is clear, using it to measure low currents may not be as obvious. A system DMM has 0.01 percent to 0.1 percent accuracy, although this doesn't include other possible errors that can affect the measurement, such as cabling. In contrast, the power supply accuracy figures in the table include all applicable factors.

A good system DMM can measure current down to the picoamp level, but you rarely need to measure DUT supply currents this low. In most cases, the toughest measurement will involve current draw by a battery-powered device in sleep mode (such as a cellular phone), where measuring 1-10 mA with reasonable accuracy is usually all you need.

Most power supplies' current readback performs well between full scale and 10% of full scale. You can also choose a power supply with multiple range readback. For example, power sources, such as the Keysight N676xA precision modules, offer full scale accuracy of 0.04% + 15  $\mu$ A at low range (100 mA) or 0.04% + 160  $\mu$ A at high range (3 A).

## Tip 10: Create DC power waveforms with list mode

Instead of using a DAC or arbitrary waveform generator to drive a power supply to create DC power waveforms, consider using a single power product with list mode. List mode lets you generate complex sequences of output changes with rapid, precise timing which may be synchronized with internal or external signals. They contain up to 512 individually programmed steps and can be programmed to repeat themselves.

Using list mode helps you create DC power waveforms such as:

- Pulse trains
- Ramps
- Staircases
- Low frequency sinewaves with DC offset
- Arbitrary voltage and current waveforms

You can create a sequence of up to 512 command steps to define voltage or current steps and set dwell times for each step. These waveforms can also trigger on internal or external events and be repeated (Figure 1). Once the list of commands is stored in the power supply, the entire list is executed by a single command. This reduces command processing time and simplifies code. Example applications include powering power supply rejection ratio test, simulating automotive crank profiles, and generating pulse dropouts.

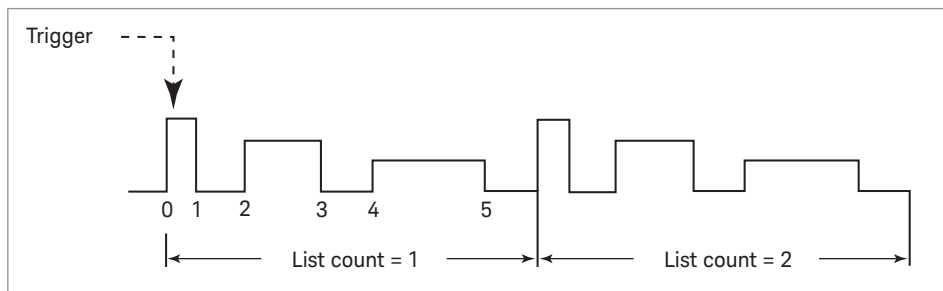


Figure 1: An arbitrary voltage waveform example with a repeat count of 2.

Power products such as the Keysight N675xA and N676x modules in the Keysight N6700 Modular Power System have list mode. The maximum frequency of the waveform is limited by the power module and voltage setting of the test.

In addition, the Keysight N6705A DC Power Analyzer is a unique bench product with list mode. You can program arbitrary waveforms directly from the front panel without writing a single line of code.

## Conclusion

We hope you have a better idea of what your power supply is capable of. A well setup power supply let's you have accurate voltage and the right amount of power with little noise. Supplement this with the tips and tools introduced, you'll achieve higher test capacity with ease.

Wait, there's more. Visit [www.keysight.com/find/power](http://www.keysight.com/find/power) to learn how you can deliver more!

You're trying to get the most from your power products and get the best power products for your money—and this booklet is a great place to start. You'll find 10 easy and practical ways to improve power generation and measurement, along with a brief look at our most popular power instruments and systems.

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