Current Sharing with Power Supplies

Improving Wireless Power Transmission Capabilities

Creating Custom Thermal Management Solutions with Phononic

Interview with Mike Bruno – VP & General Manager, Electronics Cooling at Phononic
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Crydom is now offering its improved line of panel mount solid state relays (SSRs). The industry standard panel mount relay has been in production at Crydom for over 40 years and is universally accepted as the global benchmark for panel mount SSRs.

Crydom’s new Generation 4 is an extensive redesign of all their single phase panel mount solid state relays including some of their most popular product series of both AC and DC output models on both the IP00 and IP20 versions. This redesign includes some significant improvements over their previous Generation 3 design, while maintaining the same ratings, general features and basic physical size.

Mechanical improvements include a redesigned housing with anti-rotation wire-capture plastic barriers on both input and output terminals to better capture solid and stranded wires while also allowing the use of ring or fork terminals.

The improved SEMS screw and washer provide significantly higher wire pull out strength and single or dual wire capability.

Thermal performance improvements are achieved with Direct Bond Copper (DBC) technology. DBC insulators are used on the output stage which reduce thermal impedance, therefore lowering output stage temperatures and thus increasing reliability.

Direct output lead frame termination provides significantly greater contact surface area, resulting in lower power dissipation and overall improved reliability of the relays.

Stress and epoxy-free construction reduces weight by 30% which lowers freight costs and results in an environmentally greener product.

The improved touch safe cover provides a positive latch with greater retention strength. And the new K option includes hex standoffs for applications where customers mount the SSR to a PCB or vice versa.

Electrical improvements include regulated control inputs which translates into lower power consumption at higher control voltages.

AC output models have an improved circuit performance utilizing an optical TRIAC coupler to provide input to output isolation and to trigger the output circuit, which provides a simplified and more reliable design with improved EMC noise immunity and the elimination of an internal RC snubber, which reduces the output off state leakage current.

DC output models feature an improved trigger circuit with two optical couplers which provide a significant improvement to the turn off characteristics, translating into higher PWM frequency capabilities and lower power dissipation during switching off.

Crydom’s Generation 4 SSRs maintain the same form, fit and function as the previous generation. They also maintain the same ratings and agency approvals, while featuring major improvements in termination and wiring options, circuit performance and reliability.

State-of-the-art design, materials, and assembly processes make Crydom’s Generation 4 truly the best panel mount relay in the world.

Current Sharing with Power Supplies

Bruce Rose, Applications Engineer, CUI

The need often arises to supply more current to a load than the output current rating of an available power supply. At such times it may be possible to connect two or more supplies in parallel in order to deliver the desired current to the load. Connecting the outputs of multiple power supplies in parallel will not guarantee the load current is shared between the units in an acceptable manner. Many factors contribute to the potential challenges in configuring paralleled power supplies to share load current. Some power supplies are designed with dedicated circuits to be used when placed in parallel to ensure the load current is properly shared. Users should review the documentation from the vendors of such supplies to understand how to properly configure for current sharing. This article will present some basic characteristics of power supplies and discuss the methods of paralleling units which do not have special provisions to enable them to be configured in parallel.
Ideal Voltage Sources

An ideal voltage source maintains a constant voltage and can deliver an unlimited amount of current. This implementation cannot be physically constructed since it requires the voltage source to be able to deliver an infinite amount of power as the load current rises. Although this ideal configuration cannot be physically realized, it is the basis upon which power supplies are designed.

Voltage Source with Current Limit

All real power supplies will have a limit to the amount of current that can be delivered to the load. At some load current the output voltage will collapse to zero volts. The designer of the power supply has the ability to control the behavior of the collapsing output voltage as the load current increases beyond the value for which the power supply is designed. Some possible options for current limit behavior include gradually reducing the output voltage as the current rises above I_{out max} or immediately shutting down the unit when the current reaches I_{out max}. The power supply can be designed to automatically recover from an over-current condition or it can be designed to require an external reset event. Supplies with many different types of current limit behavior can be used in parallel, the user must be aware of how to control the power supply if it does enter into current limit mode.

Voltage Source Output Impedance

Almost all real voltage sources have positive, nonzero output impedance. When a voltage source has positive output impedance the output voltage drops as the load current increases. The change in output voltage with load current is characterized as load regulation in power supply specifications. Typically it is desired to have as little change as possible in output voltage with increasing load current; low voltage droop is achieved with low output impedance. Droop in output voltage with increasing load current is typically employed to enable current sharing between multiple power supplies.

Some power supplies support remote voltage sensing in order to minimize the contributions of layout impedances to Z_{out}. When using remote voltage sensing, degradation of load regulation due to the parasitic impedances is reduced by the action of the feedback loop. A later section will explain why remote voltage sensing may not be desirable in a current sharing application.

Voltage Source Set-Point Error

When constructing real voltage sources there will be an error in the set-point voltage value. This error voltage can be either positive or negative and can be reduced to an acceptable level by controlling manufacturing tolerances or by trimming of the final product. A minimal error in the set-point voltage is advantageous when configuring power supplies to current share.
Paralleling Power Supplies
Perhaps one of the simplest topologies to connect power supplies so as to increase the current delivered to a load is to connect the outputs of the power supplies in parallel. This simple implementation may not work if the load current balance characteristics of the units are such that one of the supplies shuts down due to reaching the maximum current limit before the required current is delivered to the load. If either voltage source reaches the current delivery limit and shuts down then both power supplies may shut down.

An example of how paralleling two power supplies may not work is if the error in initial voltage setting between the supplies is larger than the droop in output voltage at maximum load current. In this example the first power supply provides the entire load current until the unit shuts down and then the second unit attempts to supply the load current but also shuts down due to having reached Imax.

Improving Load Sharing for Paralleled Power Supplies
Current load sharing between power supplies can be enhanced by many different methods. Unfortunately, many of the techniques which enhance load sharing degrade the performance of the units due to degraded load regulation or decreased power conversion efficiency.

Trimming Output Voltage for Enhanced Current Sharing
One method to ensure power supplies connected in parallel share the load current in a reasonable manner is to trim the no-load output voltage difference to be significantly less than the voltage droop at full load. However, it may not be possible or practical to trim the output voltage of the power supplies.

Increasing Voltage Droop for Enhanced Current Sharing
A second method to improve load sharing characteristics between multiple voltage sources is to increase the output voltage droop of each power supply such that the voltage droop at full load is significantly larger than the no-load voltage mismatch between the units. This method has the potential disadvantage that the voltage regulation of the system is degraded due to the intentional voltage droop with load current (load regulation).

Some power supplies have the ability to internally adjust the output voltage droop. This typically is performed by adjusting the internal reference voltage based upon the load current. External droop resistors can be used to increase the voltage droop of a power supply if internal droop adjustment is not available and the resultant decreasing in load regulation is acceptable. The droop resistors are placed in series with the outputs of the power supplies and thus the output current flows through the resistors and causes power dissipation.

The voltage droop in the resistors degrades the voltage regulation and the power dissipated in the resistors degrades the power conversion efficiency of the system. The external droop resistors can be the conductors between the power supply and the load, discrete resistors placed between the supply and the load or a combination of both of these impedances.

Remote Voltage Sense Connections for Paralleled Power Supplies
Remote voltage sense pins should be connected directly to the Vout pins of the power module when external droop resistors are used to implement current sharing. The droop resistors are selected to intentionally degrade the load regulation of the power supplies. Conventional remote voltage sensing (connecting the sense pins close to the load) enhances the load regulation of the power supplies and thus negates the droop intentionally caused by the resistors.
Preventing Back-driving of Paralleled Power Supplies

When the output terminals of multiple power supplies are connected in parallel it is possible one of the units may drive current into the output of other power supplies. In many instances this will be harmless and thus not an issue. However, with some power supplies the current driven into the output of the unit can damage the unit and thus should be prevented. One of the simplest methods to prevent current from being driven into the output of a power supply is to place an isolation diode in series with the output. The output current from the power supplies will flow through the isolation diodes and thus the set-point regulation, load regulation and power conversion efficiency will all be degraded by the use of the diodes.

Summary

While it is possible to parallel almost any power supply, it should be recognized that a number of external components may be required to accomplish the task. The characteristics of the resultant power supply system may be degraded compared to what could be obtained with a single power providing the entire current for the load. Even when knowing the performance of the voltage delivery system may be reduced due to paralleling power supplies, units may be required to be operated in parallel when the current delivery characteristics of a single power supply are not adequate to provide the entire current to the load. For more information on power supplies from CUI, please visit www.cui.com/power.

Figure 7. Paralleled voltage sources (limited output current, output impedance, set-point error, Rdroop, isolation diodes)
As devices become increasingly sophisticated, the means by which they’re powered must be improved upon too.

Wireless power transfer (WPT), or wireless energy transmission, is the transmission of electrical power from a power source to a consuming device without using discrete man-made conductors. By eliminating the use of physical cables, connectors, and electrical plugs, wireless charging provides a number of advantages including simplicity and safety. From smartphones and small electronic devices to industrial equipment, wireless power maintains a reliable transfer of power so that all forms of the device and equipment are charged and ready for use.
Many companies are recognizing the importance of wireless power transmission in order to enhance wireless charging of consumer electronics. Although the consumer wireless power market is still in its infancy, as new design options for smaller and cheaper solutions emerge, the adoption rate for mobile and consumer electronics will significantly increase. The market for wireless charging-enabled devices is expected to be 300 million units by the end of 2016.

How does wireless power transmission work?
Wireless charging is based on the principle of magnetic resonance or inductive power transfer, which is the process of electricity being transferred between two objects through coils. When using a device such as a wireless charger (which still requires a cord), the current from the wall outlet moves through the wire to the wireless charger to create a magnetic field.

This magnetic field creates a current in the coil inside the device, and the coil connects to the battery. The created current charges the battery. In order to support wireless charging, devices must be equipped with the appropriate hardware. Devices without the correct coil will not charge wirelessly. 

### How Qi Wireless Charging Technology Works

- **The phone connects magnetically to an AC-powered charging plate.**
- **The charging plate houses a transmitter coil, and the phone is embedded with a receiver coil.**
- Altering current in the transmitter coil generates a magnetic field, which induces a voltage in the receiver coil to charge the phone.
Researchers from Osaka University and the University of Tokyo have announced the discovery of a new magnet, which is capable of controlling Dirac fermions with zero mass.

It is expected this discovery will lead to a brand new field of study — strong correlated quantum transport of Dirac electrons — as well as major innovation in the area of super high-speed spintronics, which is the foundation for high-speed and energy-saving electronics.
This discovery came about following the successful creation of individual, high-quality EuMnBi₂ crystals—a layered compound which is thought to have both properties of Dirac fermions and magnets—using flux growth in a high vacuum.

What’s interesting about this material is that its architecture features two-dimensional layers of bismuth with Dirac electrons and europium with magnetic properties. To verify the correlation between Dirac fermions and the magnetic state, the team measured its electric resistance in a strong magnetic field; it recorded approximately 30–60 Tesla.

To reveal its magnetic state, the researchers conducted magnetic scattering experiments using synchrotron x-rays. They found that electric resistance changed depending on the magnetic order of europium. Additionally, it was found that when a magnetic field was applied perpendicularly to the 2D Bi layers and the direction of magnetic moment was rotated 90 degrees, the conductivity perpendicular to the layers was suppressed by 10% and the Dirac fermions were confined within each layer. This latter point is of particular importance—by confining the Dirac electrons in the 2D layer of Bi, the group observed a bulk half-integer quantum Hall effect (in which the value of the Hall resistance becomes discrete) in a bulk magnet of Dirac fermions for the first time ever.

Due to its remarkable effectiveness, should this material prove scalable, it is expected to significantly advance the capabilities of high-speed and energy-saving electronics, as these technologies rely on the principles of spintronics, in which electron spin is manipulated to produce a desired outcome.

To learn more, read the full research report, entitled ‘Quantum Hall effect in a bulk antiferromagnet EuMnBi₂ with magnetically confined two-dimensional Dirac fermions’.
Creating Custom Thermal Management Solutions with Phononic

Interview with Mike Bruno, VP and GM, Electronics Cooling at Phononic

For many designs, finding an application-specific solution is out of reach, whether because of budget or time constraints. Phononic, a solid state thermal management solutions company, is changing how companies are approaching modern cooling and heating solutions. By taking a customer-centric approach to designing thermal management solutions, Phononic brings innovative designs to life with a product offering customized to fit specific needs. EEWeb spoke with Phononic’s Mike Bruno, Vice President and General Manager of Electronics Cooling, about how Phononic creates a strong customer relationship while exploring new and exciting technology.
Tell us about your background and how you came to Phononic.

My educational background is in electrical engineering. I had worked with other semiconductor companies for twenty years prior to coming to Phononic, working in sales, marketing and business development. I was with NXP Semiconductors in a business development role for their Emerging Businesses and Advanced Research and Development, bringing innovation closer to the customer more quickly. It may sound a little strange to work on business development for research and development groups, but it was really about driving customer-centric innovation. That passion for innovative business development is what I brought to Phononic two years ago. Phononic was founded in 2009 as a material science company and we’re very focused on thermoelectric technology and the associated materials. As the company progressed, we saw the opportunity to do things a little differently by bringing advanced semiconductor manufacturing processes and techniques to the material science we were already developing. From there, we were able to bring unique devices to the market. Over the past seven years, the company has grown substantially. We have more than doubled our work space since I have been here and began commercializing products in 2014.

What type of products do you offer customers?

Phononic is a thermal solutions company and at the core of those thermal solutions is our thermoelectric device technology. As a thermal solution provider, we’ve chosen not to make a standard product. We go to market by engaging customers at the system level, understanding the challenges they’re being faced with. From there, we design and develop thermal solutions unique to each customer. This includes designing and developing a thermoelectric device or heat pump that matches their system. What we’ve seen in the marketplace is many of the companies who have made thermoelectrics for years, tend to produce a standard product catalog where customers can go online, buy the devices that they think will work for them and then try to fit the devices into their application. In terms of manufacturing designs and capabilities, Phononic has the ability to go from concept to a device in about 6-8 weeks. The devices we create for customers are high performance, application specific, that meet the form, fit and function of their design. Beyond our devices, the true value we bring lies in our full systems and electronic design teams, who bring the sub-assembly and electronic controls to the application, ultimately designing a system to each customer’s specifications.

Are your products custom made?

In the electronic world, custom tends to imply huge NREs, and long design cycles and lead times. So, I tend to shy away from the word “custom.” Phononic uses the term “application specific” because at the root of it, our designs are created for each customer’s application. Phononic is built on the fact that we make these designs with a quick turnaround without blowing the budget. It is usually a very minimum investment by customers depending on the OEM and the customer. Every application is different in the heat load of the system and the airflow for removing excess heat. We’re finding that being flexible and matching devices and assemblies to support these differences is very welcome in the marketplace.

Is there a market that is your target area?

Phononic is a global company and does not segment geographically in terms of our go-to market. Our approach is really based on the end segmentation. The current target segments for my business is in Datacom and Telecom, more specifically the fiber optic and optical laser markets. We also focus on High Performance Computing and IT as well as specialty electronic cooling, which can be anything from the device level to box level cooling such as RF amplifier cooling or enclosures for digital outdoor displays. Another interesting market area for Phononic is industrial and consumer chillers, which are typically water or liquid chillers. There is a lot of activity in the consumer beverage markets with beer, wine or soda dispensers.

As the company progressed, we saw the opportunity to do things a little differently by bringing advanced semiconductor manufacturing processes and techniques to the material science we were already developing.
INDUSTRY INTERVIEW
Power Developer

About 10-15 years ago the business of liquid cooling datacenters was a targeted business opportunity, but it cost more money to cool the datacenters than it did to actually power the data centers. Is that still the case and is Phononic actively pursuing datacenters or are they pursuing you?

I can’t speak to what the datacenter cost configuration is versus setup and cooling, but I can tell you Phononic’s strategy is not trying to take datacenter water cooling head on. Rather, we act as an adjunct more at the system or device level. For example, if a customer has a hot component within a rack mounted box that, under high performance conditions, may have difficulty with a heat load that needs to be dissipated into a chill aisle or where it can be cooled by the building cooling infrastructure, that’s where Phononic steps in and can help transfer the heat out of the box. Outside of the data center, we also provide solutions for electronic device and computing cooling, specifically workstations, high-performance computing, servers and gaming. When the traditional thermal solutions are hitting their limits, we can provide a high performance alternative.

What are the challenges Phononic faces today?

One challenge lies in the perception that thermoelectric or solid state thermal devices do not work and they are unreliable. That’s been a significant barrier for Phononic to overcome. There has been an education process we have gone through as a company to show people what is possible, which takes time. We are making progress in this area but it does take time to change perceptions. I think technologically, once people understand the devices we make are manufactured in a very similar manner as most other semiconductor devices, by leveraging the latest and greatest equipment and processes to build devices in a reliable, high volume way we tend to overcome the perception barriers. Understanding what is possible using this technology and the fact that Phononic has proprietary techniques that we use to create devices and systems that don’t always have to be on, allows us to address the legacy concerns of power consumption or power overhead associated with thermoelectric devices. It doesn’t have to be detrimental. Phononic brings a new understanding of how customers can deploy and utilize this type of technology.

You mentioned reliability. How is the reliability of your technology better than the status quo?

We manufacture device-level products and put them through extensive reliability testing and qualification requirements. We treat these like any other semiconductor device. We do reliability testing and stressing that allows us to produce thermoelectric devices that are very consistent in their performance and long-term reliability.

What will we see from Phononic in the next five years? Any new products coming soon?

You are going to see Phononic disrupting the traditional approach of thermal management and thermal system design. We plan to take on challenges where legacy solutions or no solutions have previously existed. This is possible with the devices and system capability we have. We internally have the capability to make devices ranging from 1 x 2 mm less than 1mm high to devices that are super heat pumps and compressor replacements that run in the kilowatt range of heating and cooling capacity. Solid state solutions are poised to disrupt current solutions.

When the traditional thermal solutions are hitting their limits, we can provide a high performance alternative.

We introduced a CPU cooler last year in an attempt to see how the market would react to an actively cooled CPU cooler. It was something we did as a market test, knowing that it was a very challenging environment for thermal performance. After receiving feedback on the CPU cooler, we went back to the drawing board and will be launching a second version of the CPU cooler at the E3 Gaming Conference in Los Angeles this June. The new unit is a high performance, active/passive CPU cooler that is in a small form factor. Our benchmark test on this version looks outstanding. We took our underlying technology and applied it in a way that meets performance standards in power consumption, noise levels and heat-pumping capacity.

To summarize, Phononic is a thermal solution company that has an innovative approach to bringing devices, subassemblies and overall solutions to the market. We like to use the term around here that “we’re not your father’s thermoelectric company.” We do things very differently by taking a customer-centric approach in designing and developing solutions that are meaningful for our customers.