HIGH RELIABILITY POWER SUPPLY TESTING

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The reliability of a power supply must match or exceed the rest of the system in which it is installed. Generally, this requires fast production testing that accurately characterizes key parameters.

Assuring Power Supply Reliability

To ensure reliability, power supply manufacturers perform extensive tests on production units. Sometimes this involves burn-in or accelerated stress testing to weed out infant mortality [1]. In any case, typical tests include AC ripple, DC voltage levels, temperature, AC voltage and continuity.

These test parameters could be measured using a separate instrument for each measurement. A faster, more cost effective method would be the use of a single instrument to measure all the parameters, if one were available that could be easily and quickly switched to different measurement points and functions. A practical, cost effective solution that lies between these two extremes is described below.

Test Equipment Issues

Practical considerations preclude the use of a single instrument to measure all the required power supply parameters during production. This situation calls for a switching matrix and multiple measuring instruments. Still, the number of instruments should be minimized for reasons of cost, including capital expenditures, integration, operation, and maintenance expense. With the wide range of signals to be measured and switched, test system components must be carefully chosen to minimize these costs while assuring a high level of accuracy and test system throughput.

Another important consideration is the bandwidth of the signal path through the switch matrix, since it connects multiple measuring instruments to multiple Devices Under Test (DUTs). One of the tests performed on power supplies is AC ripple on the DC output. With harmonics, ripple frequencies can be as high as several MHz. In supplies designed for fast transient response, the phase margin of the feedback loop and output stability with short risetime load changes may be spot checked during production. This also requires a high bandwidth signal path.

Of course, high test throughput is important in any production environment. To help minimize test time, manufacturers are often interested in only a pass/fail indication at the end of a test sequence. Specific parameter values may be recorded, but not analyzed during production testing

Test Configuration

The remainder of this article describes an example system and techniques for performing basic power supply tests under different load conditions and AC line voltages, i.e.:

- Measure the AC input voltage to the power supply
- Measure the DC output and its AC RMS noise voltage.
- Measure AC p-p noise (ripple).
- Measure the temperature of the test chamber, and the temperature rise of the heat sink that holds the power semiconductor output regulator.

To verify integrity of the signal paths, an ancillary test measures cable continuity before taking the power supply measurements.

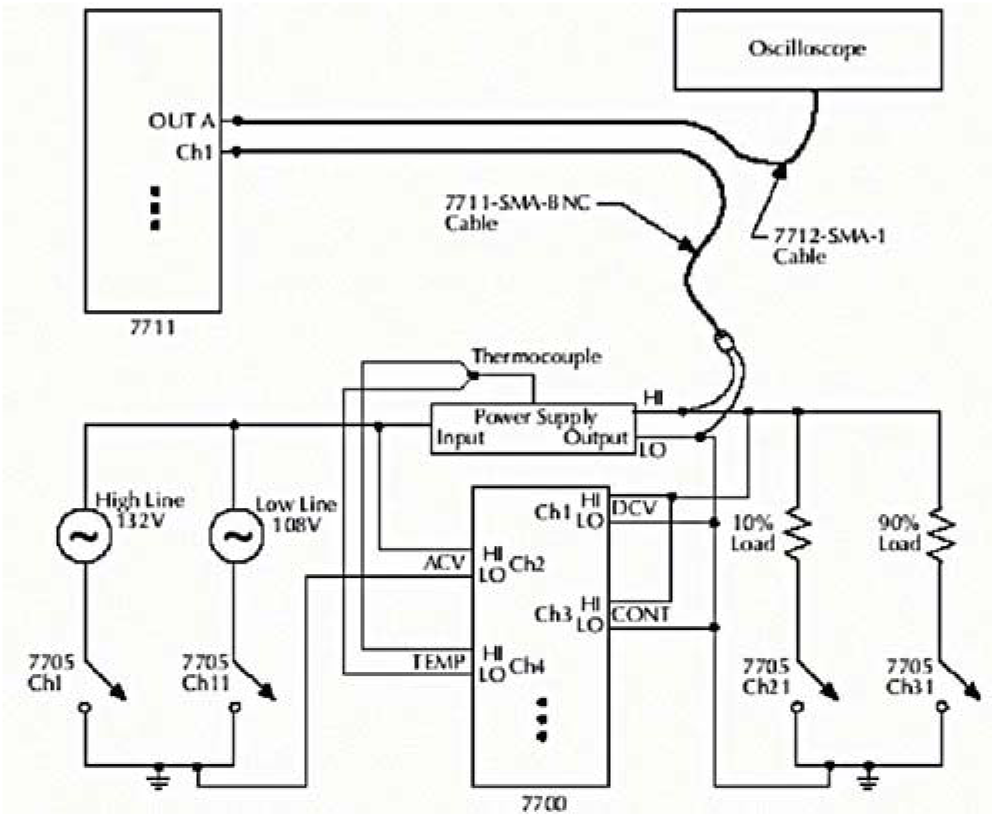

Figure 1. DC power supply test diagram. Only one power supply is shown; additional switching channels would be used to connect multiple supplies to the measuring instruments.

A simplified circuit diagram of the example test system is shown in Figure 1. Besides the DUT (power supply), there are only three elements in this configuration. A PC runs the test program, and controls the other two pieces of test equipment. These are a high resolution DMM/data logging system with expansion slots for switching modules, which is the primary data acquisition device. An oscilloscope controlled by the PC measures AC ripple on the power supply output. This test configuration minimizes the number of instruments, helps assure accuracy, saves rack space, and is convenient for cabling purposes.

The switch modules installed in the DMM expansion slots have bandwidths as high as 2GHz for minimal insertion loss and low signal reflection in the AC ripple signal path. Low loss cables are used to connect the power supply through the switching module to the oscilloscope. (See Figure 1.) Accurate measurements of ripple are important to power supply manufacturers, as they strive to minimize this parameter.

Either the Keithley Model 2700 or 2750 DMM/Data Acquisition/Switch System could be used for this test configuration, depending on the number DUTs to be loaded into the test chamber and the required number of channels. (The Model 2700 has two slots for switch modules, and the Model 2750 has five slots, providing up to 200 differential measurement channels.) Both instruments provide fast pass/fail measurements using their limit functions to detect acceptable levels of the measured parameters. They allow different limit values for each channel, which is very useful since several parameters are being measured. For purposes of this example, the following switch modules are used in three slots of a Model 2750:

1. Model 7700, 20-Channel Differential Multiplexer With Automatic Cold Junction Compensation (CJC) – This module switches channels associated with the DCV, ACV, 2-wire ohms (cable continuity), and thermocouple temperature measurements.
2. Model 7711, 2GHz/50Ω RF Module – Dual 1x4 switching channels in this module handle the high frequency ripple signals (on the supply's DCV output).
3. Model 7705, 40-Channel Control Module – This module switches loads and controls the AC line input voltage to each supply.

In this example the maximum number of supplies that could be tested is four. Using more cards and/or Model 2750s would accommodate additional DUTs. Figure 1 shows the switching channels that are opened and closed for various tests on one of the DUTs.

Test Procedures

Each measurement function must be preconfigured on the Model 2750 with respect to measurement type, range, integration rate, filter and other parameters for a the particular test. The temperature function must be configured for the appropriate thermocouple type, reference junction, etc.

The first step is to measure the resistance of the test system cabling to verify proper connections. Then for different load and line conditions, the power supply output voltage must be measured to verify that it remains within specified limits. The input AC line voltage is varied and measured to make sure it falls within the limits specified for the input transformer. The temperature of the supply is monitored to obtain heat rise data over the range of operating conditions, and during burn in. Again, this must remain within specifications. All this is combined with the AC noise measurements taken with the oscilloscope.

The details of the test sequence also are important. Typically, the sequence below is followed to place progressively higher stresses on the supply.

1. The continuity of each cable is checked to be sure it is properly connected.
2. With a 10% load, measure input ACV at the low power line limit.
3. Measure DCV output of supply and ACV RMS noise.
4. Measure ACV p-p noise on the oscilloscope.
5. Measure temperature increase of the test chamber and the supply's output semiconductor heat sink.
6. Repeat steps 2 through 5 for:
    a. 10% load and high line voltage limit
    b. 90% load and low line voltage
    c. 90% load and high line voltage

The test sequence is controlled by configuring the Model 2750 switch module channel closures. Each measurement function has a unique combination of channel closures. For example, the output of the power supply at high AC line voltage and 10% load could be measured with the following channel closures. (Refer to Figure 1 and Table 1 for channel numbers).

HI line AC power	(Model 7705 channel 1)
DCV Output	(Model 7700 channel 1)
10% Load	(Model 7705 channel 21)

Then to test with the same load, but low AC voltage, the following channels are closed:

LO line AC power	(Model 7705 channel 11)
DCV Output	(Model 7700 channel 1)
10% Load	(Model 7705 channel 21)

A complete list of channel closures for each test on a single power supply is provided in Table 1.In general there are nine channels to be switched for each power supply:

- Four channels on the 7705.
    - Two for ACV (HI and LO line).
    - Two for the load (10% and 90%).
- Four channels on the 7700
    - One channel for the DCV output signal.
    - One channel for ACV input to the 2750.
    - One channel for the temperature measurement.
    - One channel for the 2-wire Ohms measurement.
- One channel on the 7711 for the AC ripple test.

Table 1. Switch Module Channel Closure Assignments.

Function	HI line 10% load	HI line 90% load	LO line 10% load	LO line 90% load
DCV	7705 CH1 7700 CH1 7705 CH21	7705 CH1 7700 CH1 7705 CH31	7705 CH11 7700 CH1 7705 CH21	7705 CH11 7700 CH1 7705 CH31
ACV	7705 CH1 7700 CH2 7705 CH21	7705 CH1 7700 CH2 7705 CH31	7705 CH11 7700 CH2 7705 CH21	7705 CH11 7700 CH2 7705 CH31
Temperature	7705 CH1 7700 CH4 7705 CH21	7705 CH1 7700 CH4 7705 CH31	7705 CH11 7700 CH4 7705 CH21	7705 CH11 7700 CH4 7705 CH31
2 W Ohms	7705 CH1 7700 CH3 7705 CH21	7705 CH1 7700 CH3 7705 CH31	7705 CH11 7700 CH3 7705 CH21	7705 CH11 7700 CH3 7705 CH31
AC Ripple	7705 CH1 7711 CH1 7705 CH21	7705 CH1 7711 CH1 7705 CH31	7705 CH11 7711 CH1 7705 CH21	7705 CH11 7711 CH1 7705 CH31

Cabling

Connections to the Model 7700 switch module shown in Figure 1 can be made with standard insulated wire. Maximum recommended wire size for the screw terminals is #20AWG. The use of shielded cable is recommended to minimize external noise. The insulation rating for the ACV connection must be high enough for the supply's AC line input voltage (say, 220V). The DCV, 2-wire Ohms, and load signals can use lighter insulation based on the power supply output voltage and current ratings.

Naturally, the temperature measurement connections to the Model 7700 are through thermocouple wires. The Model 2750 mainframe in which the Model 7700 is installed can measure temperature with J, K, N, T, E, R, S and B type thermocouples. For this example application, a T-type thermocouple can be used, as it easily covers the range of interest (–200°C to +400°C).

The high frequency ripple signal connection at the power supply requires a spring clip/alligator clip adaptor (depending on the power supply) to an RF cable. A Keithley Model 7711- BNC-SMA cable can be used (Figure 1). One end is an SMA male connector, which is connected to the Model 7711 switch module. The other end is a BNC female that requires a BNC male to clip-on adaptor for the DUT. The common ground on the Model 7711 module is connected to chassis.

Typical Sources of Measurement Error

Sources of errors can be characterized as determinable systematic errors, and random errors that are difficult to quantify. Systematic errors are those caused by the measuring instrument, switching devices and cabling. Random errors are the result of noise from the external environment, sensors, and related measurement devices.

To minimize random errors, use shielded cables for all test leads. Cables with one shield and multiple conductors are recommended. The shield of all cables should be connected in a star arrangement to a solid earth ground at a single point.

To minimize determinable systematic errors, follow the recommendations below:

- To decrease AC noise susceptibility, increase the measurement integration time. The measurement time of the Model 2750 is adjustable over a range of 0.01 to 50 power line cycles (PLCs). For 60Hz power, one PLC is 16.67ms. For maximum rejection of noise originating on the power line, i.e., line cycle pickup, an integral number of PLCs must be used (e.g., 1,2,5, etc.)
- A certain level of DC contact potential is associated with any pair of switch or relay contacts. This EMF creates some degree of error in voltage measurements. The Model 7700 switch module contacts create a maximum potential of 1µV when they are closed. For the Model 7705 module, the contact potential is less than 4 µV. This source of error may or may not be significant, depending on the measurement it affects. However, it should be recorded and a mental adjustment made for its magnitude.
- The Model 7711 has some inherent errors associated with unterminated channels. If some of channels on this module will not to be used, they should be terminated in a 50-Ohm load.
- In some applications, the power handling capabilities of the Model 7711 should be considered. The maximum amount of power that can be routed while maintaining proper DMM accuracy is shown in Figure 2. Power levels of up to 10 watts can be used, but this may cause measurement errors. For instance, routing 10 watts of power at 1GHz may cause the DMM to have an additional 10VDC offset uncertainty with measuring DC voltages. Since the Model 7711 is being used only for AC ripple measurement in the example test configuration, power handling should not be an issue.

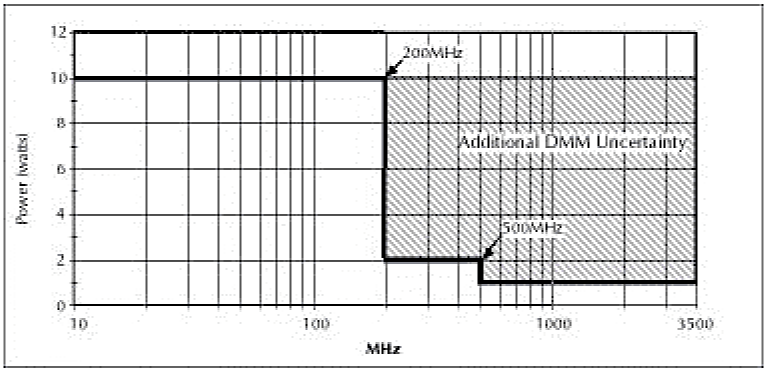

Figure 2. Carry power per channel vs. frequency for the Model 7711 switch module.

Example Program

Keithley Instruments has developed an example program for the PC controlling the test equipment. Although the program will require modification for a specific DUT and its test requirements, it provides a test development shortcut. Embedded comments in the program give the developer insights into program coding and how commands are used. The program is available in the Model 7711 User's Guide [2]. This guide is available for download on the Keithley web site by going to www.keithley.com and following the links to Document Center/Manuals/7711/Models 7711 and 7712...User's Guide PA-818 Rev A. (See Figure 9, Page 22 of the Guide.)

References

1. Keithley Application Note #2260 – Burn-in Testing Techniques for Switching Power Supplies.
2. Keithley Models 7711/7712 Single-Pole, Dual 1X4 RF Multiplexer Modules User's Guide, Publication PA-818, Rev.A/2-02.

About the Author

Dale Cigoy is a Senior Application Engineer at Keithley Instruments in Cleveland, OH His major responsibility is helping customers with measurement applications that include Keithley equipment, especially DMMs. Prior to this he wrote technical instruction manuals for Keithley products. Cigoy joined Keithley in 1976 after earning a Bachelor of Science degree in Electronic Technology from Capitol College in Laurel, MD.

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