

SPI-APPNOTES: PARALLEL CONNECTIONS

There are two distinct reasons to connect power supplies in parallel: *Current Sharing* and *Redundancy*. Combining of these reasons is common, and there are many ways to implement them. The unique considerations of paralleling deal mostly with the outputs of supplies, electrical and mechanical. The first step is to clearly identify the all of the objectives behind the intent to parallel.

There are several segments of the electronics industry that are often associated with power supplies used in parallel for power and redundancy. They are Telecommunications, Mass Storage, Storage Area Networks, Real Time Computers, and Public Safety Systems. Below are common terms used when discussing power supplies used in parallel:

TERMS DEFINED:

Current Sharing: Refers to the division of the load among the supplies connected in parallel. The supplies will provide differing portions of the load by default unless measures are taken to balance the load. Current sharing is desirable for three reasons: (a) It increases the total amount of load current available. (b) It provides de-rating for the individual supplies, helping improve their potential long-term reliability. (c) It minimizes the potential for power bus glitches after a power supply has failed.

In many redundant power supply applications, the supplies are carefully selected and implemented to provide both redundancy and current sharing. Doing so provides fault tolerance and de-rating to improve the longevity of all of the supplies. Additionally, sharing of the load keeps all supplies 'awake' and conducting current. An idle power supply takes longer to come up to nominal output voltage. This could cause an unacceptable glitch on the power bus.

Fault Tolerance: The goal of protecting a system from any single point of failure, in some systems multiple points of failure. The term can refer to simple paralleling or high tech power systems using redundant AC phases, Battery Back Up, N+1 hot swap power supplies, and remote, visual, and audible alarms. In the case of redundant AC phases, there are two power supply sections, or drawers, using separate AC phases. SPI has a great deal of experience designing fault tolerant power systems. Contact us directly to discuss a particular application. We can provide any pieces or all of the required power system hardware.

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***Hot Swap:** Used in most N+1 applications. Mounted in a rack, the individual supplies feature front panels, handles, guides, and live-insertion connectors for all electrical connections. The individual supplies can be inserted or removed without powering the system down.

Isolation Diodes: Also called ORing or Blocking diodes, these are used for two primary reasons: (a) To prevent a failed supply from causing a general system shutdown in a fault condition. The diodes in a failed supply will block the current of 'good' supplies from conducting into the failed supply. Without the diodes, the 'good' supplies could see a short circuit condition. The system power would be lost. (b) When a power supply is inserted live into a system already powered up, its output capacitors would otherwise drain power from the power bus causing a disturbance.

N+1 Redundancy: 'N' equals the number of power supplies required for the load current. '1' is an extra supply providing redundancy should one of the 'N' supplies fail.

Parallel Connection: Connecting the '+' and '-' output leads of multiple supplies to the same respective points on a load. This increases the current available to the load but not the voltage. Serial connection has the opposite effect.

Redundancy: The use of an extra supply provided as a backup. Used heavily in the telecommunications industry where system down time is unacceptable, power supply redundancy is a basic method used to create fault tolerance in a power system.

* Note that the term *Warm Swap* has been gaining acceptance. It refers to the scenario where the power supplies have a front panel On/Off switch or an AC connector. The supplies can be switched on after insertion. This will eliminate pin to socket arcing when that is a concern. When using power connectors that are safety agency approved for hot swapping, arcing is generally not of concern. It is important to check if the hot swap power supplies under consideration have connectors that are safety agency approved specifically for hot swapping. If not, the power supply model should incorporate the on/off switch. Also, be sure to check the maximum pin current ratings from the individual safety agencies.

Note that Switching Power's HS-250 and HS-350 series' incorporate on/off switches. The higher power HS-500, HS-750, and HS-1000/1001 series' use connectors that are safety agency approved for live insertion and do not have front panel switches on the catalog versions.

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CURRENT SHARING METHODS:

There are three common ways to connect power supplies in parallel for the purposes of current sharing and redundancy:

1. **Brute-force**
2. **Forced:** Also known as Active or Third Wire Current Sharing
3. **Zero Wire:** Also known as Droop Regulation; Passive Current Sharing; Slope Programming

Each method is unique from the others and has advantages and disadvantages of which the power systems designer should be well aware.

Switching Power provides standard and custom products as well as support for all three types of current sharing.

Brute-force Current Sharing:

The simplest implementation possible, brute force paralleling connects two or more supplies together at the load with no additional circuitry used to create balanced loading among the supplies in parallel. The method can be used to increase the power available beyond that which one power supply can provide, and it can also provide redundancy. The unit with the highest output voltage conducts current first. In order to create the greatest possible degree of sharing, the user must set the output voltages as closely as possible and try to match the impedance from each supply to the load. Isolation diodes can be used.

- Pros:**
- Flexible
 - Scalable
 - Inexpensive
 - Ordinary power supplies can be used

- Cons:**
- Requires precision adjustments of output voltages to achieve current sharing.
 - The output wire length, gauge and connections must be closely matched.
 - The higher set supply will conduct a greater portion of the load current causing reduced longevity for itself. This can also cause power bus glitches if the lower set supply is conducting too little when its load is stepped up quickly. This could occur if the higher set supply experiences a failure.

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- The current limit set point should be reset to 90-100% of rated output to reduce the potential for overstressing the individual supplies.
- Remote sensing cannot be used. The lower set supply would sense the higher set supply's output voltage. Interpreting this as its own output voltage, the lower set supply would shut down by closing its duty cycle.

Forced Current Sharing:

This method uses active circuitry to measure a power supply's output current and compare it to the outputs from the other paralleled supplies. A communications link called the 'third wire' connects the supplies to one another. Active current sharing circuitry provides feedback to the supply's pulse width modulators adjusting their output voltages.

There are many methods power supply manufacturers can choose from to feed back and adjust the current sharing ratios. This makes it difficult for power supplies from different manufacturers to current share together. Generally, doing so is considered impractical.

- Pros:**
- Shares load evenly.
 - Voltage regulation can be within +/-1%. The tightest of the three basic methods.
 - Good power system scalability.
 - Perceived as most high tech method.
 - Remote sensing possible.
 - No adjustments required.

- Cons:**
- Single fault potential: Although a rare occurrence, the failure of the communications link (the '3rd wire') could cause a general power system failure.
 - Complexity is greater.
 - More expensive.
 - Not practical to match with supplies from other vendors or series.
 - The current share bus (the 3rd wire) may require external noise reduction components. System noise can interfere with the power system's behavior.

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Zero Wire Current Sharing:

This is a simple and reliable method of current sharing. Circuitry in the power supply measures its own output current and ‘programs’ the output voltage up or down. As the load to a supply increases, its output voltage decreases linearly.

In a two-supply system, for example, the supply with the higher output voltage will conduct first. Once its voltage is programmed down to a point at which its voltage is the same as the other supply, they will both conduct current evenly. Individual supplies do not ‘know’ the existence of any other supply sharing the load current. They only react to the percentage of full load being drawn from them. Remote sensing should be utilized to maximize load regulation.

- Pros:**
- Good load balancing.
 - Inexpensive.
 - Reliable.
 - Best fault tolerance.
 - Excellent scalability.
 - Multiple sources possible.
 - Remote sensing possible.
 - No adjustments required.

- Cons:**
- Voltage regulation +/-2%.
 - Could be perceived as lower tech.

Please contact Switching Power for additional information regarding the methods of sharing for power and redundancy. We would like to participate in your process, helping to make certain the power system is optimized.