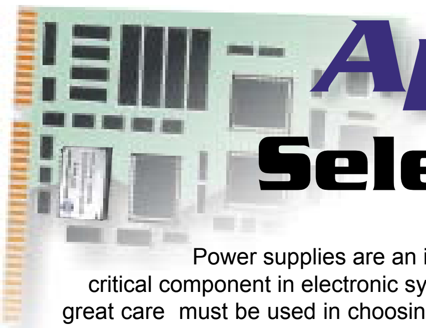

Application Guide

Selecting A Power Supply

Power supplies are an important, often critical component in electronic systems. As such, great care must be used in choosing an appropriate power supply for a particular application. A poor choice may result in poor system performance, unreliable equipment operation and/or increased costs. This can be prevented with proper planning.

System Design

As much as possible, system power should be considered and developed in conjunction with other system components. Following the old cliché of "leaving the power supply to last", may lock you into costly choices. For the purposes of this note, we will assume that only one power supply is required. A future application note will discuss the various decisions that must be made when choosing a power system architecture.

Make a Budget

First, make a simple budget of your system power requirements; those identified and those projected. Points to consider would include:

Basic Specifications

(required to even begin a search)

- Input Voltage (nominal and range)
- Output Voltage(s)
- Output Current(s)
- Space Available (max. size)
- Form Factor

Critical Features

- I/O Isolation
- Regulation
- Safety Approvals
- Thermal Performance
- Cooling
- EMI / RFI
- Protection Circuits

Other Features

- Remote On/Off
- Remote sensing
- Robust Input/Output Filtering
- Transient Characteristics

Special requirements

- High Isolation
- Special approvals (medical, ect.)
- Special Processing (Halt/Hass, etc)

How these specifications are defined will, to a large extent, determine the cost of the power supply as well as how "fit for application" its feature envelope is. As an exercise, it is worthwhile taking the "Custom Product Request Forms" available from most vendors and filling it out.

Standard vs Custom

A quick review of your power budget will tell you whether you will be able to use a standard "off the Shelf" supply or have to pursue a custom development project. In general, a standard power supply will save time and cost if it can be used. Also, since a standard may have multiple customers, usually customers are allowed greater flexibility on delivery/stocking. A quick comparison of the two is given in the table above.

	Standard	Custom
Development Costs	None	Medium to High
Development Time	None	3 to 18 Months
Volume Requirements	Low	High
Safety Approval Costs	None	$4k per Approval

Notes:

1. Custom projects typically require the payment of a "Non-Recurring Engineering" (NRE) charge. This one time charge pays for the development time spent by the vendors engineering team on the project, as well as any special processing that must be researched or added.
2. Custom projects are normally only considered for high volume applications. Custom power supply vendors (like standard power supply manufacturers) make their profits on the production of units, not engineering development. As such, low and medium volume opportunities do not offer sufficient opportunity to recoup their development expenses.
3. As a rule of thumb, safety approval costs run between $4k and $6k apiece.

If a standard product is a close fit to your application, many vendors will consider product modifications. Modified or special products fall in between customs and standards, and offer a fast, cost effective alternative for many applications.

Review the Data Sheet

Once the power budget is finished, it is time to review vendor data sheets (or custom product proposals). A clear understanding of power supply specifications is required if a good fit to the application is to be insured.

Input Spec's

Fuse: It is recommended that all power supply subsystems include a fuse in the input circuit. This is to prevent circuit damage due to excessive current drawn by the power supply under a fault condition. Most AC/DC supplies include an internal fuse (often replacable by the user), and the ratings for this component are given in the product specifications.

Most DC/DC converters (and some AC/DC converters) are potted or enclosed modules. These are not fused internally because an accidental or transient fault condition could open the fuse, causing a catastrophic failure of the power supply (that would then necessitate the replacement of the power supply). For these modules, the fuse should be added externally. The rule of thumb is to select a fuse rated at 150% to 200% of the maximum rated input current of the power supply. A slow-blow fuse should be used for a single supply application, a fast-blow for redundant power supply configurations.

Input Current: The current drawn from the input power source by a power supply under nominal input ine and full-load/no-load conditions.

Input Current, Fault Mode: The current drawn by a power supply with the output short circuited. A typical DC/DC converter specification.

Input Current, Surge: Also called inrush current, this is the maximum input current the power supply can withstand without potential damage.

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Input Frequency: This is only specified for AC/DC power supplies (it should not be confused with switching frequency). Typically specified at 50/60 Hz, if your application requires 400 Hz, ask the vendor.

Input Voltage, Nominal: The optimal input voltage for a power supply at which most parameters are specified. Normally the center point of the specified input voltage range (see below). The most common settings for DC/DC converters are 5 VDC, 9 VDC, 12 VDC, 24 VDC and 48 VDC. For AC/DC power supplies it is typically specified at 110 VAC or 220 VAC.

Input Votage Range: The minimum and maximum voltage limits between which the power supply will operate to within specifications.

AC/DC - Most AC/DC power supplies offer an input range of approximately 85 VAC to 260 VAC. This input is either:

Universal: The unit operates over the entire range with no switch required (automatic or manual).

Auto Ranging: The unit senses the input and at a preset limit will automatically switch from a 110 VAC input to a 220 VAC input (or vice versa). With this input configuration, there is a range of input (approximately 130 VAC to 170 VAC) where the power supply may experience some loss of functionality. This functionality loss is caused by hysterisis as the input switching circuit senses the input voltage level and tries to set the power supply input appropriately.

Jumper Selectable: Older units or specialized designs may be user selectable. Sometimes called "switch selectable" or "pin strappable", the user will connect input pins or connect a "flying lead" to set the desired input voltage on these power supplies.

DC/DC - DC/DC converters operate off a power bus driven by a central power or battery system. Popular inputs are 5VDC, 12 VDC, 24 VDC and 48 VDC. Low power units (<5W) are typically used in board level applications driven by a tightly regulated power line. these units are normally specified with an input range of ±10%.

Higher power DC/DC converters are typically used in battery powered or battery backed applications. These units offer input ranges that allow for battery charging and decay. Most popular are 2:1 (i.e. 18 VDC to 36 VDC, etc.) or 4:1 (i.e. 18 VDC to 72 VDC) inputs.

Comment: Like most specifications, a wider input range will typically result in higher cost (i.e. for a DC/DC converter, a 4:1 input range will cost more than a 2:1 or ±10%.

Leakage Current: The current flowing from input to output or input to case (measured at a set voltage) in a power supply. For an AC input power supply, the current that flows from the primary circuit to earth ground.

Table 1: EMI/EMC Standards

Agency	Standard	Class	Description
CENELEC	EN55022	A	Limits/methods of measurement of radio interference in information technology equipment. Tested over a range of 150 kHz to 30 MHz. Equipment may be restricted as to use.
		B	Limits/methods of measurement of radio interference in information technology equipment. Tested over a range of 150 kHz to 30 MHz. Equipment is not restricted as to use.
FCC	Part 15	A	Computing/IT equipment for commercial, industrial & business use. Tested over a range of 450 kHz to 30 MHz.
		B	Computing/IT equipment for residential use. Tested over a range of 450 kHz to 30 MHz.
CISPR	CISPR 22	A	Limits/methods of measurement of radio interference in information technology equipment. Tested over a range of 150 kHz to 30 MHz. Equipment may be restricted as to use.
		B	Limits/methods of measurement of radio interference in information technology equipment. Tested over a range of 150 kHz to 30 MHz. Equipment is not restricted as to use.

Leakage current levels are set by regulatory agencies (UL, CSA, etc.) for applications such as medical equipment. Excessive levels of leakage current may pose a hazard to system operators if the earth ground is disconnected.

Leakage current is not typically specified on DC/DC converters (an exception is products specified for medical equipment applications). It is also called "safety ground leakage current".

Reflected Ripple Current: The AC component, generated by the switching circuit, that is kicked back onto the input source by a DC/DC converter. Given as a peak to peak or rms value, it is measured over a bandwidth of 0 to 20 MHz.

Soft Start: A feature on some power supplies (typically AC input). Soft start is a circuit that limits the input inrush current at power on.

EMI Spec's

Many power supplies are specified to EMI/RFI levels set by various regulatory agencies. The most common are the FCC (Federal Communications Commision) specifications; the European Norm (EN) specifications (set by the European Commitee for Electrotechnical Standardization) and the CISPR specifications (set by the the International Special Commitee on Radiao Electronic Interference.

These specifications (see Table 1) give limits for both conducted and radiated emissions. AC/DC power supplies and high power DC/DC converters are routinely characterized to these limits. It's less common for low power DC/DC converters to be characterised to EMI specifications.

Output Spec's

Current Share: Many power supplies are capable of sharing load current (typically used in redundant configurations). The current share specification gives the percentage to within which the outputs will share the load current. Typically specified at 1% to 20%.

Hold-Up Time: The period of time a power supply will remain operating following the loss of input power. A common specification for AC/DC power supplies, it is typically rated at ≥16 mS (roughly 1 cycle of a 60 Hz sine wave).

Noise/Ripple: The noise and ripple voltage superimposed on the output of a power supply. Often specified as "Ripple & Noise" or "Periodic & Random Deviation" (PARD), it is expressed as a peak to peak or rms value over a given bandwidth at full load. Manufacturers specify different methods for testing noise. Check with the vendor to insure your test results are correct.

Output Current, Maximum: The maximum current that may be continuously drawn from an output without potentially damaging a power supply or triggering an output protection circuit. At times called "Rated Current". Some guard band (15% - 20%) should be allowed when selecting a power supply so as not to exceed this limit.

Output Current, Minimum: Most manufacturers will specify a required (minimum) level of output current to maintain proper operation of the power supply. Typically specified at 10%, operating the power supply below this limit will normally cause a degradation in load regulation.

Comment: If your application requires operation under very light load conditions, the manufacturer should be contacted. While usually not a reliability problem, some power supply designs may become unstable and be damaged under these conditions.

Output Voltage Adjustment: Some power supplies include trimmable outputs (typically the primary output only). This specification gives the range (usually ±10%) that may be changed by the user.

Output Voltage Accuracy: Typically specified on DC/DC converters, this is the tolerance of the manufacturers setting of the output voltage (it is sometimes specified as "Output Voltage Tolerance" or "set point accuracy"). Normally specified as a percentage under nominal input line and full load conditions. For multiple output supplies, it is specified for the main and auxiliary outputs.

Output Voltage Balance: Another DC/DC converter specification, output balance expresses the difference (as an absolute term) between the positive and negative outputs of a dual output unit. Typically given as a percentage, it is normally specified at nominal input line and full output load conditions.

Over Voltage Protection: (OVP) An output protection device that will clamp the output voltage to a preset level. Typically, OVP circuits are only added to the primary output of a supply.

Regulation, Cross: For a multiple output power supply, the change in voltage level on one output caused by a step change in load current on another output. Again, given as a percentage, cross regulation is typically measured with the input line at nominal and the output under test at full load.

Cross regulation is a common specification for AC/DC power supplies, but is not often given for DC/DC converters (see output voltage balance). As is the case with load regulation, there is some variation in how it is measured.

Regulation, Line: The change in output voltage caused by varying the input voltage over a specified range, all other parameters remaining constant. Given as a percentage, line regulation is normally measured with the output at full load while changing the input from low line (minimum) to high line (maximum). For some unregulated supplies, line regulation is given as a percentage change in output voltage for a percentage change in input line (%/% of Vin).

Regulation, Load: The change in output

Table 2: Product Safety Standards

Agency	Standard	Description
UL	UL 1950	Safety of Information Technology Equipment
	UL94	Flammability of Materials
	UL 2601	Medical/Dental Equipment
	UL 508	Industrial Control Equipment
CSA	C22.2 #950	Safety of Information Technology Equipment
	C22.2 #223	Power Supplies with Extra-Low-Voltage Class 2 Outputs
	C22.2 #601	Medical/Dental Equipment
CEN/CENELEC	EN 60950	Safety of Information Technology Equipment
	EN 60601	Medical/Dental Equipment

voltage caused by varying the output load over a specified range, all other parameters remaining constant. Multiple output power supplies have each output specified.

There are variations between vendors (and/or product families) as to the measurement of load regulation. These variations typically involve the size of the load change applied and the loading of auxilliary outputs. Most manufacturers state these conditions clearly in their data sheets.

Short Circuit Protection: Most power supplies include circuitry to limit the output current in the event of a fault condition. The set point is normally 110% to 150% of specified full load current.

There are a number of ways to achieve output protection (foldback limiting, power limiting, "hiccup" control, etc.) that have varying characteristics. Question the manufacturer if this is at all critical to the application.

Comment: If your application has a load that is highly capacative, a power supply that has a low current limit set point could be a problem. When the circuit is turned on, a high current will be drawn from the power supply as the output circuit capacitance is charged. If this level is too high, the power supply may go into current limit and shut down.

If you are using high capacitance levels on the output (>200 µF) for load decoupling, etc., ask what the capacitive load capability of the power supply is and what is the value of the current limit set point. Capacitive loading is not normally specified on power supply data sheets.

Transient Recovery Time: The time required for a power supply output to return to within a specified error band after a step change in load current. Normally specified only for the primary output.

The specified conditions for measuring transient recovery time (magnitude of the load change, limits of the error band, etc.) vary. Most manufacturers clearly state these conditions in the data sheet.

Temperature Coefficient: The change in power supply output voltage caused by a change in temperature (°C). Expressed as a percentage per degree centigrade.

Safety Approvals

Safety agencies ensure that products or components are intrinsically safe for the end user with regard to electrical shock, fire, mechanical hazards, etc. These approvals are required for most electronic systems and equipment and are often applied to the power supply (especially AC input supplies).

The most common safety agencies used for power supply approval are shown in Table 2. Products requiring approvals are submitted to the agency (or an authorized laboratory such as TUV) for testing. Once compliance to the applicable specification is established, the manufacturer is authorized to apply the agency mark or logo to the product.

There has been a significant effort to harmonize these standards and most are now based upon IEC 950.

To gain approval, a power supply vendor submits units and documentation to the applicable agencies. The agencies will test the units and generate a report. Any discrepencies found must be corrected and verified. Changes to the product/circuit require recertification and may require retesting.

General Spec's

Efficiency: Efficiency is the ratio of total output power to input power expressed as a percentage. It is derived by the equation:

$$\text{Efficiency (\%)} = \frac{P_{OUT}}{P_{IN}} \times 100$$

Where: P_{OUT} = Output Power

P_{IN} = Input Power

Typically specified at room temperature, full load and nominal input line, efficiency has become increasingly important as the package size of power supplies has decreased. Product efficiencies have steadily increased with improvements in circuit design, packaging techniques and component performance.

A low effeiciency results in higher power levels being dissipated within the power supply as

Table 3: Typical Efficiency Levels

	Efficiency
AC/DC (Linear)	45% to 55%
AC/DC (Switching)	65% to 85%
DC/DC (Linear)	50% to 65%
DC/DC (Switching)	75% to 90%
DC/DC (Synchronous)	90% +

Notes:

1. AC/DC linear supplies are not a significant segment of the market today because of the many advantages of switching designs. They are used primarily in applications that require very low levels of output noise.
2. DC/DC converters with "free running" designs tend to be very low power ($\leq$2W) units.

heat. In medium/high power or space critical applications, power supply efficiency can be a major factor in the expected field reliability.

Comment: A 5% decrease in efficiency will result in a 32% increase in the amount of power dissipated within the power supply. To insure reliable field operation, the power supply design must provide a thermal path to draw the heat generated by this internal power dissipation away from critical circuit components.

Isolation: The electrical seperation between the input and output of a power supply. Normally determined by transformer characteristics and component spacing, isolation is usually specified in values of voltage (VDC/VAC), resistance (MΩ) and capacitance (pF). With regard to isolation levels, most power supplies are designed to meet specifications set by regulatory agencies such as UL, CSA and IEC.

Typical input/output isolation levels are:

	VAC	VDC
AC/DC	3000	4200
DC/DC	1000	1400

Some power supplies are also specified for output to ground and output to case isolation.

Switching Frequency: The rate at which the input to a power supply is "chopped" or switched. Sometimes referred to as the frequency of operation, switching frequency can vary widely under differing operating conditions (especially output load in some designs).

Environmental Spec's

Operating Temp Range: The temperature range over which the power supply will operate to within specifications. For standard, commercial grade power supplies this is typically:

AC/DC	0ºC to +50ºC
DC/DC	-25ºC to +70ºC

Some commercial DC/DC converters are specified for operation to -40ºC. Power supplies are available with industrial (-25ºC to +85ºC and military (-55ºC to +125ºC) from some vendors. These typically cost more because of the higher grade components needed to meet these elevated temperatures.

Comment: If the application calls for the power supply to be operated at or close to either temperature extreme, the manufacturer should be contacted for advice. Although most vendor data sheets are complete, some do not contain information on derating, airflow requirements or heatsinking (if any).

Care must be taken in specifying power supplies to review how the operating temperature is characterised by the manufacturer. First, review how operating temperature is defined:

Ambient: Average temperature of air immidiately surrounding a power supply.

Case: Temperature of the power supply case when operating normally. Also called baseplate temperature.

Most high power density power supplies use case temperature (primarily to insure accuracy in measurements when applying the product). Some vendors will also specify derating and/or cooling required to operate the power supply at elevated temperatures.

Storage Temp Range: The temperature range over which the power supply may be safely stored. This is typically slightly wider than the operating temperature specified.

Cooling: A general specification that is often given to cover air flow, heat sinking and/or derating requirments (if any) for the power supply.

Relative Humidity: The ratio of the amount of moisture in the air to the amount the air could contain at a given temperature, expressed as a percentage. A common specification for power supplies is the ability to withstand high levels of humidity.

Comment: Some power supply manufacturers may include environmental specifications such as shock, vibration, altitude, etc. Typically, this type of information requires testing and/or design qualification beyond normal processing. If required, contact your vendor.

Reliability Spec's

MTBF: Mean Time Between Failure is a unit of measurement that predicts the relative reliability of a power supply. Based on MIL HDBK 217F, the MTBF figure is either calculated (per the standard) or demonstrated (based on actual performance data). MTBF is expressed in hours

For units that are not repairable (such as encapsulated power supplies), the appropriate figure to use is Mean Time To Failure (MTTF). However, if a constant failure rate is assumed (as is typical during the useful life of a product), MTTF is roughly equivalent to MTBF.

Mechanical Spec's

Mechanical specifications are typically given as a case drawing (including dimensions) and pin-out table. Depending on the supply, cable harness spec's, jumper placements, etc, may be given.

In Summary

With this note we have tried to touch on many of the decisions faced when selecting a power supply. As stated, power supplies are complex subassemblies that play a critical role in system performance. Make your selection carefully, and use the expertise of your power supply vendor if needed.