Application Note Series

Making Low Current Measurements with a Series 2280S Precision Measurement DC Power Supply
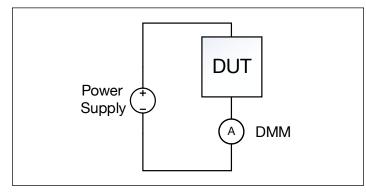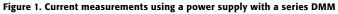
Introduction

Given today's focus on going green and on creating mobile devices and devices for the Internet of Things (IoT), minimizing the power consumption of integrated circuits and electronic sub-assemblies is a major focus for manufacturers of these components. Minimizing power consumption means minimizing the current draw of all integrated circuits and electronic sub-assemblies. In order to characterize these components, their current consumption must be measured. In the past, when power consumption was not as great a concern, measuring the current through a device was simple because current levels were relatively high—milli-amps or even amps—and could be measured with a standard multimeter (DMM). Today's devices have operating currents as low as micro-amps or less and require more sophisticated equipment to measure.

This application note explores two different methods for making low current measurements on a low power device-under-test (DUT): using a power supply with a precision DMM in series with the DUT and using a Precision Measurement Power Supply. It details how to configure a Series 2280S Precision Measurement DC Power Supply to make highly accurate low current measurements.

Using a Power Supply with a Series DMM

One method for measuring the current flow through a device is to place a DMM in series with the circuit and measure the current using the DMM. With a quality 6½-digit DMM, accurate current measurements can be made at micro-amp current levels. *Figure 1* illustrates the test setup for this method.

Figure 1. Current measurements using a power supply with a series DMM

Although this method is capable of producing a very accurate measurement of current through the device, it can introduce many problems during characterization due to the voltage burden created by the DMM. Even though the voltage at the output of the power supply may be at the programmed value, the voltage at the DUT is actually lower than the programmed value due to the voltage burden created by the DMM. Rather than the programmed voltage, the voltage seen at the DUT's terminals is equal to the programmed voltage minus the voltage across the DMM ($V_{DUT} = V_{SET} - V_{DMM}$). If this voltage drop is not accounted for and the user assumes the voltage at the device is equal to the programmed voltage, then power and resistance measurements will have significant error because the voltage used to calculate them will be higher than the value at the DUT. This drop in voltage can also cause problems when testing the device at voltages near the minimum operating voltage. If the voltage burden of the DMM is too great, the voltage seen at the device may be below the minimum operating voltage and the device will fail to operate correctly, resulting in incorrect measurements.

This drop in voltage could be compensated for by outputting a higher voltage at the power supply so the desired voltage appears at the DUT. However, the voltage burden created by the DMM varies with the amount of current flowing, so compensation is difficult. A second DMM could be used to measure the voltage at the device directly, but this not only adds cost and complexity to the test system by introducing yet another piece of equipment, it can also create a significant source of error for low current measurements. The DMM adds additional load to the test circuit, resulting in currents higher than those actually flowing through the device. Although a power supply with a series DMM is certainly a simple enough method for making a low current measurement, it is far from an ideal method.

Using a Precision Measurement Power Supply

If using a precision measurement power supply, the current through a device can be measured with the same precision as a high quality 6½-digit DMM, but it can be done more simply and more accurately as well. Testing is simplified because only a single instrument is required to test the device. *Figure 2* illustrates the test setup.

With only a single instrument, testing can begin sooner because there is less equipment to set up. Automating the measurement is simpler as well with only one instrument to program. This eliminates the need to synchronize multiple instruments and allows the test engineer to focus on making the measurement.

With a precision measurement power supply, device characterization is more accurate than with a power supply and DMM. Precision measurement power supplies are capable of
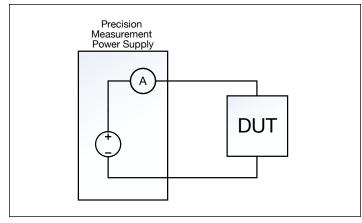
Figure 2. Current measurments with a precision measurement power supply

measuring both the current and voltage applied to the device. Current is measured internally, so it places no voltage burden on the test circuit like a series DMM would. This results in the voltage at the device being equal to the programmed voltage. For even greater accuracy, voltage can be sensed directly at the device using remote sense leads placed at the device terminals, allowing the precision measurement power supply to compensate automatically for any voltage drops across the test leads that supply current to the device. These sense leads have very high input impedance, so they place virtually zero load on the test circuit. Using these features, precision measurement power supplies are capable of performing very accurate characterization of devices at any current level. By containing all of this capability in one instrument, precision measurement power supplies greatly decrease test system complexity as well as cost.

Measuring the Quiescent Current of a Precision Voltage Reference Using a Series 2280S Precision Measurement DC Power Supply

This application note outlines how to configure a Series 2280S Precision Measurement DC Power Supply to measure the current consumption of a precision voltage reference when nothing is connected to the reference's output. This quiescent supply current of the voltage reference device being measured is specified in its datasheet at a typical current level of only $31\mu A$ and a $35\mu A$ maximum level. To make this measurement, the instrument will be configured for maximum precision and accuracy.

Equipment

Precision measurement power supplies reduce the amount of equipment necessary to make a current measurement on a device. In this example, the following equipment is used:

- Keithley Series 2280S Precision Measurement DC Power Supply
- Test leads
- Precision voltage reference

Making Connections

Connections for this test are illustrated in *Figures 3* and *4*.
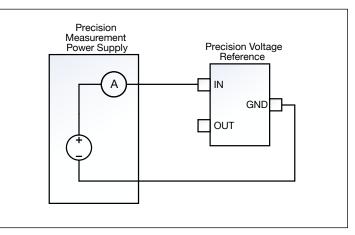

Figure 3. Test connections from a precision measurement power supply to the precision voltage reference DUT
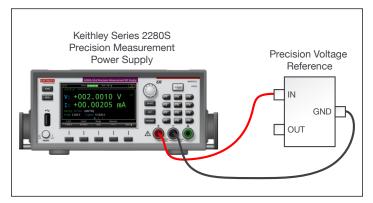

Figure 4. Test connection from the Series 2280S Precision Measurement DC Power Supply to the voltage reference DUT

Test connections are extremely simple as only two test leads, HI and LO, are required for making connections to the DUT. Remote voltage sensing is not required for accurate voltage measurements because the currents are very low, so they won't produce significant voltage drop in the test leads. Shielded cabling is recommended to reduce noise. If the test circuit is grounded, grounding should be at a single point to avoid measurement error due to ground current loops.

Configuring the Instrument

To make highly accurate current measurements in the low micro-amps range, the Series 2280S Precision Measurement DC Power Supply must be configured for maximum precision. The instrument's colorful graphical user interface (*Figure 5*) makes accessing instrument settings quick and easy to do from the front panel.

To make low current measurements with maximum precision, configure the instrument from the front panel with the following steps:

Figure 5. Series 2280S main menu showing all the functionality available in the supply

Configure the Measure Settings

- Set the instrument to 6½ digits of resolution (*Figure 6*).
- Turn Auto Zero On.
  - Auto zero will automatically measure an internal reference to zero the instrument for each triggered measurement, resulting in measurements with greater accuracy.
- Set the NPLC value to 15 (12 for 50Hz power systems), the maximum measurement aperture time. This increases both measurement resolution and accuracy.

Figure 6. Series 2280S measure settings for low current measurements

Configure the Filter Settings

When the averaging filter is turned on, the instrument will return readings that are the average of several measurements. Averaging measurements causes the readings to be more stable, enabling greater precision. Configure the Filter Settings (*Figure 7*) as follows:

- Set the Filter State to On.
- Change the filter count to 10.
  - The filter count can be increased all the way up to 100 for even more stable readings.

Figure 7. Series 2280S filter settings for low current measurements

Configure the Trigger Settings

- Set the Sample Count to 10 to match the filter count (*Figure 8*). This will fill the averaging filter with 10 back-to-back readings with very little time between readings.
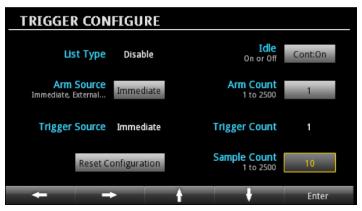

Figure 8. Series 2280S trigger settings for low current measurements

Configure the Source Delay

For low current measurements, it is necessary to allow time for currents in the test system to settle to their final values before making measurements in order to obtain accurate results. By setting a source delay, measurements can be delayed long enough for the currents to settle.

- Set the Source Delay long enough to give the current time to settle (*Figure 9*). Although 10ms is adequate for most micro-amp level measurements, a longer source delay may be necessary if the DUT has a lot of input capacitance or there is an external filter capacitor on the fixture.

Figure 9. Series 2280S source delay settings for low current measurements

Using these settings, the instrument will now make measurements with maximum precision and return readings that are the average of several high resolution measurements.

Running the Test

With the measurement settings configured for maximum precision, the instrument is now ready to start the test. To begin the test, first set the output voltage (V-Set) to the proper voltage for the DUT. For the precision voltage reference being tested here, V-Set will be set to 3V. Next, set the current limit (I-Limit) to a value low enough that it should protect the DUT but high enough that sufficient current will flow for the device to operate. For this device, the I-Limit will be set to the minimum allowed value of 100μA. Finally, turn the output on to begin taking measurements. *Figure 10* shows an image of the front panel.

Figure 10. Series 2280S low current measurements on the precision voltage reference DUT

Using the measure settings described previously, the Series 2280S Precision Measurement DC Power Supply can make measurements that are stable down to approximately the 100nA digit. *Figure 11* shows the instrument's front panel graph, which demonstrates how stable the measurement is from reading to reading given how little movement there is in the trace. In addition, statistics are displayed at the bottom of the screen, showing a very low peak-to-peak value and standard deviation for the readings.
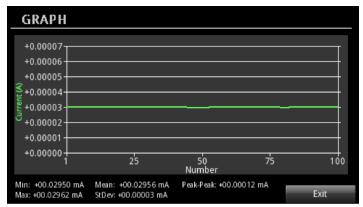

Figure 11. Series 2280S front panel graph of low current measurements

Automating Low Current Measurements

Configuring a Series 2280S Precision Measurement DC Power Supply for precise low current measurements and collecting the data can be automated by sending the following SCPI commands to the instrument:

*RST	Reset the instrument to defaults.
:VOLT:PROT:LEV 3.3 :VOLT:LIM 3.3 :CURR:PROT:LEV 0.1	Configure the Over Voltage Protection, 3.3V, Voltage Limit, 3.3V, and Over Current Protection, 0.1A, to protect both the operator and the device.
:SENS:CONC:AVER:STAT ON	Turn on the averaging filter.
:SENS:CONC:AVER:COUN 10	Set the filter count to 10 to return readings that are the average of 10 measurements.
:SENS:CONC:NPLC 15	Change the NPLC setting to 15 (12 when using 50Hz power) to maximize measurement resolution and accuracy.
:SYST:AZER ON	Turn on Auto-Zero to maximize accuracy.
:INIT:CONT OFF	Turn off continuous initiation of the trigger model.
:TRIG:SAMP:COUN 10	Set the sample count to 10 to take 10 measurements and fill the measurement filter.
:DEL:STAT ON :DELay 10e-3	Turn the source delay on and set the delay value long enough for the current flowing into the device to settle before starting measurements.
:DATA:CLEAR	Clear the buffer.
:VOLT 3	Set the proper output voltage for the device.
:CURR 0.0001	Set the current limit to protect the device. 100μA is the minimum.
:OUTP ON	Turn the output on.
:INIT	Initiate the measurement.
*OPC?	This will return "1" after all measurements are complete. Be sure to set the timeout of the read operation long enough for the measurements to finish. High precision low current measurements take much greater time to complete than normal measurements. 15 PLC measurements will take at least 500ms each with auto-zero enabled.
:TRAC:DATA? 'READ,SOUR'	Read back the current and voltage measurement data from the buffer.

Conclusion

With a Series 2280S Precision Measurement Power Supply, design and test engineers can make reliable, high quality, low current measurements on their devices quickly and easily. The easy-to-navigate, easy-to-read graphical user interface allows configuring these instruments for precise low current measurements on the bench in only seconds. As linear power supplies, their output is clean and quiet, minimizing signal noise for maximum measurement accuracy. Testing is simplified because only a single instrument must be configured and cost is reduced because no additional equipment is required. The measurement capability of Series 2280S Precision Measurement DC Power Supplies is a true revolution in what can be done with a power supply.

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