INDUSTRIES, INCORPORATED



# PARALLEL OPERATION OF DC POWER MODULES

## Overview:

This application note provides a brief summary of the reason for the paralleling power modules and offers some general guidelines to help accomplish the task.

## Common Reasons for Paralleling Power Modules:

- To obtain increased power capacity to provide redundancy or "fail safe" capabilities
- Physical design requirements, such as limited height or space restrictions
- Thermal Design Considerations
- Simplified procurement procedures by reducing the number of different power modules used in a design.

## Cautions Concerning Parallel Operation:

Because of the many different power topologies and regulation methods used in today's power converters, it should never be assumed that modules may be paralleled. Even using same model number units from a common manufacturer does not insure that the units may be connected together. Due to variances in the manufacturing process and inherent differences in component tolerances, each power module's output will be slightly different. This typically can result in one unit providing a majority of the current in a shared application, defeating the purpose of the units being paralleled.

In general, units that have a fixed, non-adjusted output without remote sense or other "feedback" terminals are poor choices for use in parallel configurations. Taking into consideration the above factors it is obvious that modules with different output voltages should not be connected in parallel configurations. Even new low voltage converters, where outputs are only tenths of a volt different should never be paralleled, as such operation would invariably lead to reduced product life and possible damage to the circuits being powered.

Many manufacturer's build units capable of being used in parallel configurations. If a units specifications or datasheet do not refer to parallel operations it is always best to contact the manufacturer to verify the modules suitability for the desired application.

Finally, always consider the primary reason for which the parallel combination is intended. If the main consideration is increased power it is best not to run the units at their full rating. This helps insure no single unit will go into a current limit condition and helps to compensate for any additional power losses encountered in the parallel network. Some manufacturers recommend designing to 80% of available power where $P_{unit}$ x $N_{units}$ x 0.8 = $P_{total}$. So if we were to parallel 4 units each rated for 50 Watts, 50 x 4 x 0.8 = 160.

When designing for redundancy the goal is to insure sufficient power is always available. If we have an application requiring 100 Watts of power then the most direct way to provide redundancy is to connect 2 100 Watt converters in parallel, so that if one should fail the 2$^{nd}$ will continue to provide the needed power.

## Methods Used To Parallel DC Power Modules:

One of the most common methods of paralleling power modules is the use of an 'or'ing diode on each unit (Refer to figure 1). By using power modules with adjustable outputs, it is possible to 'Balance' the current sharing of the units. By taking a 'differential' voltage measurement at the anodes of the 'or'ing diodes current will be shared equally the closer the differential voltage is to zero. The obvious advantage to the circuit in figure 1 is that each device output is isolated from the output rail. Should a module incur a low output voltage failure, it's 'or'ing diode will become reversed biased and prevent the failure from affecting the bus voltage. This is the esstential feature in a redundant power configuration. Another advantage to using 'or'ing diodes is the minimum number of external components required to parallel devices.

Disadvantages include the additional power loss in the diodes and dissipating the heat generated in the diodes. Simple power calculations show a diode with a 0.6V forward drop supporting 2A of current will dissipate 1.2 Watts of power. These losses can be significant in low power applications and should always be factored in to design considerations.

The ‘or’ing method of paralleling power modules can also be accomplished utilizing mechanical relays or fets, though each of these methods require additional components to support the different devices. Several semiconductor manufacturers now offer load share controllers to facilitate parallel power configurations. These devices generally depend upon the power module having remote sense terminals or some means of accessing the converters compensation network. Each controller monitors it’s associated converters output current and shares a connection with the other controllers, which allow them to provide current balancing reference signals to each converter. Depending on the controller and level of voltage bus protection, desired implementations using load share controllers can become quite detailed. Refer to manufacturers data sheets to determine the appropriate controller for your application.

Most manufacturers who produce power converters designed to support parallel operation do so utilizing one of the following methods.

## Slope compensation:

Basically, slope compensation converters rely upon voltage feedback and internal current sense to develop an optimized power ‘window’. Increased current demand will cause a lowering of the ouput voltage which is turn lowers the current. Each converter in the parallel configuration then is able to ‘self’ regulate and provide equal amounts of power to the load. While slope compensation converters are capable of very good load sharing, characteristics care must be used in placement of the converters. Lead lengths of traces or wire should be kept equal as differences in impedance of as little as 20 milliohms can have a significant impact on load sharing characteristics.

## Forced Current Sharing:

Perhaps the most reliable method used to parallel modules is known as forced current share. In this method each converter has an external parallel connector (or P-terminal) which connects to it’s internal regulation circuitry. By connecting units Parallel links a ‘summed’ compensation signal is applied to each unit, forcing them to share the applied load. When using units that utilized forced current sharing refer to manufacturer’s data for proper methods of shielding the interconnecting load so stray voltages are not injected into the unit. Also check if there is a maximum impedance the parallel connector cannot exceed, this will sometimes be listed as a fan-out or maximum units that may be connected.

## Summary:

We have given a brief review of reasons to parallel DC converters, touched upon some of the drawbacks involved in such installations and looked at some of the more common methods used to accomplish parallel operation of power modules. Our intention is to provide some quick reference points for the design engineer to keep in mind during initial system development. Always check with the manufacturers application representative to insure the power module you are considering is compatible with your implementation.

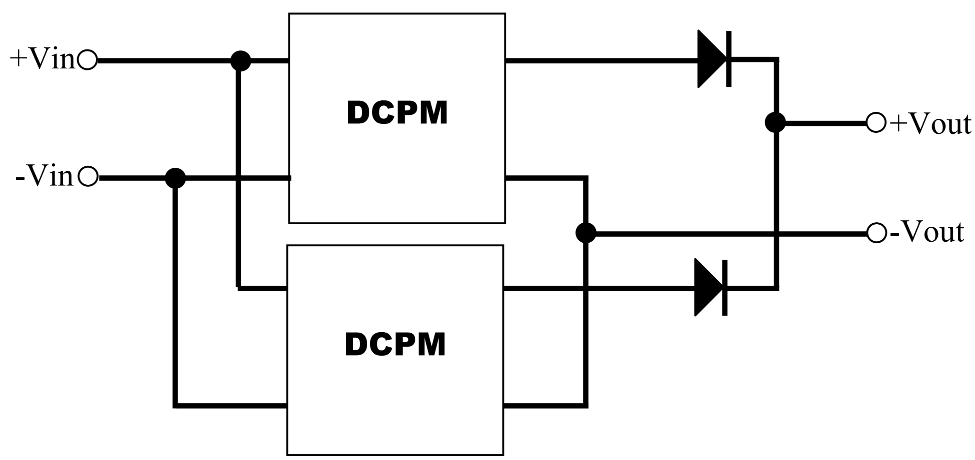


**Figure 1. General configuration of how to parallel two DC Power Modules using 'or'ing method.**