Ensuring power supply accuracy

Martin Rowe - December 22, 2005

Every day, you count on programmable system and bench DC power supplies to deliver voltage and current to products under test. You expect these supplies to deliver outputs that cover wide ranges while remaining within specified tolerances. To ensure their DC power supplies fulfill such expectations, manufacturers calibrate the instruments before shipping them to customers, yet no two manufacturers follow an identical calibration procedure.

Why calibrate?

In adjustable supplies, a reference voltage sets the output, and it's that voltage that requires calibration. For many years, power supplies used potentiometers to set their outputs. Some supplies still do, but mechanical potentiometers tend to drift. Digital potentiometers replaced mechanical ones in many supplies, which improved stability.

New power-supply designs use digital-to-analog converters (DACs) to produce voltages from digital signals that originate from a front panel or an external communication bus. A DAC's output becomes the reference voltage that controls a power supply's output. DACs are more stable than potentiometers, but they still require initial and periodic calibrations. Programmable, DAC-based power supplies, unlike their potentiometer-based predecessors, don't need their cases opened for calibration.

Because of component tolerances, a given reference voltage won't result in an identical output voltage in every unit that comes off the assembly line. To compensate for those differences, each supply's DAC must produce a slightly different reference voltage for the same output setting. A power supply's processor applies correction factors, called calibration constants, that alter a DAC's input, which in turn alters its output. Manufacturers calculate those constants by taking measurements on a supply's output during calibration. Mark Edmunds, director of engineering at Xantrex, reports that his company's power supplies are typically accurate to within 2% prior to calibration and to within 0.5% after the calibration constants are applied.
A test setup for a programmable power supply consists of an isolation transformer, a variable AC power source, switches, loads, a DMM, and a computer that automates the procedure (Figure 1). Some manufacturers also include an oscilloscope for measuring output ripple and noise. (To learn more, you can download detailed test-setup diagrams for power supplies manufactured by Kepco and Xantrex.)

The use of an isolation transformer eliminates ground loops that cause errors and create safety hazards. A variable power source lets engineers and technicians test a supply at its high and low AC voltage limits, called a line-regulation test. By using programmable electronic loads, manufacturers can use the same test setup for numerous power-supply models. Some test setups also contain an AC power analyzer that lets engineers test a power supply under known power conditions. Xantrex's Edmunds, for example, uses an AC power analyzer to record input voltage, current, power, and power factor on a UUT's AC input.

The key instrument in a power-supply calibration and test setup, though, is a DMM. The DMM measures a supply's output voltage and also measures its output current by measuring the voltage across a shunt resistor. Power-supply manufacturers use a bench DMM with at least 5½ digits of resolution, because they need to detect small voltages such as 1 mV out of 30 V. Some manufacturers, however, use 6½-digit DMMs, and Agilent Technologies uses its 8½-digit DMMs.

The switches in the test setup serve various functions. An automated calibration setup needs switches to connect the load to the UUT. Other switches may connect a DMM and a scope to a supply's output. Some DMMs include switches that can connect them to a UUT's output or load. Engineers at Kepco built a test fixture that includes switches to make the load and instrument connections; the switches are programmable though an IEEE 488 port.

Different procedures

Dual displays measure output voltage and current. Courtesy of Xantrex.
Although the test setups are similar, the calibration procedures for voltage levels and load conditions vary among power-supply manufacturers. Some manufacturers perform two-point calibrations on unipolar power supplies with their supplies at 0 V and at full scale. Others perform two-point calibrations at 10% and 90% of full-scale settings from which they calculate gain and offset calibration constants ($mX+b$).

The two-point calibration isn't a universal practice, though. "We calibrate our Sorensen line of low-power DC supplies at five points," said Elgar application engineer Lyle Hilden. "We measure voltages at 10%, 25%, 50%, 75%, and 90% of full scale, then apply five calibration constants to each supply. A five-point calibration improves linearity over a two-point calibration." Elgar performs the five-point calibrations for both a supply's constant voltage and constant-current modes.

Manufacturers that perform two-point calibrations will add a third point for bipolar-output supplies. Service technician Nick Karafotis at B+K Precision noted that he calibrates at 0 V, positive full scale, and negative full scale for bipolar power supplies. Karafotis will, upon request, take measurements at other settings. "Some customers need calibration data. For those that require test data, we check a supply's output at several points. For example, we might take voltage measurements for a 0-V to 30-V supply at 0 V, 1 V, 5 V, 10 V, and 30 V."

The loads on power supplies during calibration also vary. Some manufacturers perform voltage calibrations with open circuits (no load), while others calibrate their supplies at 50% current output (half load) and at 100% (full load). Those that calibrate at no load will check a supply's output accuracy at full load. Hilden reports that Elgar performs the calibration with the DMM as the only load (essentially an open circuit, given a DMM's high input impedance). After applying the calibration constants, a technician tests each supply under full or partial load to check its load regulation. Most manufacturers use a calibrated electronic load set to provide a constant resistance during these tests.

In addition to operating as constant-voltage sources, a DC power supply also operates as a constant-current source, another feature that needs calibration. Typically, a manufacturer inserts a current shunt in series with a UUT's output, then measures the voltage across the shunt with a DMM (Figure 2). Manufacturers must accurately know the value of the shunt resistor. Some measure it...
with a DMM while others send their resistors to an outside lab for measurement. "We use a calibrated and cooled shunt resistor," said Liviu Pascu, senior engineer at Kepco, "and a 6½-digit DMM to measure the voltage across the shunt." Cooling is often necessary, because self-heating can cause a shunt resistor's value to change. A stable temperature also minimizes errors introduced by thermocouple effects in the wires.

**Feedback calibration**

Because programmable power supplies report the voltage and current they supply through digital displays and to a host computer through a communications bus, they need to measure their own outputs. Programmable power supplies have analog-to-digital converters (ADCs) that digitize their outputs. No power-supply calibration is complete, therefore, without calibration of the unit's readback circuits. After calibrating a supply's output, a test setup will set the output to a known value (typically 0 V and full scale, but that can vary) and measure it with a DMM. The test setup's computer then requests measurements from the DMM and from the supply under test. If the difference isn't within tolerance, the test setup will calculate $mX + b$ and store those constants in the supply's nonvolatile memory. It can then apply those calibration constants to the ADC.