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 kΩ results in a calculated current of 12 µA. However, with the additional series meter shunt resistance (10 kΩ), the measured current through the device under test will drop to 10.909 µA. To improve the sensitivity of low current measurements, ammeter 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 µA and 200 µA. 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 µA 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.

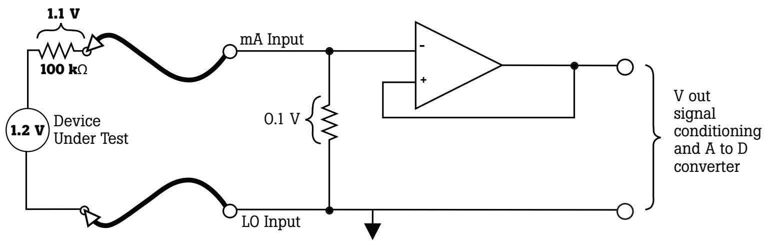

Figure 1. Circuitry of a shunt multimeter used as an ammeter.

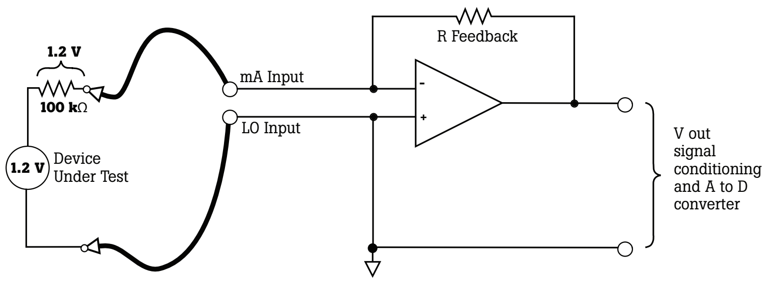

Figure 2. Circuitry in a feedback DMM used as a low-current ammeter. The Fluke 8808A DMM is such a tool.