WHITE PAPER

How to Manage Heat in Modular, COTS Enclosures

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The term SWaP-C – size, weight, power and cooling – is a now ubiquitous term used to describe the thermal challenges of housing electronics. Today's enclosures are viewed as a much more integral part of the overall system — not just a means to keep all the components protected and in place.

Every design element must be analyzed to see how it can positively contribute to the system's operation and protection. And as components have shrunk, embedded systems have made their way into more mobile applications. Systems need to withstand more intense vibration, shock and EMI parameters and still function effectively. All of this affects the ruggedization of enclosures.

Another critical area where designers look to optimize the enclosure is heat dissipation. Just as shrinking electronics have made it possible for systems to be used in more compact environments, the number and density of the actual components have increased dramatically. More power is needed to run the system; more integration is required to enhance functionality; more shielding is mandated to protect the electronics.

Increasing electronics density and faster data throughput places tremendous amounts of heat into smaller packages, making the demand for proper cooling a priority (see example in Figure 1). And as more systems are designed for mobile use, they are faced with tougher thermal challenges, often having to survive outdoors, where dust and moisture can be an issue.

Figure 1: An example of an enclosure optimized for air ventilation.

So, the electronic enclosure must meet the demands of today's applications in terms of size, weight and power as well as cost. Fortunately, enclosure design has kept pace with changing application demands. This is seen most notably in flexible sizing parameters that enable systems to fit into a wider variety of spaces and keep costs down on small volume applications as well as enclosure design that better mitigates environmental elements, especially heat.

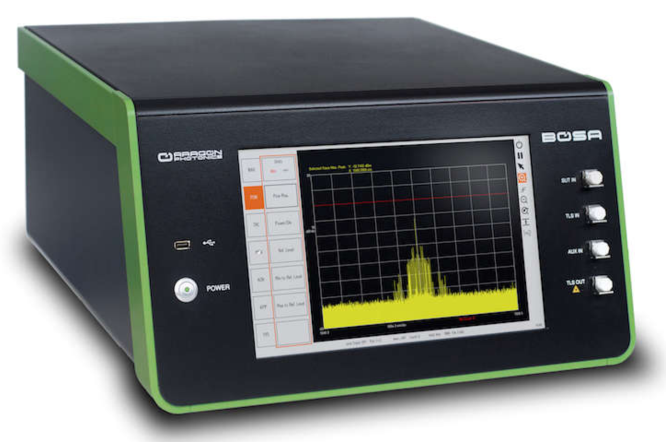
A custom design for cost-effective development

Often, a designer must develop a highly customized design to meet a specific application. Balancing this custom enclosure design with low volumes for prototypes and small projects can be a daunting task. While the goal is to maximize packaging density and performance, the typically high costs, particularly during prototyping, for tooling has prevented the development of cost-effective, custom-tailored enclosures.

And historically, custom enclosure design significantly increases time to market and incurs more risks, with single sourcing and obsolescence of custom parts tops on the list.

But a modular approach to enclosure design provides endless, and cost-effective, design possibilities that account for speed, flexibility, load and a host of other factors critical to system operation. For example, when the enclosure incorporates a standard mechanical board form factor, the board and component standoffs and retainers can be installed before shipment. The engineer gets a tailor-fit case at a low cost and in smaller volumes – customization usually reserved for high volumes, yet without the typical higher development costs.

Figure 2: Tailor-fit case design based on a modular approach (iD-Box 16)



Hot it is not
New cooling technologies, such as liquid or vapor are emerging, but forced air using fans or blowers is still the dominant method. Although tried-and-true, this cooling method is not without its pitfalls that can easily be addressed from the onset of system design. First and foremost is understanding total power dissipation and localized "hot spots" of the embedded system.

There are some simple ways to mitigate these challenges and achieve an optimum enclosure design:

- Employ air baffles or plenums to optimize air flow and eliminate hotspots.
- Minimize airflow restrictions by avoiding radical bends that will impede air movement.
- To optimize incoming air and ensure it is properly directed, keep air leakage in the fan mounting area low.

There are some other common practices in forced air cooling that are beneficial, no matter the custom dimensions of the enclosure. For instance, the air flow cutout on a fan mounting plate should be larger than the inlet diameter of the fan, and objects in the air inlet area should be located more than 1/2” from the fan diameter.

Since fans and blowers are measured in static pressure, a good rule of thumb is to select a model that will perform at greater than 60% of its "free air" maximum, based on estimated static pressure.

As in any system design, certain tradeoffs need to be made when considering cooling parameters. An air filter designed to protect electronics can hinder airflow, yet may be needed to protect certain electronics and noise attenuation, which can conflict with maximizing airflow. When considering EMC, the system may require a honeycomb filter that allows more than 90% airflow at the opening, but is far more expensive than simple perforations.

But options exist, and can easily be integrated into a modular design. For example, variable speed temperature regulated fans can be employed to reduce noise and tachometer output fans can monitor fan fail conditions and increase system operation.

The answers are found not only in hardware options, but in software, too, through thermal simulation, which enables the designer to input all of the variables into a program and verify that the cooling is adequate prior to system fabrication. Better yet, if time and budget allow, building and testing a thermal "mock up" will provide even deeper insights into how well the cooling structure performs.

Smart design for optimum operation

To satisfy the demands of any given environment—and especially as electronics get increasingly smaller—an engineer must consider a myriad of design elements from mechanical constraints, cooling requirements and power distribution, to system monitoring, reliability (MTBF) and maintainability (MTTR).

Addressing any one of these issues can be a difficult design task, but balancing these requirements—while hitting a specified cost target under time-to-market pressures—illustrates the importance of experienced packaging design.

Figure 3: A right-sized enclosure design example (Stylebox-15)

Properly designing an enclosure requires smart thinking at many levels, and heat dissipation is merely one aspect, albeit an important one. Modular dimensions means there is no one-size-fits-all and denser electronics put more pressure on cooling techniques. But by relying on proven design principles that incorporate a whole system view, designers can produce custom-tailored enclosures for modern electronics applications, while keeping design costs to a minimum. ~~