Managing High-Power DC Requirements for Life and Durability Test Systems

Application Note

Introduction

DC Power Systems for Life and Durability Testing

New product life and durability testing (life testing) is critical in highly competitive markets. Life testing takes thousands of hours, and the test instrumentation you use must be up to the task. Central to life testing are the device-under-test (DUT) power source and power distribution system.

DUT power system requirements for life testing applications are demanding. Life testing facilities use temperature chambers to apply lengthy environmental stresses to the DUTs. The instrumentation rack is usually located outside the chamber, so the DC power supply can be several meters from the DUTs. Wire resistance, inductance and capacitance can all combine to impede delivery of power. Transient response may be impacted, resulting in voltage overshoot with abrupt current level change. As a result, the DC power distribution must be carefully designed for these long distances.

The power distribution system extends into the chamber, so materials must be selected correctly or long-term exposure to temperature and humidity can result in dendrite growth or degraded material properties. Considering the high-energy nature of the DC power system, care taken to properly design your power distribution is a wise investment.

By its nature, life and durability testing involves a large sample size of DUTs, all installed in the chamber at one time. Power system interaction between DUTs must be minimized, and a defective unit must not shut down testing for the rest of the DUTs. You need to account for failure modes that could potentially bring down the power system (for example, a shorted power capacitor). And when you replace a defective DUT, power system transients that occur when you plug in a new DUT must not disrupt the other DUT tests in progress.

You also need to consider operator, facility and product safety when you design your power systems. The last thing you want to do is injure a colleague or damage your workplace.

This application note offers hints and tips to help you address these issues.

Power Distribution – Delivering High Power in Test Environments

In the simplest case, a power distribution system is a point-to-point route -- from the power source to the DUT. In practice, it is more complicated than that. High current demand can result in significant voltage drop across the cabling. Also, the current draw is not static. Instead, power system transients occur as the DUT runs through its operation. When you design your power distribution system, you need to take these complications into consideration.

First determine static current carrying requirements. Consider both the voltage drop and the heat generated across the conductors. During normal operation, the voltage drop is usually your biggest concern -- maintaining the proper voltage at the DUT is obviously a must. However, during a fault condition (for example, a short circuit) the heat generated is usually your biggest concern. You need to design for both conditions.

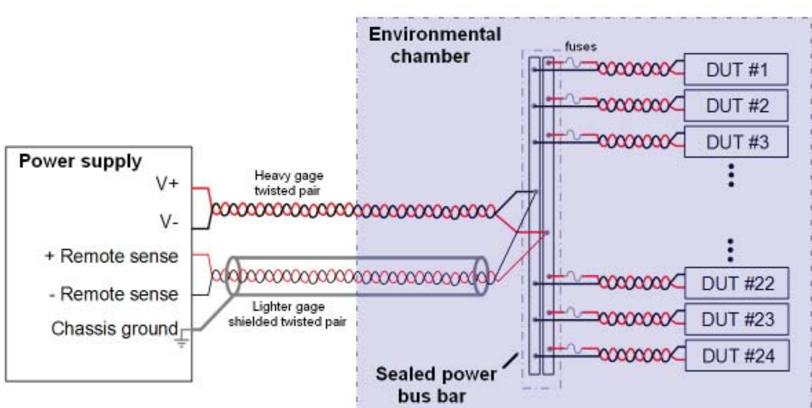

Figure 1. Power system for life and durability testing

Designing for voltage drop constraints

Using remote sensing is a common way to reduce the impact of voltage drop across the power conductors. When you sense the voltage at the endpoint of the cable, the power supply can quickly adjust for the cable voltage drop, maintaining a precise voltage at the end of the cable where it counts. Proper remote sense connections are shown in Figure 1.

When you are designing your system around voltage drop constraints, keep in mind:

- It is important to keep the remote sense cables from picking up extraneous noise. To this end, using twisted pair is important. With twisted wires, the effective "loop area" of the cable is reduced and electromagnetic coupling is less likely to occur. In some very noisy environments you may also need a shield. If you use a shield, connect it to chassis ground on the power supply side of the cable only. If the shield is grounded on both the power and DUT sides, there is a risk of ground loops being formed, and resulting ground currents may couple into the sense lines.
- Make sure the power supply can handle the voltage drop you expect across your cabling. Some power supply remote sense circuits can compensate for several volts of drop, while others can compensate for as little as 1 volt. You may need to adjust the gauge of wire used to keep the voltage drop within the acceptable limits.
- Most power supplies will continue to operate if they lose one remote sense connection but at an incorrect voltage. This could present a problem. Imagine after a 2000 hour test you discover that one of the sense lines has come loose; all of your test data in now suspect. Automatic remote sense loss detection is built into some supplies and can be used to verify the integrity of the connection. If remote sense loss detection is not built into the power supply you have, you may want to consider using your measurement system to verify the voltage at the DUT is correct.
- The amount of voltage overhead that you require for the supply to operate is dependent on the voltage dropped across the source connections. For example, if you need 12 volts at 100 amps at the DUT and expect to drop 2 volts on the forward and 2 volts on the return path, a maximum output of 16 volts will be required by your supply. Make sure you take this "headroom" requirement into account.

Distributing power across many DUT's creates some challenges. You can only remote sense at one location. Where should that be? A common architecture for power distribution is shown in Figure 1. The main power leads route to a central point, and the power is distributed to the individual DUTs from there.

The logical location to connect the remote sense is where the branches to each DUT are connected to the main power feed. Using a bus bar is good practice to keep the voltage drop and inductance to the DUT branches at a minimum. A heavy-duty bus bar that has very low resistance and inductance can be installed in the rear of the chamber. From the bus bar, the voltage drop to the individual DUTs will be minimal.

When you select the bus bar, be sure to choose a sealed power bus style. Since the bus bar will be inside the chamber, it will be subject to months of harsh conditions. A sealed power bus will prevent accidental mechanical- and dendrite-induced shorts. Various third-party providers have engineered power bus products that are ideal for these applications.

Designing for power constraints

Keep in mind that there is also power (heat) dissipation in the power distribution system. Make sure you do not undersize the cabling -- for both voltage drop and power. Is your power system sized properly in the event of a fault condition? Perhaps a short in the DUT, or a bent pin on the DUT connector? Make sure the power distribution is designed to prevent damage in the event of a short circuit.

1. The best approach is to size your system to carry the maximum current that can possibly be delivered by the power supply. This task is made easier if the power supply selected has a programmable current limit. Set the current limit just above the sum total of the DUT requirements, and then size your power system appropriately.

2. Adopting a power bus bar structure makes the above task easier, although the branches to each DUT may need special attention. Many times you cannot size the cable or connector for all the current the power supply may deliver, making the branch connections to each DUT vulnerable. In these cases, consider fusing each branch. That way, in the event of a fault on a branch, the fuse will quickly open and prevent damage or even a fire in the chamber.

Table 1 shows current capabilities (ampacity) and resistance for various size wires. Use the resistance column to determine the voltage drop of the cables. Use the ampacity to determine the total power capability of the cables.

Table 1. Cable Characteristics

AWG	Equivqalent area in mm^2	Nearest Metric wire size	Ampacity note 1	Resistance (ohm/1000 ft) note 2
18	0.823	1.0 mm^2	14	6.385
16	1.31	1.5 mm^2	18	4.016
14	2.08	2.5 mm^2	25	2.526
12	3.31	4 mm^2	30	1.589
10	5.26	6 mm^2	40	0.9994
8	8.37	10 mm^2	60	0.6285
6	13.3	16 mm^2	80	0.3953
4	21.15	25 mm^2	105	0.2486
2	33.62	35 mm^2	140	0.1564
1/0	53.48	70 mm^2	195	0.0983
2/0	67.43	70 mm^2	225	0.0779
3/0	84.95	95 mm^2	260	0.0618

Note 1. Ampacity is based on 30 deg C ambient with conductor rated at 60 deg C
Note 2. Resistance is nominal at 20 deg C wire temperature

Designing for transient performance

As discussed earlier, remote sense does an excellent job of reducing the effects of voltage drop across the source lines. However, the remote sense lines are part of an extended control loop, and as with any control system, excessive phase shifts within the loop can cause instabilities. The effects of these instabilities can be as minor as a small transient overshoot or as major as an all-out oscillation. Agilent power supplies have been carefully engineered to minimize effects of phase margin shifts. But to be sure, use methods to reduce overall path reactance and coupling susceptibility:

- To minimize the source lead inductance, use heavy-gauge twisted pair for the source lines. The inductance of a single wire is inversely proportional to the wire diameter. So a larger diameter wire reduces overall inductance.
- Twisting the source leads reduces the overall inductance. The mutual inductance coupling created between twisted pair lines reduces the overall inductance seen at either end of the cable.
- Using twisted pair cabling has a secondary advantage of reducing the effective magnetic "loop area," and hence the susceptibility to crosstalk transients is lower.

Changing DUTs with the power on is another source of transients that is commonly overlooked. During life testing, it is common to remove a defective DUT for failure analysis and replace it with another. If you change the DUT with the power on, the sudden placement of a large capacitive load onto the power distribution system will cause a surge current and potentially a transient large enough to disrupt other DUT tests. The best way to minimize this impact is via software. As simple as it may sound, don't forget to include a "park" feature in your test software. This feature allows you to pause your test plan at a safe, non-power section.

System Development, Reuse and Longevity – Key Features

To help get life and durability test systems up and running quickly, select a power supply with ease-of-use features. Select a full-featured, remote-programmable power source complete with read-back and current limit capability. Key features that are helpful:

- Overvoltage protection
- Overcurrent limit
- Overtemperature protection (power supply)
- Power fail detection -- recovery options
- Front panel lock-out
- Safety interlock
- Parallel and series operation
- LXI interface access

Overvoltage protection

DUTs used for life testing are usually expensive prototypes created during a special prototype build. Overvoltage conditions on a power bus may occur for various reasons, from a simple programming error to an incorrect remote sense connection. Having over-voltage protection in your power system is essential, and it may save you many hours of explaining to others how the prototypes were destroyed.

Overcurrent limits

A shorted capacitor or a dendrite growth across the power bus can result in high current. As previously discussed, limiting the power supply current can prevent additional damage to the DUT and power distribution system.

Overtemperature protection (power supply)

DC power systems for life and durability testing need to run thousands of hours. Built-in power supply overtemperature monitoring and shutdown will help you meet the reliability goals of your system.

Power failure detection -- recovery options

Unattended testing is common during life testing. In the event of AC power mains momentary drop-out, what should the DC power system do- resort to the currently programmed setting or start up in a "safe" mode (with outputs off)? The right answer depends on your particular testing needs. Having a DC power system that supports both modes of operation gives you the flexibility to implement either recovery method.

Front- panel lockout

Developer access to front-panel controls is convenient during test plan development. However, once your system is deployed, instrument front panel access should be disabled to prevent accidental setting changes from the front panel. Select a power supply that supports programmable front-panel lockout.

Safety interlocks

The extended duration of life testing may lead to operator complacency. Operators may be tempted to open test fixtures and reach in to make adjustments at times. In cases where high voltages or high currents are present, you must guard against this possibility. A well-designed power supply hardware interlock is the best solution for preventing this potential hazard.

Parallel and series operation
Regardless of how much planning you do, voltage and current levels you face today may not be sufficient in the future. To prepare for future capacity, you may want to oversize the power supplies for both voltage and current. But obviously that doesn't make financial sense. Another option is to choose a power supply that you can place in parallel for greater current or place in series for greater voltage. If your power supply supports this, when you need additional capability you can simply procure a second supply from your stock area, integrate it in parallel or series with your existing power supply, and proceed with your system design. Selecting a power supply that can be paralleled for higher current or placed in series to get more voltage helps you improve the flexibility of your test system

LXI interface access
Power supplies targeted for system applications are physically small to conserve valuable rack space. But this means limited front panel space for developer and operator interaction. Choosing a product with LAN extensions for instrumentation (LXI) I/O can help. All LXI instruments have a built-in Web server that allows basic access to the instrument. With a simple Web browser, you can open a window and control the power supply just like you do from its front panel, even from a remote location.

Operator and facility safety

DC power system overcurrent, overvoltage and overtemperature monitoring and shutdown are features that help protect the DUT and test system during life and durability testing. But what about protection for the operator and facility? The safety interlock and power distribution attributes discussed previously may help in this effort, but proper implementation is key.

The interlock and safety shutdown should incorporate a "fail safe" design. In other words, any single point failure will not defeat the safety interlock. For example, consider the cabling for the emergency shutdown button. Broken wires or faulty connectors are a common cause of failures. It is best to design the safety interlock circuit to detect this kind of failure and respond appropriately.

To support a safety interlock, select a DC power source with a remote enable feature. To be useful, the remote enable should be self-biased and require a short circuit to enable the supply. Consider the circuit shown in Figure 2. In the event of an open wire or switch anywhere along the route, the supply will fail to turn on. The operator will know immediately that there is a problem and begin debugging procedures. This is a much better scenario than the alternative: the operator is not aware of any issues until he or she presses the emergency shut-off and nothing happens.

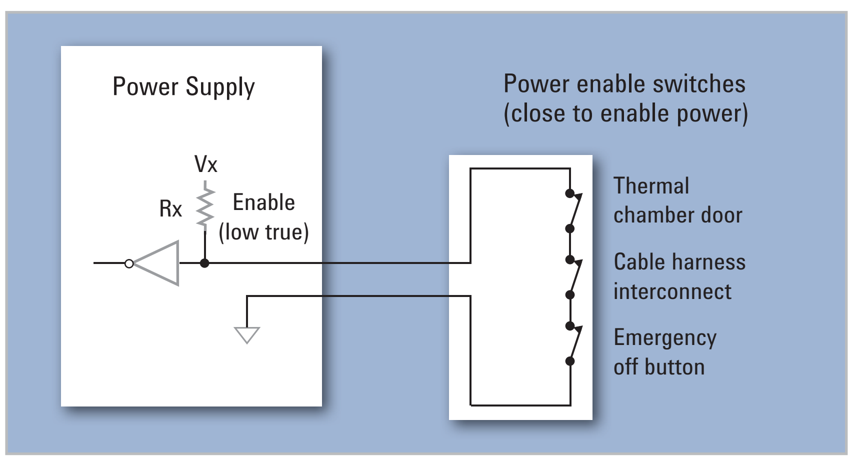

Figure 2. Remote enable should be self-biased and require a short circuit to enable the supply.

N8700A power supply family - ideal for life and durability test systems

Agilent Technologies N8700A Series power supplies are ideal for life and durability test systems. A selection of twelve 3.3-kW and nine 5-kW DC power supplies gives you the flexibility you need. You can place up to four of the same model supplies in parallel to get greater current, and two may be connected in series to achieve greater voltage.

Figure 3. Agilent N8700A power supply

Table 2. Specifications for Agilent N8700A power supplies

Model	Voltage	Current	Max Power	Series
N8731A	8	400	3200	3.3kW
N8732A	10	330	3300	3.3kW
N8733A	15	220	3300	3.3kW
N8734A	20	165	3300	3.3kW
N8735A	30	110	3300	3.3kW
N8736A	40	85	3400	3.3kW
N8737A	60	55	3300	3.3kW
N8738A	80	42	3300	3.3kW
N8739A	100	33	3300	3.3kW
N8740A	150	22	3300	3.3kW
N8741A	300	11	3300	3.3kW
N8742A	600	5.5	3300	3.3kW
N8754A	20	250	5000	5kW
N8755A	30	170	5100	5kW
N8756A	40	125	5000	5kW
N8757A	60	85	5100	5kW
N8758A	80	65	5200	5kW
N8759A	100	50	5000	5kW
N8760A	150	34	5100	5kW
N8761A	300	17	5100	5kW
N8762A	600	8.5	5100	5kW

The supplies' low-profile 2-RU (rack unit) height makes efficient use of valuable rack space and the high efficiency (more than 80%) means a cooler-running test rack.

The N8700A supplies support all the key features discussed in this application note. The remote sense can correct for more than 2 volts of source lead drop. Overcurrent, overvoltage and overtemperature monitoring and protection are standard on all models.

The N8700A remote enable feature can be configured to support a "fail safe" wiring configuration. And in the event of an AC power interruption, the N8700A supplies can be configured to either start up in the previous programmed state or start up in a "safe" output off state.

Conclusion

When you invest in life and durability test equipment, it makes sense to design your DC power system for usability, safety and longevity. And since the life and durability test systems will be reused over dozens of new product launches, it is easy to see that time spent up front designing your DC power solution will pay dividends over many years. The Agilent N8700A family of power supplies can help you meet these test system challenges. The N8700A features are ideally suited for life and durability testing as well as other burn-in applications. For 3.3-kW and 5-kW DC power supply applications, the N8700A is an ideal addition to your test system. Also, consider the N5700A family power supplies for applications that require up to 1.5 kW in a smaller, 1-RU-high package.

For more information, visit the following Agilent web sites:

Agilent N8700 Series Power Supplies	www.agilent.com/find/N8700
Agilent N5700 Series Power Supplies	www.agilent.com/find/N5700
Agilent Technologies' broad range of power supplies	www.agilent.com/find/power

Related Agilent Literature

Publication title	Pub number
Agilent N8700 Series System DC Power Supplies - Datasheet	5990-3881EN
Agilent N5700 Series System DC Power Supplies - Datasheet	5989-1330EN
10 Practical Tips You Need to Know About Your Power Products - Application Note	5965-8239E
Selecting DC Sources for Telecommunications Equipment Test Systems	5990-4370EN
Power Sources for Energy-Efficient High Input Voltage Telecommunications Equipment Development	5990-4371EN

Agilent Email Updates

www.agilent.com/find/emailupdates
Get the latest information on the products and applications you select.

Agilent Direct

www.agilent.com/find/agilentdirect
Quickly choose and use your test equipment solutions with confidence.

LXI

www.lxistandard.org
LXI is the LAN-based successor to GPIB, providing faster, more efficient connectivity. Agilent is a founding member of the LXI consortium.

Remove all doubt

Our repair and calibration services will get your equipment back to you, performing like new, when promised. You will get full value out of your Agilent equipment throughout its lifetime. Your equipment will be serviced by Agilent-trained technicians using the latest factory calibration procedures, automated repair diagnostics and genuine parts. You will always have the utmost confidence in your measurements. For information regarding self maintenance of this product, please contact your Agilent office.

Agilent offers a wide range of additional expert test and measurement services for your equipment, including initial start-up assistance, onsite education and training, as well as design, system integration, and project management.

For more information on repair and calibration services, go to:

www.agilent.com/find/removealldoubt

Product specifications and descriptions in this document subject to change without notice.

For more information on Agilent Technologies' products, applications or services, please contact your local Agilent office. The complete list is available at:

www.agilent.com/find/contactus

Americas

Canada	(877) 894-4414
Latin America	305 269 7500
United States	(800) 829-4444

Asia Pacific

Australia	1 800 629 485
China	800 810 0189
Hong Kong	800 938 693
India	1 800 112 929
Japan	0120 (421) 345
Korea	080 769 0800
Malaysia	1 800 888 848
Singapore	1 800 375 8100
Taiwan	0800 047 866
Thailand	1 800 226 008

Europe & Middle East

Austria	01 36027 71571
Belgium	32 (0) 2 404 93 40
Denmark	45 70 13 15 15
Finland	358 (0) 10 855 2100
France	0825 010 700*
	*0.125 €/minute
Germany	07031 464 6333
Ireland	1890 924 204
Israel	972-3-9288-504/544
Italy	39 02 92 60 8484
Netherlands	31 (0) 20 547 2111
Spain	34 (91) 631 3300
Sweden	0200-88 22 55
Switzerland	0800 80 53 53
United Kingdom	44 (0) 118 9276201

Other European Countries:
www.agilent.com/find/contactus

Revised: March 24, 2009

Printed in USA, August 04, 2009
5990-4369EN

Agilent Technologies