Guidelines - Custom Power Electronics

Specifying a power supply for use in a particular application is often thought of as a relatively simple job, and usually left until the very end of a project. This often leads to a hasty decision and a compromise on a unit which does not fit the application perfectly, but which is available off-the-shelf and can be in house. Typically, such a unit winds up being "over specified," but the justification is usually "this will buy us reliability". This is not usually the case.

While running a power supply at reduced load will usually allow it to run cooler, there are many components which do not benefit from this fact, and the way the supply is mounted and cooled can often make a bigger difference. Ideally, your potential power supply manufacturer should be consulted as early as possible in the design cycle to allow them to offer cost saving suggestions.

When comparing supplies, you should have a specification written which defines exactly what you need. Never assume that a power supply will operate under certain conditions, make sure you specify it.

The following items are specifications which Milectro requires for a custom power supply design. If engineering and design help is required, Milectro will work with you to develop the necessary specifications.

DETAILED SPECIFICATIONS

INPUT VOLTAGE

What is the source of the input voltage?

Specification: The input voltage of a power supply should be specified for worst case operating conditions based on the requirements and the expected operating environment. A range of 90 to 132 is typical. In a very cost sensitive, high volume application, a narrower range such as 100 to 130 may save some money. In a critical industrial control application, a wider range such as 80 to 140 may be appropriate where surges and dips caused by heavy loads can cause problems. If 220-volt operation is required, these voltages should be doubled. If the application environment will be varied, a wide and continuous range input may be appropriate, such as 80 to 270.

DC/DC converters are usually specified in a similar manner. Input voltage can either be from a single DC input voltage, allowing the design to be optimized at that voltage, or a wider input range if the converter must run off of an unregulated DC supply. If the converter is to run off of batteries, the input range must include the highest float voltage as well as the lowest full load voltage. This range is often 2:1 or greater. For instance, in a typical 12 volt automotive electrical system, the float voltage while driving may be as high as 15 volts, while the voltage while cranking a cold engine may be 6 volts or less. Also, in a battery system with more than one load on the battery, relatively large input filters will usually be required. Contrary to popular belief, batteries are not particularly well-regulated voltage sources, and their equivalent series resistance goes up dramatically as the battery is discharged.

INPUT FREQUENCY

Input frequency is usually not an issue with switching power supplies, but it is with a supply that uses an off-line transformer. Some switchers, for instance, use a 60 Hz transformer for the housekeeping supply, which can preclude 400 or 1,000 Hz operation. However, if known please specify the input frequency. Typical specifications are 0Hz, 48-52 Hz, 58-62 Hz, 100 HZ, 120 Hz, 400 Hz, 500 Hz, 600 Hz, and 1,000 Hz.

INPUT PHASE

Is the input voltage source single phase, two phase, three phase, etc.?

SURGE CURRENT

Surge current is usually specified on larger power supplies, usually on line operated supplies of 300 watts or more. The intent is to limit surge currents to prevent false tripping of circuit breakers or interference with other supplies on the same line. On power-up, supplies with large input filter capacitors can draw peak currents 10 times greater than the steady state current. If the environment requires it, specify it. A typical specification for limited surge current is 2 to 4 times the steady state current.

HOLD-UP TIME

Hold-up time is another important input parameter. It is usually specified when the load is a digital system which will be interrupted by a momentary power glitch. Studies have shown that over 95% of all power failures last no more than 1 to 5 AC cycles. This means that by specifying a holdup time of 16 to 80 ms, your system can ride through the vast majority of power failures. For critical applications, specifying a long hold-up time of 100 mS will usually eliminate the need to consider a UPS for the system.

EFFICIENCY

Efficiency is usually specified for one of the following reasons: 1) The supply will use enough power that the cost of the power compared to the cost of the supply is worth considering, 2) The input power is limited, as when a DC to DC converter is operating from a battery, or 3) The power dissipated by the supply will be difficult to dissipate. A "typical" power supply design has a fair amount of efficiency optimization in its' design. However, when efficiency is a very important consideration, it can usually be raised. The tradeoff is primarily in cost, size, and weight.

OUTPUTS

Outputs of a power supply must be specified for the particular type of load. For example, a 12-volt output for analog circuitry will have different requirements than a 12-volt output used to power a stepper motor. In addition, the type of output must be specified. Most power supplies are constant voltage, current limited types. This means that the output maintains a constant output voltage until the load current reaches the limit point, after which the voltage begins to drop in order to maintain a constant output current. Conversely, there are situations when the supply must deliver a constant current, regardless of load resistance or output voltage. Examples of this are laser supplies, charging systems for batteries or capacitor banks, and torque controlled motor controls.

OUTPUT VOLTAGE

Output voltage should be specified with a tolerance. If the output voltage must be adjusted with the final system, field adjustability must be specified. If it is a high current design and/or great precision is required, remote sense capability should be specified. This allows the supply to sense the actual voltage at the load, and adjusts the supply such that the desired voltage is maintained at the load, not at the supply. There can be substantial voltage drops in the wires connecting the load to the power supply.

OUTPUT FREQUENCY

If an AC output is called for, please specify the frequency required. Typical specifications are 50 Hz, 60 Hz, 120 Hz, 400 Hz, and 1,000 Hz. You may also specify a variable frequency range, but this adds cost.

OUTPUT PHASE

If an AC output is called for, specify single phase, two phase, three phase, etc.

OUTPUT CURRENT

Output current should be specified with a nominal number, which should be a best estimate as to what the average load will be, as well as a minimum and maximum number. If the maximum current differs substantially from the nominal current, then a duty cycle and time period should be specified. NOTE: Peak power requirements lasting for milliseconds or more are in essence steady-state to the semiconductors in the power supply. Only the thermal design can take advantage of a supply having a high peak to average current ratio. The minimum current drawn by the load usually becomes a consideration in multi-output supplies. This is because the usual topology for a multi-output supply involves a single control loop on the primary output, with secondary windings providing the extra outputs. The secondary windings are left in a semi-regulated state, or they can include secondary regulators to provide fully regulated outputs.

MINIMUM LOAD and REGULATION

To maintain reasonable output voltage on all the secondary outputs, the primary output must have a minimum load on it. For this reason, most multi-output supplies specify a minimum load for the primary output. The secondary outputs also require a minimum load if they have no further regulation. Secondary outputs can be fully regulated either by putting linear regulators on the outputs, or by using magnetic amplifiers "magamps". Magamps are more efficient than linear regulators, but they do require an extra inductor and associated control circuitry. When specifying the regulation on secondary outputs, specify a minimum load if you know that your application will always provide it. Do not over specify the amount of regulation needed. This will allow Milectro to provide the most cost-effective solution possible.

Regulation should be specified as a percentage change (% delta) under specific load changes. It can be specified as total regulation, meaning that the output will be in the specified tolerance under all conditions of line and load conditions. Or, it can be specified as individual components. Some suppliers specify the individual components, in order to enable the customer to estimate performance under their own conditions. Unfortunately, this often leads to confusion. The definitions of the various regulation components are as follows:

Line Regulation: The change in output voltage resulting from a change in input voltage. Usually specified as a percentage under specified input changes (1% from 85 to 130 VAC, etc.).

Load Regulation: The change in output voltage resulting from a change in load current. Usually specified as a percentage under specified load changes (1% from 25% to 80% load, etc.).

Thermal Regulation (stability): The change in output voltage over a specified temperature range or time period. Usually specified as a percentage per degree or a percentage over time.

Cross Regulation: This refers to the fact that in some multi-output supplies, the voltage of one output can be affected by load changes on another output. This is usually specified as a percentage change for a specific change on another output (5% for a load change of 25% to 75% on output #1).

RIPPLE and NOISE

Ripple describes periodic variations in the output voltage which are usually fed through the output filter. The ripple frequency is the operating frequency of the primary transformer, which is usually 60Hz for a standard linear supply or at the switching frequency of a switching power supply. Most power supplies have a combination of 60Hz ripple as well as high frequency ripple. A limit of 1% is typically placed on the outputs of switching supplies; this is generally a good compromise between ripple and transient response. Lower ripple translates to higher output inductance and higher capacitance, which slows transient response. Noise is not often specified. One reason is that it is very difficult to measure consistently. The best and most consistent way to measure noise is with an oscilloscope and a piece of 50-ohm coaxial cable terminated at both ends with a 50-ohm resistor. A high frequency bypass capacitor is sometimes used at the supply output since most loads will have one on their input. To be accurate, all noise specification must include a bandwidth, since the measured noise will be limited by the capability of the measuring instrument.

INPUT and OUTPUT CONNECTIONS

Please specify all known connection types. What type of connectors and plugs, if any, are required. If non-terminated wires are to be used, what gauge, type (stranded or solid), and metal (copper, copper clad aluminum, aluminum, silver, etc.) are to be used?

PROTECTION

Are fuses, circuit breakers, thermal breakers, low voltage disconnects, etc. required?

DISPLAY

Are LCDs, LEDs, or any other displays required?

INTERFACE

Some customers require an interface to the power supply at the logic level. Often, this is to enable an orderly shutdown upon the detection of an imminent power failure. This signal is actually a power good signal. The best way to specify it is to indicate it as active low, such that when the input capacitors start to discharge, an open collector driver goes high and stays high. Also it may be desirable to be able to turn the supply on/off with a logic signal. Another typical interface signal is a synchronization input and/or output. This is used to synchronize multiple supplies in a system to prevent a beat frequency from developing. Other times it is used to synchronize the power supply to the system clock in a large digital system. With the supply synchronized, the possibility of the coincidence of power supply switching noise with data transitions will be minimized.

SIZE & WEIGHT

As much of an allowance as possible should be given on size and weight. Ideally, a maximum size and weight should be given to allow flexibility in design. The only part of the mechanical specification that usually needs to be firm is the mounting screw pattern.

THERMAL CONSIDERATIONS

Potentially the single most important factor in specifying a reliable power supply is the thermal design. The thermal design of a power supply cannot be isolated from the rest of the system, nor can data sheet references to allowable temperature rise be used alone. The power supply will generate heat, usually a fixed amount plus a variable amount based on output loading. Most power supply designs specify efficiency at full load, but it is poor practice to operate anything constantly at 100% full rated load (because fluctuations, transients, and environmental conditions may push the supply well over 100%). Consequently, the actual efficiency in your system may be lower than you believe. In the absence of actual data, a good guess is to decrease full-load efficiency by 5% when operating at 60-80% full load. The heat generated by the supply will be the difference between the input power and the output power, or:

Input Power = Output Power / Efficiency

Power Dissipated = Input Power - Output Power

This power is the power dissipated by the supply. However, if the supply is mounted in the same enclosure as the load, the enclosure must dissipate almost 100% of the supply input power, assuming that the load is not performing much useful work in the mechanical sense. Assuming you have a prototype enclosure to work with, it is quite easy to use resistors as heat sources of various types in the expected locations. If your system is almost complete, except for the supply, then the system should be assembled and run off of an external lab supply. A dummy supply (this can be as simple as a single aluminum plate) can then be installed with chassis-mounted resistors (attached to simulate the actual supply.

If the supply is to be conduction cooled, the dummy chassis temperature can be expected to closely approximate the actual supply chassis temperature. If the supply uses convection cooling extensively, then the dummy chassis temperature will not necessarily be a good indication of the actual supply chassis temperature, however the temperature of the inside air will still be fairly close to the actual. The purpose of this is to evaluate the cooling capacity of a system. If the housing is a large intricate molded plastic assembly, a model such as this is the only realistic method to investigate temperatures. With this test data, you will be better able to specify the highest ambient temperature the power supply will have to operate in, what the base plate temperature will be (assuming conduction cooling,) and what airflow will be required. You will also be able to evaluate the effect of power supply efficiency on the overall system by simply varying the power in the resistors.

For more accurate testing, Milectro can set up a dummy chassis using a combination of conduction and convection cooling, as appropriate. We accomplish this by using one or more resistors to simulate the conduction cooled power supply components, and air cooled resistors to simulate the convection-cooled components.

COOLING METHOD

If there will be a metal base plate which will be cooled reasonably well, then conduction cooling may be the most efficient way to get the heat out of your enclosure. However, if there is not a good mounting surface to act as the cooling base plate, then convection cooling will likely be the best approach. Many of our custom designed power supplies use a combination of conduction and convection cooling. If the supply will be mounted in a plastic enclosure, and the desired supply requires some conduction cooling, then a sub-chassis to increase surface area should be considered.

OPERATING TEMPERATURE

Operating Temperature is part of the overall thermal design, although it is frequently specified separately. It can also be a somewhat misleading specification, because it is really tied closely to airflow and to the thermal characteristics of the supply itself. A supply, which is rated to operate to 70°C, can overheat in a 25°C environment if the supply is not mounted and cooled properly. Additionally, environmental chamber tests can be misleading, because the test conditions are designed to maintain a uniform thermal environment, usually by high rates of air flow. This can give a false sense of reliability in a power supply test, since this airflow has the effect of dramatically decreasing the thermal resistance of the power supply heat sinks. It is quite common for semiconductor heat sinks to run 20°C cooler in a high rate of airflow at a given temperature.

HUMIDITY

Power supplies destined for an office environment usually do not need to have a humidity specification. However, many consumer applications and most industrial applications specify a humidity range. The easiest design specification is to require operation in up to 95% non-condensing humidity. This means that temperatures will not be changing fast enough to cause condensation on the surfaces of the supply. Without condensation, any supply should work under high humidity conditions, except particularly high voltage supplies. If the supply will be located in an area where condensation is possible, condensation must be included in the operating specification (i.e., 100% condensing). This may force the pc boards to be conformally coated, or the supply may be totally sealed in potting.

SALT SPRAY

There are many commercial applications where resistance to salt spray is necessary. Examples of this are marine applications where the end product will be exposed to this sort of environment. Military specifications such as MIL-STD-810 give detailed procedures for salt spray testing, but for a commercial product, a less costly test may be appropriate. The best approach here is to discuss the requirement with a Milectro' engineer to determine the best way of assuring the supply will perform properly in the expected environment.

ALTITUDE

Typically, there is no problem in meeting an altitude specification; it simply means more attention must be paid to high voltage insulation. Convection cooling is much less effective, but air temperatures are cold enough at high altitudes that the effectiveness of the cooling air is not dramatically affected. Moreover, airborne applications typically have plenty of air volume, which also helps. Commonly, 10,000 feet is called out if the unit is not expected to fly, or if it would always be in a pressurized environment. If the power supply must operate at higher altitudes, this should be clearly specified. Space applications are even more demanding, since air-cooling is not possible. In addition, temperatures can usually be expected to vary widely due to solar heating.

SHOCK and VIBRATION

This is a very important specification. If the power supply will be operated in a stationary location, it is a good idea to let the specification take the form of a shipping specification with the supply in its' shipping container. Some customers add a shock specification as an indication that the supply should be very rugged. Often, the intent is to allow the unit to survive bench handling, which is a term often used to describe a fall to the floor. If this is your intent, please state this clearly. A simple drop test is quite easy to verify informally. Conversely, a detailed shock specification requires more costly laboratory testing. If the power supply is to be used in a mobile application or high vibration environment, a more direct vibration spec should be imposed. MIL-STD-810 offers many versions for different types of environments.

MEAN TIME BETWEEN FAILURES (MTBF)

Specifying MTBF must be done with detail for this specification to be meaningful. MTBF can be determined either by calculation or by demonstration. Demonstrated MTBF is an ideal goal, but it is usually impractical. Many units must be run for many hours, and the variations due to environmental anomalies can make consistent results difficult at best. Usually, a calculated MTBF is used as verification that the design is sound. NOTE: The temperature that this calculation is based on must be specified.

PROCESS CONTROL

In some cases, our customers have particularly strong feelings about certain processes. A common example is a restriction on using certain hazardous materials (i.e., capacitors with PCBs, beryllium insulators, etc.). If there is a good reason for it, specify it. However, discuss it with us first, as it usually adds cost.

MILITARY SPECIFICATIONS

If a power supply is associated with military hardware, then often it will be required to meet various military specifications. One of the most common system specifications which involve power supplies is MIL-STD-461. This specification limits the amount of noise a power supply may generate and defines what types and levels of interference it must tolerate. Meeting the limits of this specification can be quite complex, adding size and weight to the supply. Another specialized requirement is for a unit to survive a nuclear event. This requires specialized surge protection as well as special component selection and circuit design techniques.

Very often, a requirement will have quality requirements specified. Most typical is MIL-I-45208. It contains requirements for equipment calibration, handling of discrepant material, and vendor surveillance. When very high quality standards apply, then MIL-Q-9858A is specified. This relatively brief specification refers to many others, and usually requires considerable effort to comply with. As always, the key is not to over specify. Environmental test methods are elaborated on in MIL-STD-810 as well as others. Milectro can meet any MIL SPEC. As always, please confer with one of our design engineers before specifying and MIL SPEC, as this will likely add significant cost.

AEROSPACE APPLICATION

When a power supply must be designed to operate in space, there is usually a complete set of the extremely stringent requirements. Aside from the obvious environmental problems such as shock, vibration, temperature and radiation, there are quality requirements, component selection restrictions, and approval of non-standard components, special circuit design techniques, EMI requirements, and extensive documentation requirements. Additionally, size and weight are usually at a premium as well.

The quality requirements usually involve traceability of all components, and extensive vendor surveillance. Very often the program will require MIL-Q-9858A compliance, or, as a minimum, compliance to the relevant parts.

Component selection must be attempted from a program-approved parts list, with exceptions handled in a specified way. Usually this means that justification must be written for the use of the non-standard part, and a specification control drawing must be generated. Certain parts, such as opto-couplers, must be avoided because of their inherent susceptibility to radiation. Although FETs can be used, specific circuit design techniques must be used to assure that a shift in gate threshold voltage over time will not cause problems. Several suppliers now offer radiation hardened FETs for these applications.

APPROVALS

Milectro can design and manufacture power supplies that will meet all standard approval requirements. The most basic approval is the appropriate UL/ETL approval. Unless a supply is a completely packaged stand-alone unit, it would not be possible to obtain a UL/ETL approval on the unit itself. Instead, it is usually done under the UL recognized component program. Under this program, the component is recognized for use in a particular type of equipment or application. The end product must obtain UL/ETL approval, but this is much easier if the individual components (such as the power supply) are already covered as recognized components. The next approval that is usually sought is CSA, the Canadian agency that closely parallels UL in the United States. The requirements are usually quite similar to UL, and CSA will usually want to see a UL/ETL report first. For export to Europe CE approval is usually required. Other approvals are UV/JS, and JIS (T-Mark). For some high frequency switching power supplies FCC approval may be required. However, keep in mind that the cost of obtaining all of these certifications is relatively high, and so it may not be practical if your production run is small and you target price is relatively low.