Testing a power system with an appropriate load platform

Accurate testing of portable power systems, such as those based on fuel cells or primary batteries, requires testing under realistic load conditions. This can be accomplished using an electronic load, provided it is carefully selected, and the test platform carefully designed.

By David Weber

A well-engineered electronic load is not designed for exclusive use in the laboratory. It should be carefully engineered and built to test real power systems. This is true for portable systems for military applications, such as fuel cells, which must be tested under the real-world conditions in which they will be deployed. To meet this challenge, electronic loads can be manufactured as portable units, capable of running from a battery pack for use in the field. They can also be packaged as fully encapsulated units for which harsh conditions and other environmental hazards, such as sand, dust or silt, present no operational problem. There are also no maintenance or calibration problems to take into consideration with these units (Figure 1).

However, before running tests on any power system with an electronic load, it must be determined which type of electronic load is the most suitable for recreating the conditions that will be encountered in its operating environment. Because the variety of load types is broad, understanding the strengths and weaknesses of each type can make selecting the appropriate load nearly as challenging as the actual power-system testing process itself.

Broadly defined, there are several categories of electronic loads. For example, there are the older standard transistor types, the newer electronic FET high-power types, and then there are the latest, most reliable types of electronic loads. These latter types are of the low-voltage, low-on-resistance FET variety. And they work well for testing portable power systems based on batteries and fuel cells.

Two additional load types should be mentioned—as well as their inherent disadvantages. One type is based on the dated technique of using an array of power resistors. While relatively low in cost, this technique suffers from limited accuracy. The other type is what is called the switching electronic load, and this type should not be used for load-testing a power system as it can cause serious problems for the device being tested. However, there are several alternatives to this specific load type, as well as several crucial factors that must be considered when making the final selection.

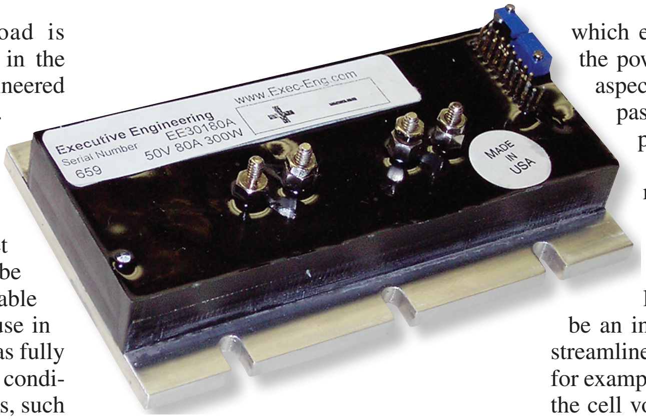

Figure 1. Product image of an electronic load.

Overview of electronic loads

Essentially, an electronic load functions as a constant-current power resistor, with an adjustable range of current controlled by some external control signal, such as an analog voltage. This feature removes the uncertainty of the power-system's output current. The electronic load can, therefore, maintain a constant current during testing, something that is impossible to do using only a power resistor. This simplifies the calculation for the power-system's output power, which essentially becomes a function of the power system's output voltage. This aspect of operation is favorable to the pass/fail testing used in high-volume production of batteries. This application, however, has the additional requirement that the load be able to ramp up to the desired current quickly (Figure 2).

Selecting the proper electronic load for a specific application can be an involved process that should be as streamlined as possible. In a fuel cell system, for example, the first requirement is to know the cell voltage or stack voltage of the fuel cell. Second, the current of the cell (or the entire fuel cell stack) must be determined. From these two parameters, the output power of the fuel cell system—or any other portable power system—is easily calculated. Once the power capacity of the unit under test (UUT) is known, the range of electronic loads suitable for testing can be restricted to those rated for this power level.

Nearly all electronic loads are rated in Watts at room temperature (25 °C). If testing at other than room temperature is required, then the electronic load's specifications must be carefully reviewed, because most loads will require de-rating at higher temperatures.

The next factor to consider when selecting a load is not as simple as it might first seem:

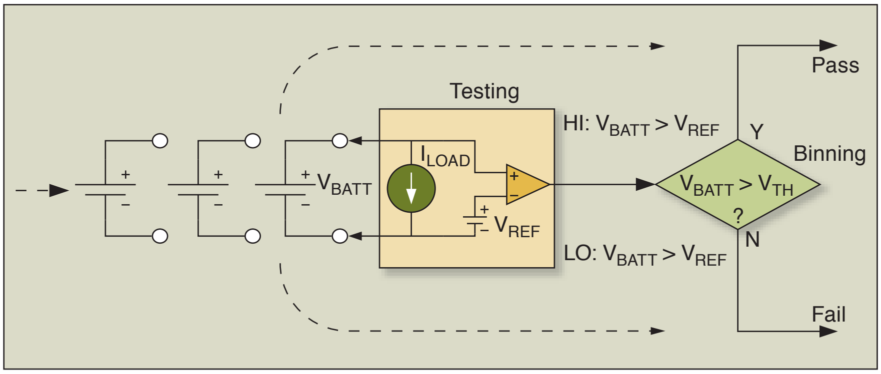

Figure 2. High-speed battery testing requires good understanding of the chemical slew rate of the battery to ensure that the slew rate of the load does not exceed the battery slew rate.

both the minimum and maximum voltages supported by the electronic load must be discovered. As the voltage applied to a load decreases, the load's ability to accurately control the current also decreases. Many electronic loads only work down to about 0.7 V (or even only down to 3 V). Below that, the load may function improperly, or even fail completely.

Wiring selection

Wiring is an important issue in electrical testing, and it should be considered together with the load selection. Unfortunately, many engineers fail to consider it when testing high-power systems, such as fuel cells that can generate from 100 A to 250 A. Yet, a few milliOhms of resistance in the wiring and connections can have a tremendous impact on the final voltage drop felt across an electronic load (Figure 3).

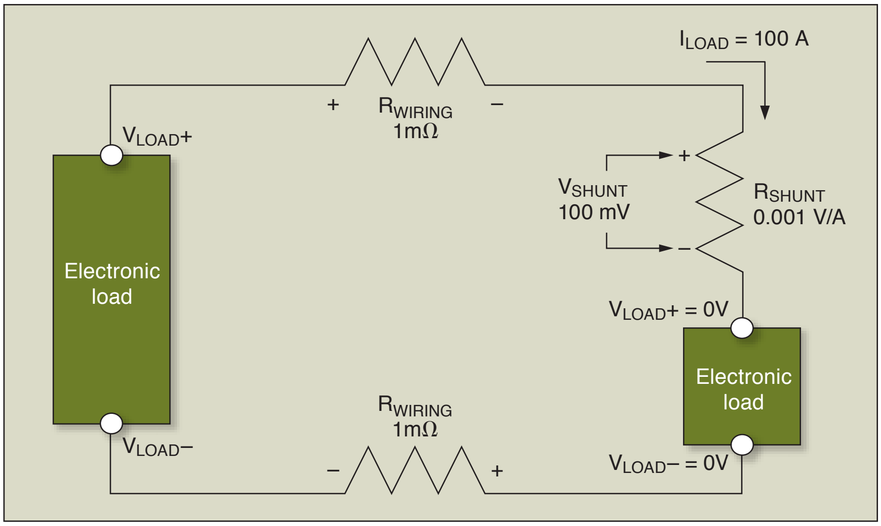

Figure 3. Troubles with low-voltage/high-current testing.

Current shunts represent a common and effective way to measure high currents, but they must be used with great care. For example, to measure 100 A, a 0.001 V/A shunt would produce 0.1 V. However, if the power system under test is a single fuel cell that can generate only 0.3 V under load, then at best only 0.2 V can be applied across the load, and resistive losses in the wiring alone could fully consume this voltage.

Therefore, especially in the case of fuel-cell-based power systems, it is desirable to have as much voltage at the electronic load as possible in order to accurately test a power system at high currents.

Boosting the load voltage

Because the difficulties associated with low-voltage operation in electronic loads can be severe in fuel-cell systems, one method used to deal with this drawback is to use a second power supply. This power supply is placed in series with the power system under test (and the electronic load). This boosts the voltage applied to the load, restoring it to the range needed for proper operation.

However, this practice introduces drawbacks of its own, including voltage instability of the second power supply, instability of the electronic load, and increased electrical noise (contributed from the second power supply). Other drawbacks include the following: overheating of the UUT, invisible high-frequency components in the output current during testing, dynamic instability in the UUT, and reduced slew-rate in the UUT. All of these problems can sabotage the effectiveness of using a second power supply in the test platform.

For example, the instability of the power supply line and load regulation can be several hundred millivolts (and, in some cases, even greater than the voltage of a single cell of a fuel cell stack). If a second power supply is used to boost the voltage, then electrical measurements must be taken frequently, and at multiple points in the output-current circuit path, in order to correctly gauge the performance of the UUT.

If the practice of using a second power supply is unavoidable, then switching power supplies should never be used, as they have problems concerning noise and current spikes that may be undetectable on standard test equipment, such as a multimeter.

When testing the UUT, such as a portable power system based on fuel cells, with an electronic load in conjunction with a second power supply, the line and load regulation of the power supply are the two most important considerations.

Before use, the specifications of a power supply intended for placement in series with an electronic load should be independently measured. This is due to the unfortunate reality that data-sheet specifications can make a power supply's performance appear greater than it would be under actual working conditions.

There can be yet another issue associated with the use of a second supply. Incorrectly connecting the second supply's sense leads. The original purpose of these sense leads is to bypass the voltage drops caused by high currents through the supply's output wires. Therefore, the traditional practice is to connect them directly to the interface terminals of the application being powered (or at the ends of the power supply output wires).

However, in the case of a test-platform configuration in which a second power supply is used in conjunction with an electronic load, the sense lines should be connected directly to the output terminals of the supply, not the ends of the supply output wires (Figure 4). This will help stabilize the power supply and allow it to give optimal performance when testing fuel cells.

Attaching the second power supply's sense leads to any other nodes in the main output current loop will invariably lead to false readings in the power-system measurements. Of course, the sense leads should be kept as short as possible, and sufficiently far away from any obvious sources of electrical noise.

Nevertheless, despite the limited effectiveness of these measures, the use of a power supply in series with an electronic load should only be used as a last resort. Furthermore, a power supply engineer should be consulted when using this method.

Electronic load attributes

The single greatest problem with electronic loads is leakage current, or idle current; it is always present to some degree. It can vary from a few milliamperes (mA) to hundreds of mA, and most manufacturers will usually not specify the amount in their devices. Even for cases where leakage may not seem to be a critical factor, it is always prudent to seek measured data for this parameter from the manufacturer.

In reality, the amount of leakage can change as test conditions change. For instance, the leakage can fluctuate as the applied voltage fluctuates, causing the leakage current to become non-linear. In some cases, the current contributed by leakage paths in the electronic load can even fluctuate with the change in the amount of current being drawn through the main current path.

Temperature instability can be another source of problems during testing. Good engineering practices can supplement common sense in order to avoid entry into thermally induced instability or failure modes.

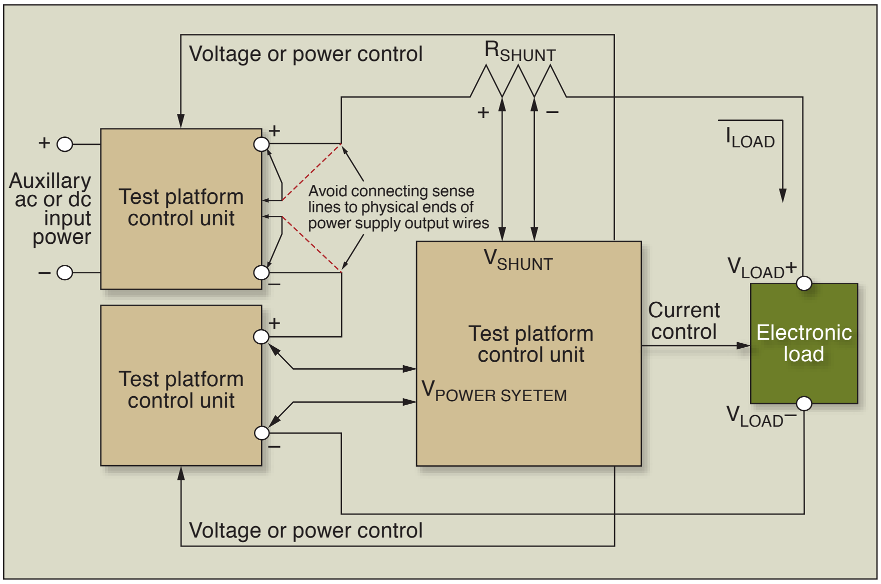

Figure 4. In a test-platform configuration in which a second power supply is used in conjunction with an electronic load, the sense lines should be connected directly to the output terminals of the supply, not the ends of the supply output wires.

More power devices create more leakage current, as well as greater temperature instability. Therefore, the power rating of the electronic load must be carefully selected to provide the optimal range for best stability for a given power-system testing platform. The generally accepted rule of thumb is to use loads that have a power capacity ranging from 20% to 50% more power than will be needed to fully characterize the UUT.

Electronic loads using older load designs can often be another source of trouble when testing a power system. Like their more modern counterparts, these units generally dissipate heat through power transistors. They also give good stability for long wire connections to the device being tested. However, the slew rate for this type of load is slow, limiting the minimum voltage supported by these loads to approximately 2.5 V.

Any voltage applied across the load below this value usually causes problems with the load (or, at the very least, reduces the control accuracy of the current channeled through the load). Therefore, the actual load current should always be independently checked with a separate instrument to ensure that the electronic load is working correctly.

Another type of electronic load, the field-effect-transistor (FET) type, has faster slew rates and can operate at much lower voltages (including the 0.3 V regime needed for testing fuel cells). FET-type loads also have lower current leakage and higher operational temperature stability, but their major drawback is that long leads to the load can cause instability or oscillation of the FETs in the power stage. Even though the FETs usually contribute capacitance to the output of the circuit, many manufacturers of FETs will place additional output capacitors within the loads to improve stability.

Additional problems, many also related to stability, can occur when attempting to remotely control the electronic load with software or hardware. Ground loops from the load to the control card are likely to introduce instability into the test circuit. To guard against this effect, the best electronic loads offer electrically isolated stages (or other options) for remote control of the electronic load.

For analog control schemes, it is also important to verify that the slew rate of the electronic load tracks with the slew rate of the control voltage. While typical control ranges for analog control schemes are 0 V to 5 V, or 0 V to 10 V, the input voltage may not control the slew rate of the electronic load in some instances. For these units, the voltage-to-current relationship between the input and the output (which is almost always linear) only applies to the steady-state condition of the load.

In these instances, the electronic load will usually be working in constant-current mode. If a constant voltage or constant power is desired for the output of the power system under test, then the software or firmware controlling the test platform must then adjust the current accordingly. This, in turn, may require a multifunction data acquisition control card to adequately monitor the appropriate nodes in the electronic load's circuitry.

The algorithms needed to perform this monitoring and control can be quite complex. Furthermore, if an IEEE-488 bus is used to remotely control an electronic load, the send and receive latencies of this interface can make it virtually useless for any type of high-speed testing.

Additional load characterization

While voltage and current are the fundamental parameters needed to calculate power dissipation in electronic loads, it is often necessary to test some of their other parameters. For example, it is usually quite beneficial to know the minimum on resistance of an electronic load. This parameter reveals the lowest possible voltage across the load, as well as the highest possible current supported by the load.

On resistance also reveals something about the circuit impedance, which can be used to predict how the load will react with a particular power system, such as a basic fuel-cell stack (in general, the on resistance of the load should be approximately 10% of the impedance of a fuel cell). One additional insight provided by an electronic load's on resistance is its susceptibility to thermal drift. Thermal drift tends to increase with on resistance.

Given these many challenges, it is clear that for most power systems, especially portable military systems based on fuel cells or batteries, a custom-designed electronic load would be the best option. However, engineers should not expect to find ready-made loads specifically designed for the comprehensive testing of fuel cells or batteries. Rather, it is often the responsibility of the military design engineer to develop multiple testing platforms for a single power system. To meet this challenge, the availability of customized modules, each having the necessary voltage, current, resistance, and thermal parameters, would be highly beneficial.

Executive Engineering makes electronic load blocks specifically for this purpose. Each block is a miniature module that can be connected in different ways to produce an electronic load that is tailor made to fit the needs of any project. **DE**

ABOUT THE AUTHOR

David Weber is the founder and president of Executive Engineering, Lauderdale, Fla., which has been in business for about 12 years. Prior experience includes design engineer, IRD Mechanalysis in Columbus, Ohio, R&D engineering specialist for Allied Signal Corporation, director of engineering for National Avionics, and test engineering manager for Unipower Corporation.