Active ORing Solutions in Redundant Power System Architectures

In its simplest form, an ORing device is a diode that protects the system against an input power source fault condition. A diode ORing device allows current to flow in one direction only, thus isolating the fault from the redundant bus, allowing the system to keep running off the remaining redundant power source(s). New active ORing solutions combining a high-speed ORing MOSFET controller and a very low on-state resistance MOSFET in a high-density thermally enhanced package feature very low on-resistance and fast dynamic response, eliminating the drawbacks of previous diode and MOSFET Oring solutions.

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A basic redundant power architecture that might be used in high-end systems like servers and telecomms and communications infrastructure equipment essentially comprises two or more power sources driving a load. ORing solutions are required to protect the redundant bus and the system in the event that one input power source fails. Redundant power architectures are used on a variety of different bus voltages, depending on the type of end system, typically including low voltage 5, 3.3, 2.5 and <1V, intermediate bus voltages of 9.6 and 12V, and medium voltage -48 and 48V.

Diodes are effective protection devices that will disconnect an input power source short circuit virtually instantaneously. Nevertheless, a diode in an ORing application spends most of its time in forward conduction mode, all the while dissipating power and heat due to the high forward voltage (VF), and creating an undesirable requirement for significant thermal management overhead and increased board space to be allocated.

In the past, system power levels and demands on improved density were lower and, in many cases, standard ORing diodes were tolerable from a performance perspective. Conventional solutions are no longer acceptable for today's high-end systems.

Active ORing solutions drastically reduce power losses and size

An active ORing solution is the combination of a Power MOSFET and a controller IC. The MOSFET has an on-state resistance characteristic, $R_{DS(on)}$, that when multiplied by the square of the current through the device, creates power loss in the MOSFET. This can be substantially lower than the power loss of a schottky diode for the equivalent current. In fact, active ORing solutions typically show a 10x reduction in power loss versus diodes.

However, active ORing does have trade-offs. A MOSFET, when it is turned on, allows current to flow in either direction through its channel. If an input power source fails due to a short circuit, a large reverse current will be induced and will be allowed to flow through the MOSFET as long as its gate is enhanced. If the redundant bus is exposed to an input short circuit for a prolonged period of time the bus voltage will discharge, thus bringing down the system. Because of this, it is essential that the active ORing solution be very accurate and capable of extremely fast detection of reverse current fault conditions. Once the fault has been detected, the controller is required to turn off the MOSFET as fast as possible, and thus, in turn, isolate the input fault from the redundant bus and prevent any further reverse current.

The controller IC senses information across

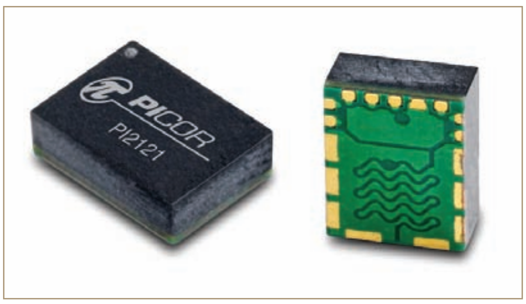

Figure 1: **Full function active ORing solution of 5 x 7 x 2mm thermally enhanced LGA**

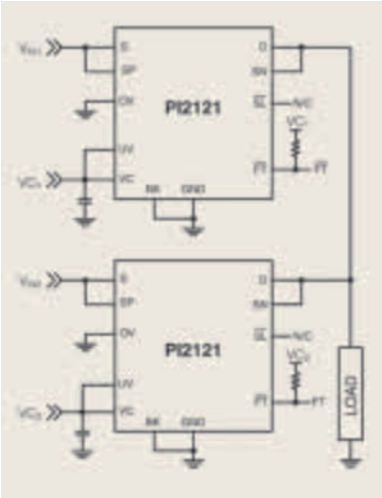

Figure 2: Typical application of PI2121 high-side active Oring

the MOSFET to determine the magnitude and polarity of current flow through it. The most critical parameter is the reverse current threshold, that when exceeded, provides an indication of an input power source failure. It is very important that the reverse current threshold have tight accuracy to provide consistent and fast detection of a fault, and the response time to the fault needs to be extremely fast to limit the amount of reverse current and potential voltage droop on the redundant bus. The speed of an active ORing solution is critical as it determines the magnitude and duration of reverse currents. In some of today's low impedance power architectures, this can make the challenges even more significant. Higher peak reverse currents can require larger MOSFETs to be used to prevent reliability concerns, which add cost and increase real estate.

To summarise, an active ORing solution must deliver the following attributes: (1) accuracy with respect to the reverse current threshold across the MOSFET, (2) fast response time from detection of reverse current, (3) high efficiency resulting in very low power dissipation and lack of dependence on thermal management overhead, (4) small size and (5) ease of use.

Benchmark active ORing solutions

A line of full-function active ORing solutions (Cool-ORing Series) from Picor Corporation (a subsidary of Vicor Corp.) combines a high-speed ORing MOSFET controller and a very low on-state resistance MOSFET in a high-density thermally enhanced land-grid-array (LGA) package. These solutions achieve as low as 1.5mΩ typical on-state resistance while enabling up to 24A of continuous load current over a wide range of operating temperature. The LGA package (5 x 7mm) is thermally enhanced (see Figure 1) and can be used in low voltage, high side (Figure 2) active ORing applications. Picor's Cool-ORing solutions offer over 50% board space savings versus conventional active ORing solutions. They enable extremely low power loss (Figure 3) with fast dynamic response, as fast as 160ns, to fault conditions, critical for high availability systems. A master/slave feature allows the paralleling of devices for high-current active ORing requirements.

These devices provide very high efficiency and low power loss during steady-state operation, while achieving high-speed turn-off of the internal MOSFET during an input power source fault condition that induces reverse current flow through the MOSFET. The PI2121 is an 8V, 24A solution suitable for ≤5V bus applications, the PI2123 is a 15V, 15A solution suitable for ≤9.6V bus applications and the PI2125 is a 30V, 12A solution suitable for ≤12V bus applications. The

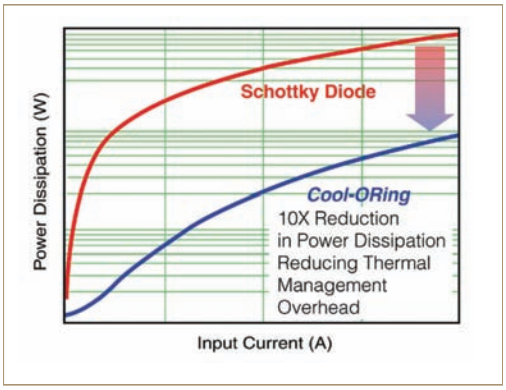

Figure 3: Power dissipation comparison between Cool-ORing solution versus industry standard Schottky diode solution

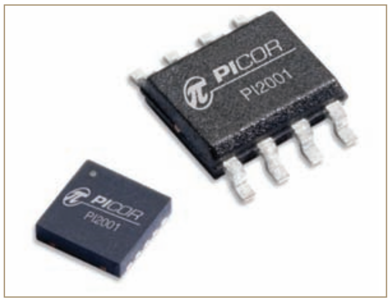

Figure 4: Universal active ORing controllers in industry standard packages (10-lead 3 x 3mm TDFN and 8-lead SOIC)

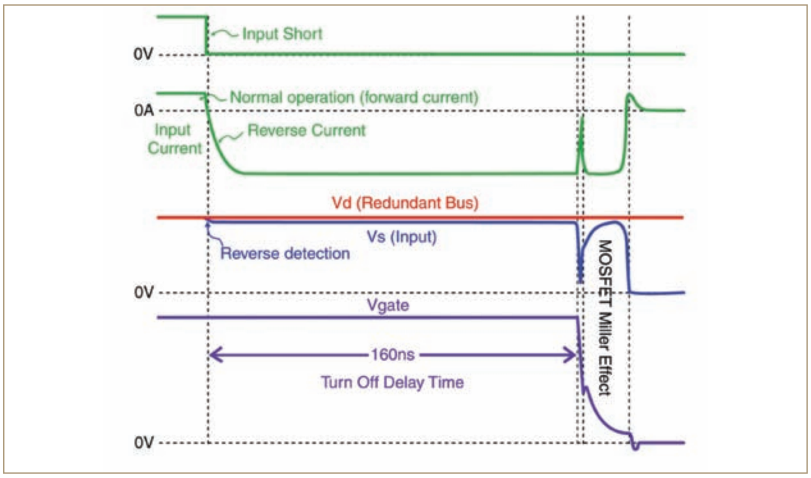

Figure 5: ypical dynamic response of PI2001 to an input power source short circuit fault condition

typical on-state resistances are 1.5, 3 and 5.5mΩ respectively for the PI2121, PI2123 and PI2125.

Cool-ORing solutions are also available as stand-alone controllers that are capable of driving external industry standard N-channel MOSFETs (Figure 4) and are functionally similar to the full-function integrated solutions. The controller enables an extremely low power loss solution with fast dynamic response to fault conditions (Figure 5), critical for high availability systems.

Picor's PI2003 controller is specifically optimised for use in -48V redundant power architectures, and is suitable for systems requiring operation during input voltage transients up to 100V for 100ms. The low quiescent current of the PI2003 enables simple low-loss biasing directly from the -48V rail.

Combining active ORing with a load disconnect feature

There are a variety of end systems employing redundant power architectures that require protection, not only against input power source failures, but also from output load fault conditions. For end systems requiring the performance and protection of active ORing while demanding protection against output load fault conditions, a new solution is required.

The Cool-ORing family also includes solutions that incorporate a load-disconnect feature. The PI2122 full-function solution integrates a high-speed controller with back-to-back configured MOSFETs and the PI2002 is a discrete controller for use with industry standard MOSFETs. The PI2122 is a 7V, 12A solution with an effective 6mΩ typical on-state resistance enabling very high efficiency. The PI2122 solution works as an active ORing solution, but also senses for excessive forward current that would be indicative of an output load fault condition. If the forward over-current threshold is exceeded, then the back-to-back MOSFETs will be turned off. In addition, this device will turn off the MOSFETs in the event of an over-temperature, over-voltage and under-voltage condition. Figure 7 shows some typical applications using the Cool-ORing solutions with the load disconnect feature.

Figure 6: Typical applications of PI2001 high-side active ORing (left) and PI2003 low-side active ORing (right)

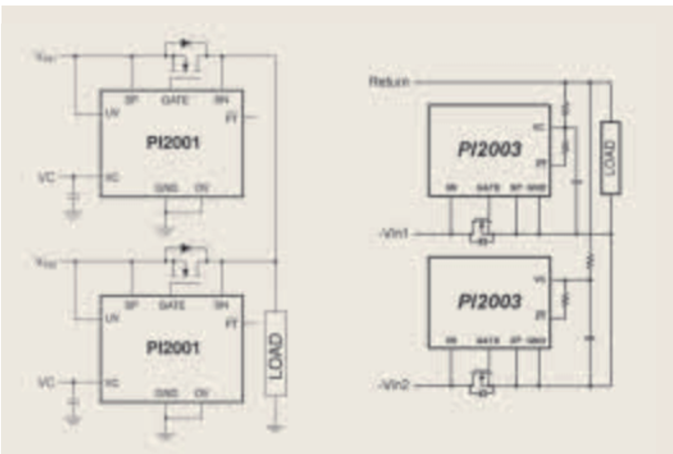

Figure 7: Typical applications: high-side active ORing with load disconnect