

## Accurately measuring nanoamperes Using the Fluke 8808A Multimeter

### Application Note

Makers of battery operated electronic devices are familiar with so-called current leakage, which is sometimes referred to as standby or dark current. The phenomenon occurs because there is always some impedance in a battery-powered circuit even when the power switch is off or the device is otherwise not “powered up.”

Standby current leakage is often designed into a device. It occurs in electronic products such as cellular phones and automobile stereos with microprocessor controls and memory circuits that draw some amount of current off the battery even when they are turned off. There are, in fact, some legendary accounts of electronic devices experiencing short battery life due to design flaws that allowed excessive current leakage to prematurely drain their batteries.

The goal of electronics manufacturers, of course, is to make products that work, and constant testing during design and then during assembly as components are added, helps ensure that outcome. Specific to the present discussion, design and test engineers need to confirm that when a product's battery is charged and the device is powered down for a period of time, it will work when powered up and not have a dead battery.

It is also important to note in this context that electronic devices are often incorporated into larger systems, such as when stereos, clocks, and diagnostic computers installed in automobiles. The original equipment manufacturer—in this case, the auto manufacturer—will specify how much current leakage a component may draw off the battery. Auto manufacturers do not want dead batteries due to the current leakage of onboard electronics.

### Measuring standby current leakage

To avoid producing cellular phones that “die” after a few hours or stereos that produce drained car batteries in the morning, design engineers must be able to measure current leakage on prototypes. Then, during production, test engineers must be able to ensure products meet specifications (operation times, etc.) when they ship. In other



words, in order to avoid excessive current leakage, one must be able to determine the amount of current leakage that is occurring.

On the face of it, the task seems straightforward. Simply apply the leads of a quality digital multimeter (DMM) to the appropriate terminals and measure for direct current amperes. In reality, the task is not so simple, because current leakage typically falls in the low microampere range, and measurements made with traditional DMMs can be inaccurate.

The reason for the inaccuracies is that DMMs usually measure current by applying a known resistance in the form of a *shunt resistor* in series with the circuit being tested and allowing a current to flow through the circuit. With the current flowing, the DMM measures the voltage drop across the shunt resistor and uses Ohm's Law to calculate the current. This shunt-resistor method introduces a voltage drop, called the *burden voltage*, across the shunt. (See Figure 1.) The burden voltage becomes a source of error because, in accordance with Kirchoff's voltage law (KVL), it subtracts from the supplied voltage in the circuit. Errors of 50 % or more are possible.

By using a lower shunt resistance, a design or test engineer can reduce the amount of error, and high-end DMMs do offer selectable current ranges with variable shunt values. However, using low shunt resistance values will increase the measured voltage sensitivity to the point the measurement becomes inaccurate and unstable.

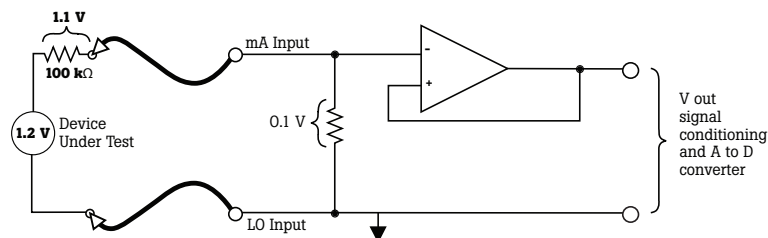
Much better accuracy can be achieved using a DMM that functions as an ammeter in low-current applications by using a current-to-voltage operational amplifier (op amp) conversion technique in series with the circuit. (See Figure 2.)

Using a theoretical example to describe the errors, a circuit with a 1.2 V dc supply with a device under test load of 100 k $\Omega$  results in a calculated current of 12  $\mu$ A. However, with the additional series meter shunt resistance (100  $\Omega$ ), the measured current through the device under test could drop to 11  $\mu$ A or less. To improve the sensitivity of low current measurements, amp meter design engineers will increase the shunt resistance; as the shunt resistance increases, so will the error.

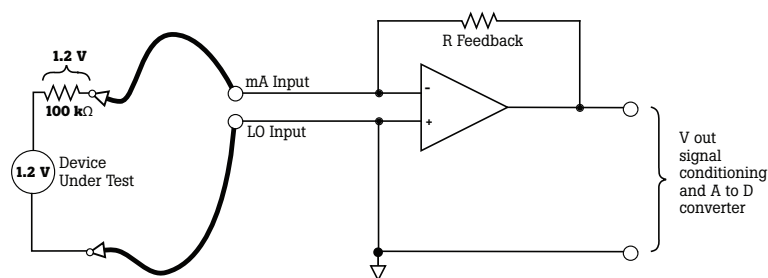
The new Fluke 8808A Digital Multimeter employs a current-to-voltage op amp in two low direct-current ranges: 2000  $\mu$ A and 200  $\mu$ A. In these ranges, the op amp introduces a low impedance into the circuit and converts the unknown input current to a voltage, eliminating

the need for a low resistance shunt and thereby eliminating the burden voltage. The result is an instrument that, in low-current measurements in the stated ranges, provides a resolution up to 100  $\mu$ A with a 0.03 % accuracy, and has minimal loading affect on the measurement, giving results reflecting the real world application.

The age of battery-powered micro electronics is here. And as battery performance specifications tighten, the importance of standby current measurement accuracy will only increase. Now that we can matter-of-factly measure nanoamperes with a standard bench multimeter, one can only speculate what new battery performance improvements may develop as a result.



**Figure 1.** Circuitry of a shunt multimeter used as an ammeter.



**Figure 2.** Circuitry in a feedback DMM used as a low-current ammeter. The Fluke 8808A DMM is such a tool.

## Be alert to error sources

In making low-current measurements, designers and test engineers should be aware of the possible sources of measurement errors and how to keep them from having an impact. Here are some common error points:

- Extraneous leakage current such as those caused by contaminants—dirt, grease, solder flux, etc. Whether on the device being tested, the test instrument itself or the test cables or connectors, contaminants can provide alternative paths for current to follow and thereby introduce errors into measurements. In design situations, before conducting low-current tests, designers should clean all potentially contaminated surfaces with alcohol. In assembly, cleanliness in every respect is essential. A fingerprint can become a conductor.

- Noise of any kind can introduce errors into low-current readings:
  - AC line noise can overwhelm sensitive amplifiers creating inaccurate readings. Filtering can help, and using either coaxial or shielded twisted-pair test cables will reduce erroneous readings.
  - Audible noise of any kind can introduce vibration into the measuring process. Vibration can, in turn, lead to the movement of a conductor against an insulator, creating error-producing noise in the circuit.
  - Thermal noise is produced when heat in the shunt or the device being tested stimulates the random motion and collisions of electrons in the circuit. The resulting voltage and current are proportional to the square of the resistance in the circuit (from both the device under test and the measurement circuit). Using shunts with lower resistances and feedback resistors along with low-noise resistors will help.



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11/2007 3129201 A-EN-N Rev A