Considerations When Specifying a DC Power Supply

By Bill Martin

System integration made easy.
Almost every automated test system that tests electronic circuit boards, modules or equipment needs one or more power supplies. This could be DC to simulate the DC power-bus within the equipment that powers the internal circuit boards or modules or this could be AC to simulate the AC mains of different countries or the AC power-bus used in aircrafts.

In any case the power supply simulates the environment the electronic circuitry is used in, thus it is the device under test (DUT) that determines the power supply requirements. In addition, we need to consider the requirements for margin testing. This means what internal or external standards apply to this DUT. For instance some automotive standards require margin testing up to 27VDC on a 12VDC device. This means that although the DUT runs nominal on 12VDC, the maximum test voltage is much higher.

In the next paragraphs I would like to discuss most common power supply parameters to be considered when selecting a power supply to match your DUT testing requirements.

Ripple & Noise
Ripple & noise specifications are traditionally the first specifications we look at. This is important, because the first choice we must make is that between a linear or switch-mode DC power supply. Actually there are three main topologies of DC programmable power supplies to consider: linear, switch-mode and hybrid. The linear power supply has low ripple & noise and has fast transient behaviors. However, it’s inefficient, producing a lot of heat in the air and becomes large and heavy and is therefore only desirable at lower output power levels (typically less then 500 Watts). Most linear DC power supplies are bench-type supplies. The following are two main reasons to consider a linear bench supply. First, when the DUT is a communication device like an RF radio or mobile phone, or the demodulator module of a radar system. What this type of equipment has in common is a very sensitive discriminator or demodulator circuitry that works the best with a low noise figure. In other words, to test its true signal-to-noise (S/N in dB) performance, we need to ensure that the DC power supply does not add any parasitical noise to the test setup. The second reason to consider a bench-type supply is when the power requirements are low. The main benefits for a switch-mode supply are only relevant at higher output power levels. It will be less expensive to use linear DC power supplies in applications with requirements not more then 100 to 200 Watts per DC output channel. Important to consider is the total power of all required DC output channels combined. Up to four channels it could be easier to just take four linear bench supplies in a 19-inch rack-mount kit. In switch-mode technology, 12 channels together providing over four thousand Watts will take the same rack-space, with less complex multi-channel control for a similar price per channel.

If ripple & noise is not the driving specification, realize that switch-mode programmable supplies do give you more flexibility. Switch-mode programmable supplies provide more value, or output power, for the same price in a smaller box. Better stated, they provide a larger DC output voltage and current range, covering different needs for testing your DUT.

Transient response
Over the years, innovative topology in power electronics (like zero-switching), has improved the ripple & noise specifications of switch-mode power supplies dramatically and pushed this requirement to the background. Other specifications became the gating item in supporting
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A practical trick to limit the over- and undershoots is to use a pre-load. Putting a pre-load in parallel with the DUT and the DC output of the programmable power supply will now limit the percent current change, causing the DC voltage over- and undershoots to be significantly less. Imagine that 50% of the current travels through this additional pre-load and 50% through the DUT. When the DUT creates a 100% current demand step, the power supply only sees a 50% current demand change. Always a base current demand remains present flowing through the pre-load. For the power supply to manage 50% in current demand changes, instead of 100%, it is much easier and almost eliminates the effect of high voltage overshoots and therefore eliminates any damage to the DUT. A simple inexpensive resistive load can be used in this case to function as a pre-load. Any ratio is fine. In other words, to obtain the transient response and overshoot specifications improvements it does not really matter if this load absorbs 40%, 50% or 60% of the current demand.

Again some disadvantage arises; twice as much DC output current is now required, therefore more output power is required. At AMETEK, additional power in the same product family comes with just 50 cents per Watt more. A much cheaper and more practical approach than specialized power supply sub-systems uniquely dedicated for this specific application.

Slew-rate

The next specification to consider is the DC output voltage slew-rate (rise & fall time). To improve the ripple & noise specifications, DC programmable power supplies have a large output filter that includes large capacitors with obviously a lot of stored energy. It’s mainly the change and discharge time of this filter, combined with the current demand of the DUT that determines the DC output rise & fall time.

This output voltage rise-time is mostly independent of the connected DUT. This depends mainly on the internal LCR network filter design and its LCR time constants. This rise-time is relatively fast and sufficient in most applications. It is the DC output fall-time that is causing trouble. The fall-time depends not only from the internal LCR filter network at the DC output of the programmable power supply, but also of the connected DUT. If the current draw through the DUT is relatively low compared with the power supply current capability it can take many seconds before all stored energy has “leaked” away through the DUT. If the DUT requires a minimum current demand of at least 60% of the power supply capability, the stored energy will leak away instantaneously and the output voltage fall-time will be the shortest. Never the less, in most cases the DC output fall-time will be two to three times slower then the DC output rise-time.

How to improve the DC output rise-time: Choose a programmable power supply with a higher DC output range. For example, if the DUT is an automotive related device and a 30VDC power supply would cover all test applications, choose instead a 60 VDC programmable supply, but only use up to 30VDC. For the output...
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capacitor to support 60VDC maximum DC output range, the capacitance will be much smaller than the 30VDC programmable supply, thus to program from zero (0) to 30 or 60 VDC will take the same rise-time. In other words, when looking at the rise-time in V/ms, the 60 volts power supply will be twice as fast.

How to improve the DC output fall-time: Use a pre-load in parallel with the DUT or DC output of the power supply. Ensure that the total current demand of the pre-load and the DUT combined is at least 65% of the programmable power supply’s current capability.

This approach requires more power from the supply as more DC output voltage range is required with the same output current demand. Also current slew-rate depends on the programmable power supply output stage, but is less different between different models of DC power supplies. Typically the output current slew-rate is 45A/ms. AMETEK also makes some DC power supplies to support solid-state laser applications. These are current sources with an output current slew-rate up to 400A/ms.

Faster current slew-rates are possible by putting an electronic load in series with the power supply and using the electronic load as a current modulator. This combination allows for a current slew-rate up to 6000A/ms.

Load regulation
A similar specification of programmable power supplies is load regulation. This means a permanent output voltage change from its set-point due to a continuous output current demand of the DUT. Normally this effect should be very small (less than 0.01% of set output voltage). Only when the internal impedance of the programmable power supply is relatively high, the load regulation becomes an unwanted factor.

Line Regulation
One of the requirements for an ATE is that it can be used in different countries of the world. The test system is designed in one country, but used at an offshore production facility in another country. Often the AC mains is not that stable, or not even the same AC voltage (http://kropla.com/electric2.htm). Line regulation specifies the percent change of the DC output voltage or current as a function of AC input line voltage change.

Stability
Stability specifies the long-term drift of output voltage and current. To related more specifically to an application, users want to know how repeatable is the programmable power supply in its output voltage and/or current set-point accuracy. In short, this is a repeatability specification, not an absolute specification for set-point accuracy. What most users really need to ensure when the supply is programmed to a specific value it always comes back to that same value as close as possible over a long period of time. A typical application is magnet drive, in which the programmable supply works as a current source in constant current mode. What the user really wants is to return back to the exact magnetic flux value, therefore to control the DC output current to exactly the same set-point value. Stability is primarily specified in parts-per-million or PPM.

Parallel operation
If more output current is required, paralleling power supply outputs is generally the solution. AMETEK uses a dedicated parallel control bus that daisy-chains multiple power supplies in parallel. The benefit of this dedicated paralleling bus is that the total performance of the units in parallel still meets the original specifications for just one single power supply. The system configures itself automatically, identifying which unit is the master and which units are the slaves. With fast transient DUT’s it is sometimes recommended to use protection blocking diodes in the positive output line of each power supply. When paralleling, the different programmable supplies used can be from a different current range, but should have the same output voltage range. All manual or remote control is done through the master unit. Any sense lines are also connected only through the master unit.

Do realize that the total current is the sum of the current values displayed on each individual power supply. Some advanced models can compute and display the total system current (e.g.: SGI from Sorensen).
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Series operation
Series operation sounds simple, "just put multiple supplies in series by connecting the positive from one supply to the negative of the other supply." True, but there are some limitations. Every programmable power supply has voltage isolation specifications. One for the negative to chassis isolation and one for the positive to chassis isolation. For example if the maximum allowable isolation from the negative to chassis is 150VDC and the maximum allowable isolation from the positive to chassis is 600VDC, one could take a 150V power supply and put in series a 600V power supply as long as the total set voltages together do not exceed more than 600VDC.

The highest serial output voltage AMETEK can provide is 1200VDC, but only when the common is connected to chassis-ground and the DUT that is connected across the 1200VDC remains floating. Typical application: solar inverter testing. With series operation there is no master/slave concept. In other words, all series power supplies need to be programmed individually. When using remote control for this, all interfaces need to be galvanically isolated through opto-couplers. In the AMETEK programmable power supplies, isolated interfaces are, analog, RS-232, RS-485 and Ethernet.

Digital programming
In general the output voltage and current is set most accurately with the highest resolution through its different digital interfaces. For this the interface set-point accuracy and resolution to set the output voltage and current is specified. AMETEK offers RS-232, RS-485, USB, GPIB and Ethernet control. The digital infrastructure of all these digital interfaces provides a 16-bit resolution with a multi-point internal reference table to calibrate for the DAC’s linearity and offset errors. Important is that all interfaces are SCPI compliant to accommodate easy programming of the power supply and low switching costs.

Through digital programming with SCPI commands, many more features can be activated, such as sequencing. Controlling the power supply through SCPI commands takes 25 to 50 ms per command. The sequence capability allows you to download an auto-run program that can run through a sequence of voltage or current steps or true ramps with a 1ms fast step-time—a function that could never be done by conventional SCPI remote programming. Application examples are automotive testing according to the ISO 7637 standard or fuse rating testing according to the IEC 60269 standards.

Important is that at least IVI drivers are available. Most other drivers can be created by easy conversion of an IVI driver.

Analog programming
Every AMETEK programmable power supply provides a standard and isolated analog interface. Through the analog interface the DC output voltage, current and over-voltage-protection (OVP) can be set. The control is through an analog voltage signal, current signal or resistor. The example would be to use a PLC to control the power supplies, or a thermistor controlling the output of the supply. Also provided are voltage and current monitoring signal lines and control lines to enable or disable the power supply with ms reaction time. Important is that the analog control interface provides a control bandwidth, faster than the power supply output voltage and current slew-rate. AMETEK DC power supplies provide a 2kHz bandwidth, ensuring that the analog control interface is always faster than its output capabilities. Therefore the analog interface will never be the limiting factor.

Sense lines
The Sense feature "senses" (measures) and then regulates the voltage at the point it is connected to the output. When the sense leads are connected directly to the output terminal of the power supply we call it "local sense". By default AMETEK delivers new power supplies configured for local sense. Depending on the model, the sense leads may be connected to the output internally or they may be connected through external jumpers. For accurate output voltage setting, remote sense mode should be used. In this mode we regulate the power supply at the load. This method compensates for the voltage drop across the leads. If sense lines are long, it is recommended to use shielded cables to avoid any interference being superimposed on the main DC output. Sense mode can compensate a voltage drop much larger then the specified 5% to 10 %. The issue is that other specifications, like transient response, should not suffer from to large of a sense loss.

[Diagram of programming and control]
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Other considerations:
Voltage source in constant voltage mode or current source in constant current mode. These considerations drive some of the relevance for different specifications. For instance, in constant current mode, sensing is not applicable; neither is the output voltage set-point accuracy and resolution, but accurate current control is. Also, less relevant is the output voltage ripple & noise compared to the current ripple & noise.

In constant current mode the analog control can drive current changes at least 100 times faster than output voltage changes. The crossover from voltage to current mode is automatic. As soon as the current demand is larger then the set current limit, the DC power supply regulates its voltage down to match the set current limit and keeps the output current constant. This crossover process is a nano-second event.

Inrush current:
AMETEK programmable power supplies accommodate DUTs with large inrush currents. The function is called “Foldback Mode.” It is a current limit with a time constants, settable with a milli-second resolution from zero (0) to a 10-second range. This means that the power supply will allow for a higher inrush current for a limited amount of time, before disabling the power supply output. An application example would be any electric motor.

Bench vs. linear power supply?
When the application requires low DC power combined with low ripple & noise and fast transient response time (e.g. mobile phone testing), a linear-type bench supply could be the best solution. Do realize that there are many low-cost bench supplies on the market, meeting the ripple & noise and transient response requirements thought the virtue of being from a linear topology. The issue you could face is insufficient programming and read-back accuracy and resolution. Accuracy, resolution, interfacing and other digital features set good bench supplies apart form the average performing models. In other words, “buyer beware” for cheap deals.

Verify the availability of accessories like rack-mount kits. An off-the-shelf rack-mount kit is always less expensive than constructing one yourself.

In conclusion
When selecting a DC programmable power supply, there are many parameters to consider. From fundamental specifications, to form-factor, to control, etc.

Most important is to start with the needs of the application or what makes the device under test run and what margin testing is required according to which standards.

About AMETEK Programmable Power
Headquartered in San Diego, California, AMETEK Programmable Power is the new global leader in the design and manufacture of precision, programmable power supplies for R&D, test and measurement, process control, power bus simulation and power conditioning applications across diverse industrial segments. From benchtop supplies to rack-mounted industrial power subsystems, AMETEK Programmable Power produces Sorensen, Argantix and PowerTen brand DC supplies ranging from 30W to 150KW, Elgar and California Instruments brand programmable AC sources from 800VA to 480kVA, and Sorensen brand AC/DC loads in both modular and high-power models. AMETEK Programmable Power is a division of AMETEK, Inc, a leading global manufacturer of electronic instruments and electromechanical devices with annual sales of more than $3 billion. For more information, contact AMETEK Programmable Power, 9250 Brown Deer Road, San Diego, CA 92121. Web site: www.programmablepower.com.