Test-System Development Guide

Operational Maintenance

Application Note 1465-8

This application note is part of the Test-System Development Guide series, which is designed to help you design a test system that produces reliable results, meets your throughput requirements, and does so within your budget.

This application note examines what to do as your system is put to use. It covers issues related to worldwide deployment, calibration, diagnostics and repair, cleaning, upgrades and expansion.

See the list of additional application notes in the series on page 7.

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Agilent Technologies

Introduction

Once you've created and debugged your test system, you will be putting it to use. But even the best-designed system requires routine calibration and maintenance, and will occasionally fail. Planning for such eventualities will help to reduce the system's downtime.

The issues most often encountered are:

- Worldwide deployment considerations
- Calibration
- Diagnostics and repair
- Cleaning
- Upgrades and expansion

Worldwide considerations

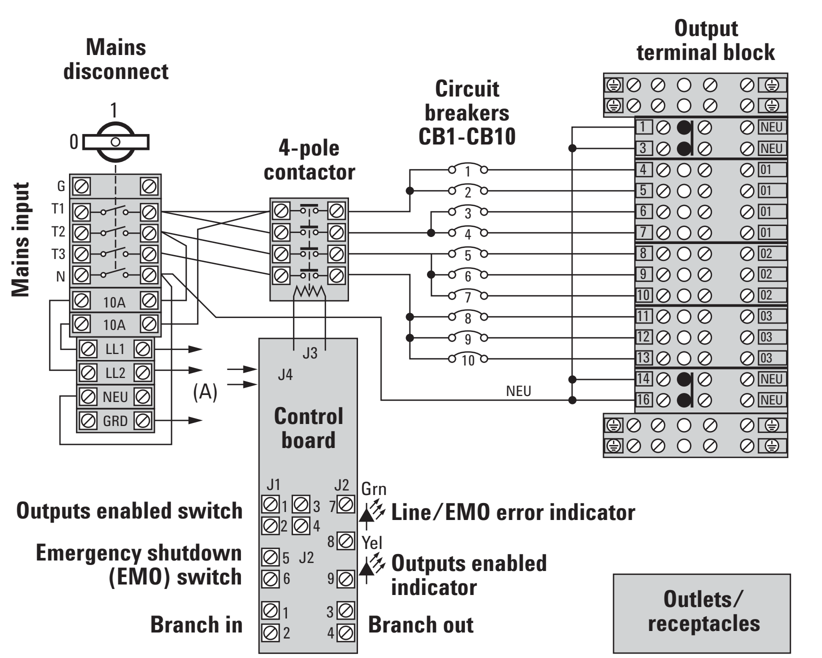
Sometimes, systems are shipped from country to country as needs change or manufacturing lines are moved. If you are building a system that might be transported elsewhere, you need to account for the difference in line voltage and line frequency, both from the standpoint of equipment power input and changes to cooling fans that may be required. In addition, there are ergonomic considerations you should think about because of differences in culture or physical characteristics of the operators who will use the system.

Power

Your system is composed of instruments, power supplies and computing equipment that could all be required to run on different line voltages and frequencies. If your system will travel from country to country, you must plan for the changes in voltage or it will be a tedious job changing the equipment's fuses and input switches. Some older equipment must be removed from the system and have its top covers removed in order to reach the internal switches. If possible, choose equipment that runs from 90-252V (to handle Japan's 100V lines at low-line and Europe's 240V lines at high-line) without requiring changes to switch settings or fuses. Information on the most common line voltages, power plug styles and other useful data for various parts of the world is available from the U.S. Department of Commerce at **http://www.ita.doc.gov/media/Publications/pdf/current2002FINAL.pdf**.

Another useful item to consider when shipping systems from country to country is a power distribution unit (PDU). These devices can convert 3-phase inputs into line-to-neutral or line-to-line voltages, and they also can detect low- or high-line conditions. They sometimes can be connected to uninterruptible power supplies, too. A good PDU will also have an emergency off (EMO) switch input, allowing the operator to shut off all or some of the power in an emergency. Figure 1 shows typical wiring for a PDU that is used in many Agilent systems.

Figure 1. A typical AC power distribution unit.



Cooling

Fans are another problem area when line voltage varies. A 240V fan may work when operated at 120V, but at a much lower speed. Thus, the airflow may no longer be sufficient to cool the system. Conversely, a 120V fan may burn up when connected to 240V. It can be a nuisance to replace the fans every time the system is shipped from country to country. But fans that can be operated from any line voltage are produced in smaller quantities and are thus much more expensive than single-voltage AC fans.

DC fans, though, can be an excellent choice for systems that must be moved often. A small, fixed 12 V or 24 V DC power supply with universal AC input (i.e., 100-240 VAC) can be installed in the system and connected to the DC fan(s). Other advantages of DC fans are:

- More control over airflow and noise. The speed of the fan is directly related to the input voltage. A 24-volt DC fan can typically be operated between 12 and 28 volts DC. At 12 volts DC, the fan will operate at half speed, producing less air and less noise.
- The life expectancy of a DC fan is higher than that of a comparable AC fan, since DC fans are many times more efficient. The correspondingly low heat dissipation reduces the thermal load on the bearings, thereby increasing lifetime.

In non-air-conditioned factories, temperatures sometimes may exceed the ability of simple fans to keep the instruments operating within their specifications. In this case, consider a dedicated air conditioner for the system. NEMA enclosures are available for a wide variety of rack sizes. These completely enclose the system, and provide a way to attach air conditioner intake and exhaust. Appropriate ductwork must also be added to the factory. See **http://www.nema.org**

Line frequency

The frequency of AC line voltage varies in different parts of the world. In the U.S., 60 Hz is standard. In many other countries, it is 50 Hz. While this won't affect most modern power supplies, it can certainly affect signal measurements. It is common to take low-noise DMM readings with a "1-line-cycle" integration time. At 60 Hz, this is 16.667 ms. At 50 Hz, it is 20 ms. Some DMMs, such as Agilent's 34401A, automatically adjust their integration time based on internally measured line frequency. Others must have this information programmed into them. It is important to set your DMM correctly based on line frequency.

At lower frequencies, the magnetizing current of transformers and motors can go up, even to the point of saturating the core. This can cause nonlinear magnetic fields and overheating of the core, especially at 47 Hz, creating a situation where products designed in a 60 Hz environment can cause problems in other parts of the world.

Logistics and ergonomics

The doorways in many European countries are short, since many buildings are old and were built when people were shorter. Thus, a 2-meter rack may not fit through the doors. Taller racks also require larger aircraft to transport them. If you build systems this tall, your shipping costs may be significantly higher over the life of the system if it is moved or shipped frequently.

In some Asian countries where real estate is in scarce supply and space is at a premium, facility aisles and hallways are extremely narrow. It may be difficult or impossible to move a deeper- or wider-than-normal system to its intended location. Once positioned, it could be difficult to open front or rear doors.

The average population height varies country-to-country, too. Use care to place keyboards and monitors at an elevation that is not too high for shorter operators. It is also a good idea to provide keyboard/mouse trays with adjustable heights and provisions for left or right-handed operators.

Your safety department can provide you with modern guidelines for ergonomic standards.

Calibration

Most electronic instruments require periodic calibration that is traceable to a government standards agency such as NIST (National Institute of Standards and Technology) in the U.S. This requirement guarantees that measurements meet their published accuracy specifications. Calibration is not the same thing as diagnostics, which are simple tests to verify that the instrument is operating and taking measurements that are at least close to what they should be. Diagnostic tests and fixtures are discussed in the next section.

It may seem logical to build calibration fixtures that would allow your system to be automatically calibrated without having to remove equipment. Unfortunately, such fixtures would be prohibitively expensive. Calibration requires use of components that meet stringent specifications under closely controlled conditions of temperature and humidity. Oil-baths containing "standard" resistors at controlled temperatures, frequency-measuring equipment that connects to the NIST cesium-beam frequency standard and the like are not easily contained in a removable fixture.

There are three ways of assuring that a test system is calibrated:

- Have an in-house calibration lab perform calibration either in the system or by removing instruments, calibrating them and returning them to the system
- Hire a firm that provides calibration services at the location of your system
- Swap instruments with calibrated spares, then send the replaced units out for calibration

Whichever plan you use, it is essential to track the date of each instrument's last calibration, and to set up a method for notifying appropriate personnel when the next calibration due date arrives. You could simply place a dated sticker in a conspicuous place on the instrument whenever it is calibrated, and have someone check dates periodically, or you could program the system with "due" software that notifies appropriate personnel automatically.

Figure 2. Cal sticker

Agilent LOVELAND STDS LAB 17025

	DD	MM	YY	BY/NO.
CAL				
DUE				

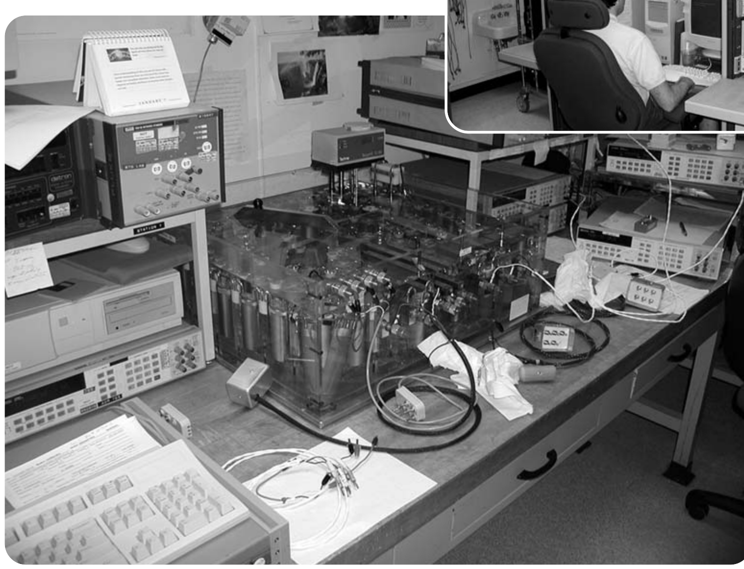
In addition to regular calibration, keeping a log is a good practice. It's good to be able to correlate manufacturing anomalies to the particular operator, time of day, calibration period, run number and to many other manufacturing variables.

Before you build that test system in Germany for shipment to Thailand, for example, try to answer these questions: Do I have the same calibration system in both places? If not, can I guarantee the measurements made by my test system here will be the same after I ship the test system overseas? Can I get the accuracy I need in both places, and are the calibration services adequate?

In-house calibration lab

If you do not already have an in-house calibration department, you might consider setting one up, although the cost and time to do so can be considerable. If you intend to offer calibration services to others outside your company, your customers may require you to have international accreditation. A good place to start is the International Laboratory Accreditation Cooperation (**www.ilac.org**). Members of ILAC, such as the American Association for Laboratory Accreditation (A2LA—**www.a2la2.net**), will certify your lab after you have met their requirements, a process that can take from four to nine months once the lab is fully operational. If you desire to have your lab accredited, the international standard ISO 17025 will apply. It is not necessary to become accredited, but at the least, you may wish to become ISO 9000 certified.

Figure 3. Cal lab



Fluke Corporation has a great deal of support for creation of calibration facilities. There are several companies that provide support software for Fluke's Met/Track and Met/Cal software. More information is available from **http://calibration.fluke.com.**

Contract services

For a broad range of calibration services covering many types of instruments, professional instrument calibration services are available from Agilent. See **www.agilent.com/find/calibration** for details. Non-Agilent equipment is included. Contracted services can be arranged in various levels, from single instruments on an as-needed basis to scheduled volume on-site calibration (VOSCAL).

Swap and return

The third method of calibrating equipment is to simply replace units when they need calibration with others that are still within their calibration period. This requires keeping one or two spares on-hand, which can be expensive. However, it is a good idea to keep some spares handy anyway if system uptime is critical. We'll talk about this more in the next section.

There is one caveat in swapping instruments. A replacement may be completely within its calibration specifications, but if it is operating at the opposite end of its calibration range from the original instrument and the production device being tested is already near its limit, a statistical variation could result that is large enough to cause a yield problem. The solution is to run a statistical analysis on the results. This analysis is called a "Gage R&R" study, and it is covered in the next section.

Diagnostics & Repair

Perhaps the hardest thing to do once you have a test system finished is to spend some extra time designing a diagnostics test program that can help locate the source of problems when they arise. But it is time well spent. Here's what to do:

- Execute a self-test on every instrument that has this capability.
- Measure the output of every stimulus device with an appropriate measurement device to verify that all instruments are working and taking readings that are nominally correct. This is not sufficient to guarantee that they are in calibration, but it is good enough for a diagnostic tool.
- Feed a small DC voltage from a stimulus device (digital-to-analog converter, power supply, etc.) successively through all internally available switching paths and back to a DMM. This verifies the switching subsystem.
- Create a special fixture that loops signals that cannot be automatically connected internally back into the system. This is called a diagnostic fixture. Use the same procedure previously described to measure continuity of these paths.
- Read switch cycle count information from any switch box that has this capability. This data can give you early warning of relays that are nearing the end of their specified lives.
- Some instruments can do limited internal automatic calibration (sometimes called "auto-adjustment"). This automatic procedure should be done periodically, but not necessarily every time diagnostic test programs are run. Keep a programmatic calendar to remind the operator to run such programs when the due date occurs (usually about every 30 days).
- Attach a known good device under test (DUT) to the system and run a full suite of tests on it. This technique is not foolproof, since characteristics of such a "golden DUT" can change over time as components age. A useful way to counter this effect is to periodically run a "Gage Reliability and Reproducibility" (Gage R&R) test on the system. There are two sources of variation in any system: the variation of the product and the variation of the measurement system. The purpose of conducting the Gage R&R is to be able to distinguish between the two so as to reduce the measurement system variation if it is excessive. This means running a large quantity of known good boards on the system periodically to obtain a statistical sampling that can be compared to reference data to see if there is any long-term drift in the measurements. Such a study can also be used initially to study the measurement statistical parameters, which can be used to set acceptable upper and lower limits on each test. Look for "statistical process control" (SPC) and "statistical quality control" (SQC) software tools that can help you create such data.

In a production environment, diagnostics can be run daily or at the beginning of a shift. In a design validation or R&D environment, running the test once a week or less may be adequate. Once a problem is identified, the next step is to fix it. There are several things you can do to ensure fast repair:

- Make it easy to replace instruments. Make sure that mounting screws are not hidden, that cables are easily removed from the instrument (and labeled so they are replaced correctly), and that instruments are not buried, necessitating removal of other instruments to get to them.
- Although PCI slots in a rack-mounted computer are tempting spots to put instruments (since they do not take up additional rack space), remember that removing the computer from the rack to get to them is tedious and time-consuming.
- Use a limited set of custom cables and keep spares on-hand in case they need to be replaced. Use standard, easily available cables whenever possible.
- Fixture connectors can wear out over time. Have a good stock of replacement connectors available.
- Computers are a constant source of problems. Hard disks go bad, monitors quit, and keyboards and mice get dirty. Have spares available. Most importantly, keep important files somewhere else or back up the computer regularly to guard against loss of data.
- Maintain an inventory of spare instruments – this can be expensive, but so is a down production line. Remember, too, that the cost of many plug-in cards for PXI and VXI is greater than an equivalent rack-and-stack instrument because rack-and-stack instruments typically are produced in higher volumes. Thus, it is less expensive to inventory spares of box instruments, and they can double as debug tools when not in use inside a system.
- Place more than one of a key instrument in your system when you design it. For example, an inexpensive DMM could be integrated into the system for use during manual debug, but pressed into service should the main, high-speed DMM require service. With IVI drivers, such interchangeability should not require a change to the software.
- Heat and thermal gradients are enemies of any test system. Provide adequate airflow to minimize heat rise, and avoid a situation where you are continually changing the thermal environment of the test equipment.

Cleaning

Maintaining good airflow through your system is essential, because it keeps the temperature under control, assuring that instruments are operated within their temperature specifications. Many instruments have removable air filters, so be sure to inspect these regularly and clean or replace them when necessary. Some racks are also available with air filters. These should also be inspected regularly. Keep cables away from the filters. If cables must be moved in order to reach the filters, the flexing can make the cables eventually break, causing reliability problems unrelated to dirty air.

If many operators will be using the system, it is a good idea to periodically clean the keyboard, mouse, barcode reader and touchscreen, as applicable. You generally can use simple household cleansers. Disease can be spread easily from one person to the next via these devices. Trained operators may be hard to find, so keep them healthy!

Upgrades and expansion

If you've designed your system well, using the concepts highlighted in earlier papers of this System Developers' Guide, it will be able to handle new instruments easily. You've left extra space in the rack for additional or bigger instruments, and you've allowed expansion room in your switching or instrumentation cardcage if present. You've also designed the switching system in such a way as to allow instruments to be added to the system by simply plugging the new inputs and outputs into a place you've reserved for future instruments (such as the unused rows of a switching matrix, as described in Application Note1465-5, *Choosing Your Test-System Hardware Architecture and Instrumentation*). You've got room in your fixturing system for more pins, and you've developed a small set of reusable cables to connect those into your instruments and switches.

In the software realm, you've planned for upgrades by doing regression testing every time a major piece of software is changed. This means allowing time to re-run the Gage R&R, diagnostic test plan and/or known-good DUT when the operating system, test executive, drivers or other support routines are modified. You've also documented the software and allowed for code changes to be easily tracked. You've written the software in an environment standard to the PC industry so anyone familiar with languages like Visual Basic or C can take over the system software and make necessary changes as the years go by.

Conclusion

Test systems have made the task of repetitive testing both faster and more reliable, but there's a much to consider to keep them running. You must factor in worldwide power issues, calibration, diagnostics, repair, cleaning, upgrades and expansion. At Agilent, we appreciate the talent and effort required to design, build and implement exceptional test systems. We hope this series of application notes in the System Developer's Guide has helped make your life a little easier.

If you are creating a test system or need help with one you already use, you can find more help at Agilent Developer Network, **www.agilent.com/ find/adn**, or search our systems information at **www.agilent.com/find/systemcomponents.**

Related Agilent literature

Application notes

Test-System Development Guide:

- *Introduction to Test-System Design* (AN 1465-1) pub. no. 5988-9747EN **http://cp.literature.agilent.com/litweb/pdf/5988-9747EN.pdf**
- *Computer I/O Considerations* (AN 1465-2) pub. no. 5988-9818EN, **http://cp.literature.agilent.com/litweb/pdf/5988-9818EN.pdf**
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- *Choosing Your Test-System Software Architecture (AN 1465-4)* pub. no. 5988-9819EN **http://cp.literature.agilent.com/litweb/pdf/5988-9819EN.pdf**
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- *Operational Maintenance* (AN 1465-8) pub. no. 5988-9823EN **http://cp.literature.agilent.com/litweb/pdf/5988-9823EN.pdf**
- *Using LAN in Test Systems: The Basics* (AN 1465-9) pub no. 5989-1412EN **http://cp.literature.agilent.com/litweb/pdf/5989-1412EN.pdf**
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- *Using USB in the Test and Measurement Environment* (AN 1465-12) pub no. 5989-1417EN **http://cp.literature.agilent.com/litweb/pdf/5989-1417EN.pdf**
- *Using LAN in Test Systems: Applications,* (AN 1465-14) (available in February 2005)

To discover more ways to simplify system integration, accelerate system development and apply the advantages of open connectivity, please visit the Web site at **www.agilent.com/find/systemcomponents.** Once you're there, you can also connect with our online community of system developers and sign up for early delivery of future application notes in this series. Just look for the link "Join your peers in simplifying test-system integration."

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