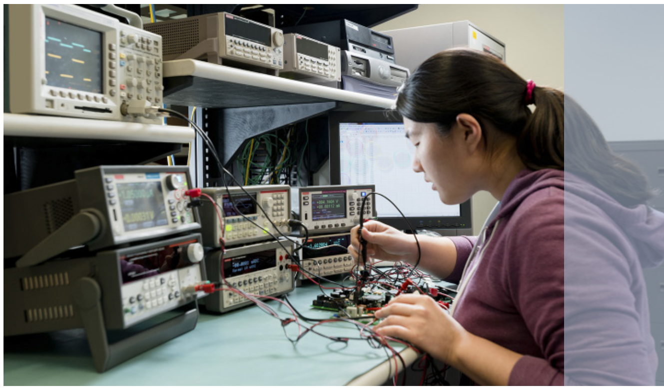

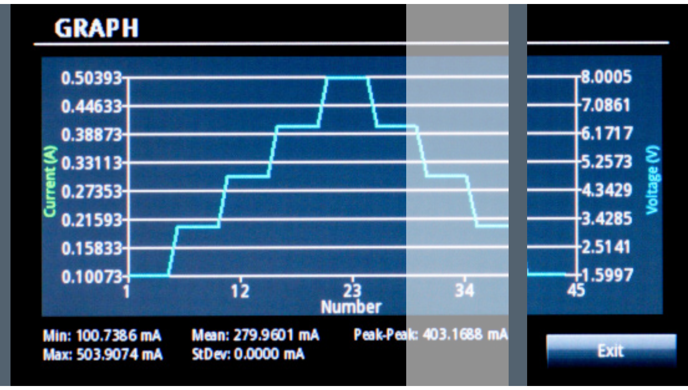

Analyzing Device Power Consumption Using a 2280S Precision Measurement Supply

Application Note

As battery-powered wireless devices have become a standard part of everyone's life, battery consumption becomes a critical factor of the device's performance. More and more studies are focused on improving the power efficiency of electric devices and components.

For the battery-powered devices, the power consumption can be represented by the input current because the input voltage is a constant voltage during a load current measurement. If we can measure the load current under different working modes, we will be able to compute power consumption. As a result, we will be able to deduct the device's battery life in its active modes and its standby mode. However, measuring DC current precisely, especially low current can be a difficult challenge. Accurately measuring the load current down to milliamp or even to microamp levels without affecting the original circuit current presents significant challenges for the test methodology used and for the selection of appropriate instrumentation with sufficient sensitivity.

Traditional ways of measuring low current

There are two traditional ways to measure low currents:

1. Connect a precision resistor, R, in series with the circuit and measure the voltage across the resistor, V_R with a high-precision digital multimeter. Calculate the current value as V_R/R.
2. Measure the current by using an oscilloscope and a current probe.

However, both ways have limitations.

Measuring current with a digital mulitimeter

To measure the current with a precision sense resistor in series, the engineer has broken the circuit and inserts a resistor in a location which will not compromise the resistance with components that would be in parallel with the sense resistor.

KEITHLEY
A Tektronix Company

For low current measurement, a resistor with resistance of at least 1Ω and a high-precision voltage measurement device must be chosen. This technique adds a number of error terms. If a resistor with 1% tolerance is used, a measurement error of as much as 1% must be accounted for in the measurement uncertainty. In addition, the resistor has a temperature coefficient and; the resistance value of the resistor will rise as the resistor's temperature increases due to the power dissipated in the resistor. The resistor's temperature coefficient determines how much the resistance will change. An example of a good temperature coefficient is 100ppm/°C. If the temperature of the resistor raises 10°C, a small temperature rise, the resistance of the 1Ω sense resistor will increase by 1000ppm or 0.001Ω. That adds another 0.1% error to the measurement. Furthermore the addition of the sense resistor reduces the load current; this increased resistance in the load circuit adds another small error term. Finally, the DMM has a measurement uncertainty that adds a further error term to the measurement of the current. With a 10µA sleep mode current, the DMM will be measuring 10µV, a small voltage. The DMM has both % of range and offset error. A good 6½-digit DMM may have a voltage accuracy specification of 0.005% of reading and 0.004% of range. A 10µV reading can be subject to a 4µV of of range uncertainty if the DMM is on its 100mV range. The DMM measurement uncertainty is the dominant error term. Thus the standby or sleep mode current measurement using a sense resistor and a DMM can have a substantial uncertainty. Thus the test result for a low current measurement can be easily compromised.

A wireless device will transition near-instantaneously to its full power mode during the device's RF transmission state. When the device's load current changes from a low standby current of 10–500µA to full power current draw of 1A or more, the voltage across the sense resistor will change by a factor of up to 100,000. That forces the DMM to make a range change. If the RF transmission is short, 1ms or less, the DMM will miss the peak current measurement while the DMM is changing range. Options are to change the sense resistor value to make the higher current measurement or set up the DMM to be on a higher range and trigger it to make a measurement when the RF transmission starts. Also the DMM needs to be fast enough to make a measurement on a short load current burst. Making standby and peak load current measurements to determine total power consumption is a challenging task for even high resolution DMMs. A sense resistor with a lower temperature coefficient can be used and a DMM with more resolution and more speed can be used but at much greater expense. Those items are less likely to be readily available to the design engineer.

Another alternative is to use the digital multimeter as a current measurement instrument and eliminate the sense resistor. The sensitivity of a good digital multimeter reaches well below a microamp and provides multiple measurement ranges. However, connecting a multimeter in series in a circuit does not reduce the measurement error. The DMM's current function introduces its own shunt resistance or burden voltage, which is the resistance value the DMM inserts in the circuit or the voltage drop the DMM causes in the circuit. Therefore, the measured current value will differ from the actual current due to the voltage drop caused by the DMM.

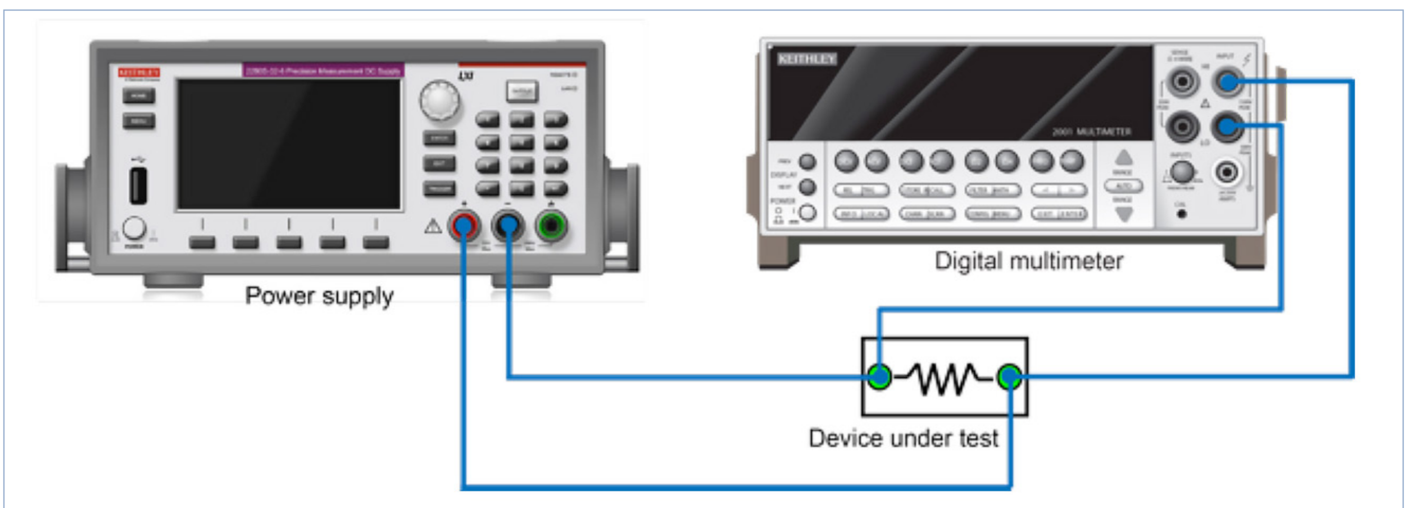

Figure 1. Current measurement with digital mulitimeter

DC current	10.00000 mA	< 0.1 V Burden Voltage	0.005 + 0.010	0.030 + 0.020	0.050 + 0.020	0.0020 + 0.0020
	100.0000 mA	< 0.6 V	0.010 + 0.004	0.030 + 0.005	0.050 + 0.005	0.0020 + 0.0005
	1.000000 A	< 1.0 V	0.050 + 0.006	0.080 + 0.010	0.100 + 0.010	0.0050 + 0.0010
	3.00000 A	< 2.0 V	0.100 + 0.020	0.120 + 0.020	0.120 + 0.020	0.005 + 0.0020

Figure 2. Burden voltage shown on a digital multimeter

The Burden Voltage shown in the above figure is caused by the multimeter shunt resistor. Under different measurement ranges, the multimeter will change its resistance value to ensure the most accurate measurement. Thus the voltage drop varies. Furthermore, 6½-digit multimeters from different suppliers will generate different test results since they will have different voltage burdens. Using the DMM's current function is no better a solution than using the DMM's voltage function with a sense resistor.

In Figure 3 below, a 300 ohm resistor is the load; and, the circuit is powered with high precision power supply with output voltage set at 3 V. On the screen of the power supply, the output current readout is 9.9513 mA. In Figure 4, a high precision 7½-digit multimeter is connected in series to the circuit with the current measurement range chosen as 20 mA, which corresponds to the Burden Voltage of 0.4V. The current readout is 9.5978 mA as you can see from Figure 4. There is a 0.4 mA difference when the digital multimeter is connected. For the low current measurement, 0.4mA is a large error.

Measuring the load current with an oscilloscope and a current probe

In comparison, measuring the load current with an oscilloscope and a current probe is a better option because the probe sensing is based on Hall Effect technology and neither a sensing element nor a measuring instrument needs to be connected into the circuit. In addition, an oscilloscope has a much higher sampling frequency than a multimeter, which is an advantage for measuring dynamic load current bursts which occur during a wireless device's RF transmissions. However, the oscilloscope and the current probe are not accurate enough for low current measurement on low-power consumption devices. The accuracy of a current probe is only 3% and the minimum current a sensitive current probe can detect is 200µA. Thus, the oscilloscope and probe can capture the peak burst load current; however this technique does not have the sensitivity to measure the low sleep or standby load current.

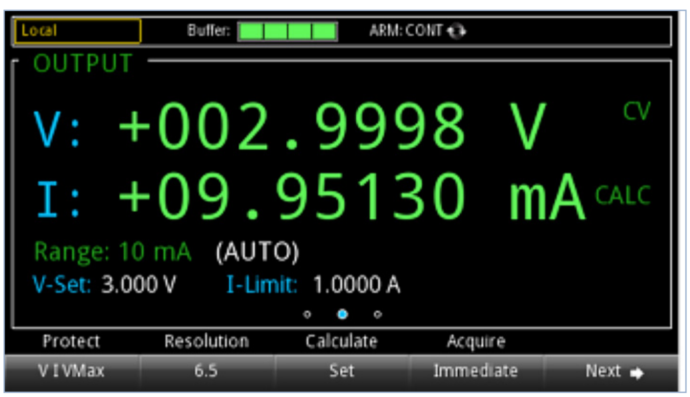

Figure 3. Current readout when the multimeter is not connected

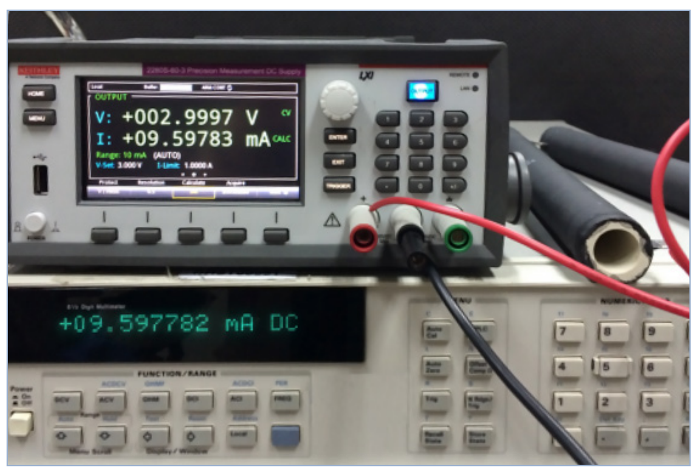

Figure 4. Current readout when a multimeter is connected

Figure 5. Current probe

Measuring current with a high precision measurement power supply

There is a third option to either using a digital multimeter with a sense resistor or an oscilloscope with a current probe. A precision measurement power supply has the sensitivity to measure low load currents and also has the speed to measure short load current bursts. Other benefits in addition to measuring low current with excellent accuracy, especially for battery-powered devices, include: a stable DC power supply for the device and the circuit is not modified by the addition of any sense components. Thus the measurement results will not be subject to additional uncertainties. However, there are a few requirements for this kind of power supply.

1. High precision measurement: To measure the low current in standby mode, the power supply should be able to detect very small currents down to microamp levels with resolution beyond 5½ digits;
2. Digital multimeter capability: The power supply should perform variable power line cycle ingrations to eliminate the effect of noise, particularly power line noise.
3. Low ripple and noise: The output should be as clean as possible with very low ripple and noise;
4. Fast transient response to instantaneous, large load changes: The power supply can respond instantly to a large, narrow load current pulse-like increase. Typically, the load current from most mobile devices changes very quickly from microamp levels to ampere levels, so only a power supply with a short response time can maintain a stable voltage during the large load change. If a typical power supply is employed and the load current makes a fast transition, the DC supply will need hundreds of microseconds to recover to the original voltage, which is detrimental to measuring the peak load current of the device under test.

As shown in the following figure, the 2280S Precision Measurement Power Supply is designed to integrate a programmable DC power supply with a 6½-digit multimeter, an easy-to-use graphical interface and multiple interface ports. The 2280S can provide stable DC power supply as well as accurately measure power consumption of the battery-powered devices.

Figure 6. Benefits of 2280S Precision Measurement Power Supply

Major benefits of the 2280S Precision Measurement Power Supply are as follows:

1. The 2280S offers four current measurement ranges: 10A, 1A, 100mA, and 10mA. Therefore full load currents as well as standby mode and sleep mode currents can be measured accurately.
2. The 2280S permits setting the measurement integration time to either capture short load current bursts with 33µs (for 60Hz power lines and 40µs for 50Hz power lines) or to minimize noise and maximize accuracy with integration times as long as 300ms.
3. Furthermore, the 2280S responds to a large load current change very quickly to ensure a stable output voltage with minimum overshoot and undershoot to avoid damaging the device-under-test. The 2280S' fast transient response is a very short 50us. Thus the supply can be used as a very stable supply for mobile phones or other mobile, wireless devices.

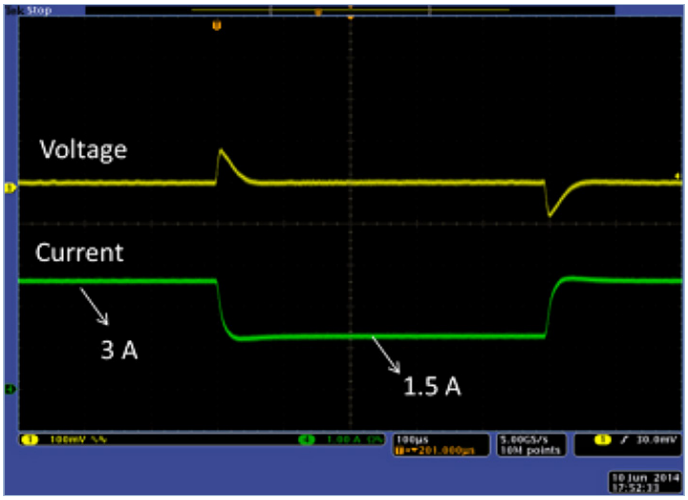

Figure 7. The load current instantaneously transitions from 3 A to 1.5 A and then back to 3A. The output voltage recovers within a very fast, 38 us

4. The 2280S supports four-wire sense connections which ensure that the programmed voltage is applied to the load and compensates for the voltage drop in the leads between the power supply and the load.

Test sample

To conduct a power consumption (total energy) measurement with a 2280S power supply, the following steps are recommended:

1. Connect a 2280S to the DUT (device under test). The following figure shows that 2280S is connected to a wireless optical mouse.

Figure 8. 2280S is connected to the DUT

2. Set the output voltage. For the wireless mouse, the voltage is set to 3 V, and the current limit is left at the default value of 0.1A. All other settings are default settings.
3. Read the current changes from the display or display the readings using the data sheet display.

Calculate the power consumption (total energy) and the total charge consumed using $E = \Sigma V * I * \Delta t$ and $Q = \Sigma I * \Delta t$.

Calculate average power as $P_{AVE} = \frac{\Sigma V * I}{n}$, where n = the number of data points.

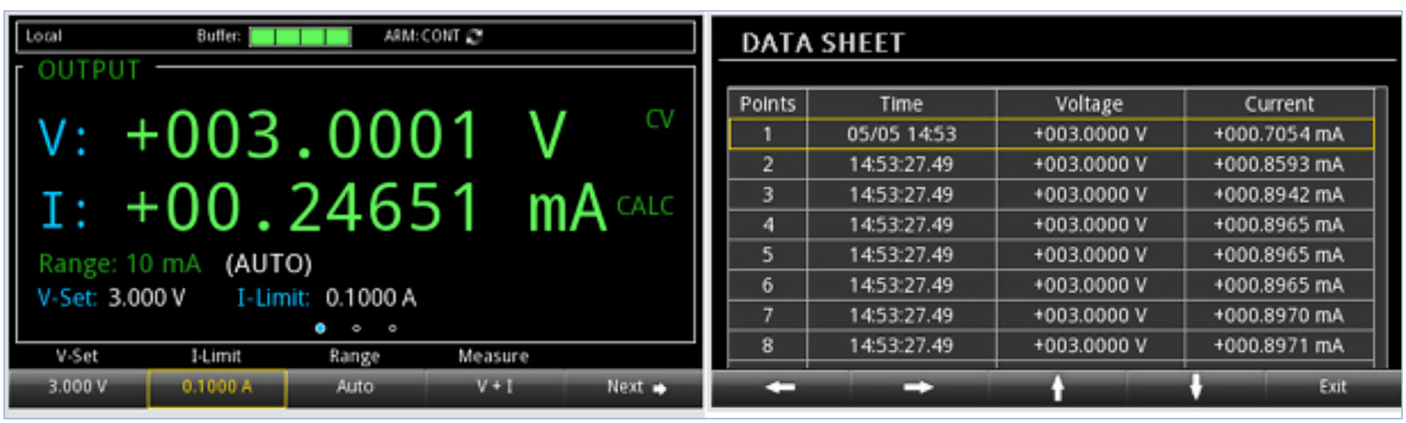

Figure 9. Current readout from the display (left) and the data table display (right).

Contact Tektronix and Keithley:

ASEAN / Australasia (65) 6356 3900
Austria 00800 2255 4835
Balkans, Israel, South Africa and other ISE Countries +41 52 675 3777
Belgium 00800 2255 4835
Brazil +55 (11) 3759 7627
Canada 1 800 833 9200
Central East Europe and the Baltics +41 52 675 3777
Central Europe & Greece +41 52 675 3777
Denmark +45 80 88 1401
Finland +41 52 675 3777
France 00800 2255 4835
Germany 00800 2255 4835
Hong Kong 400 820 5835
India 000 800 650 1835
Italy 00800 2255 4835
Japan 81 (3) 6714 3010
Luxembourg +41 52 675 3777
Mexico, Central/South America & Caribbean 52 (55) 56 04 50 90
Middle East, Asia, and North Africa +41 52 675 3777
The Netherlands 00800 2255 4835
Norway 800 16098
People's Republic of China 400 820 5835
Poland +41 52 675 3777
Portugal 80 08 12370
Republic of Korea 001 800 8255 2835
Russia & CIS +7 (495) 6647564
South Africa +41 52 675 3777
Spain 00800 2255 4835
Sweden 00800 2255 4835
Switzerland 00800 2255 4835
Taiwan 886 (2) 2656 6688
United Kingdom & Ireland 00800 2255 4835
USA 1 800 833 9200

Rev. 06/15

For Further Information
Tektronix and Keithley maintain a comprehensive, constantly expanding collection of application notes, technical briefs and other resources to help engineers working on the cutting edge of technology. Please visit **www.tektronix.com** and **www.keithley.com.**

06/15 KI 1KW-60143-0

Tektronix®

KEITHLEY
A Tektronix Company