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Inspiring the Evolution of Embedded Design

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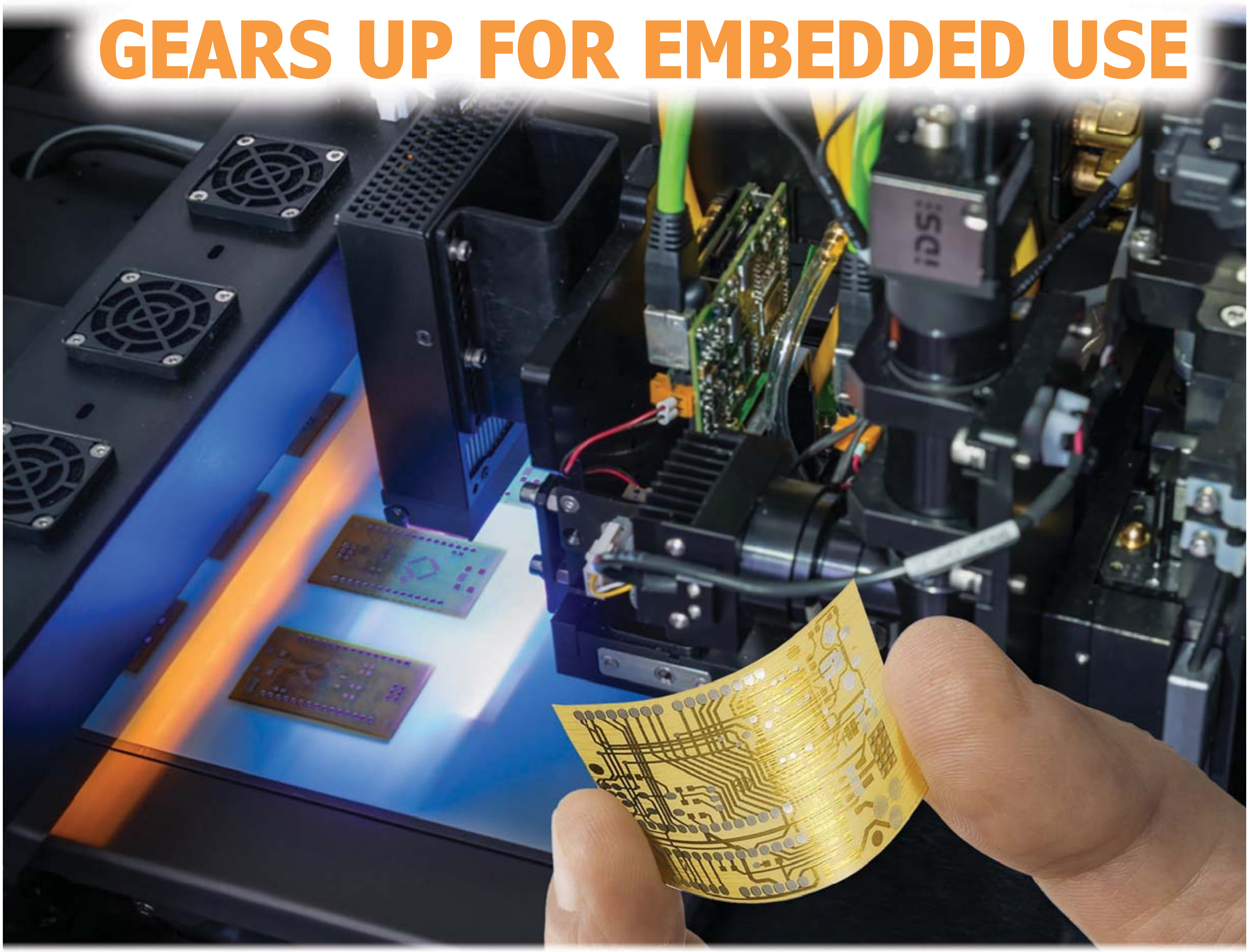

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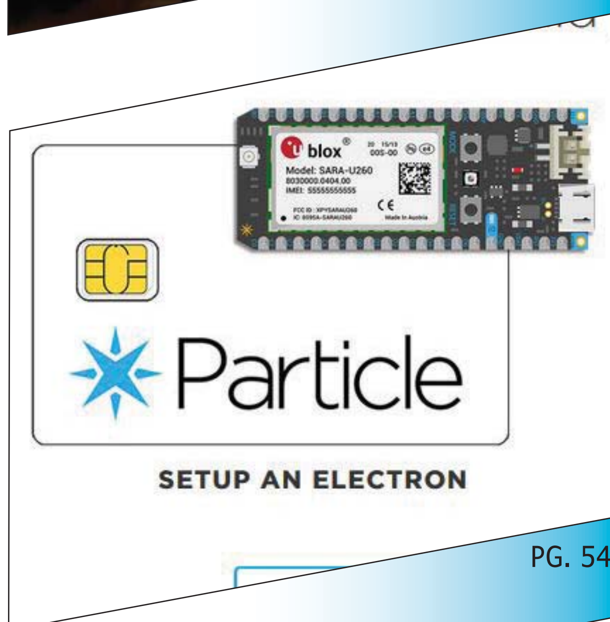

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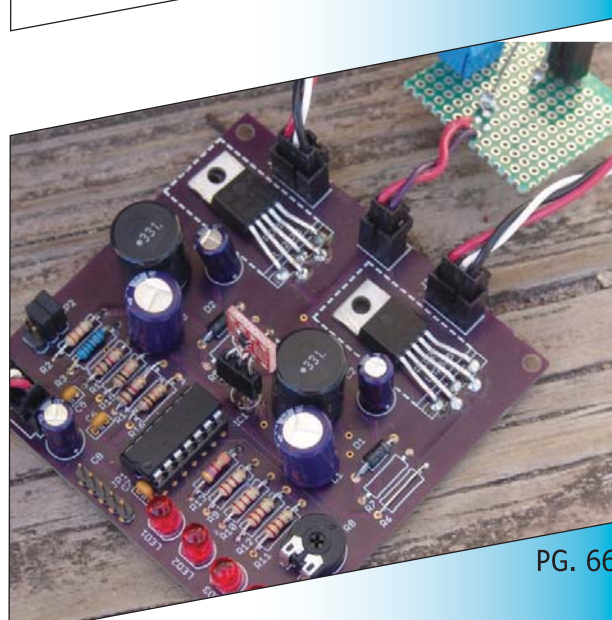
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The Future of Thermal Management

Why Cooling is a Priority in Embedded Systems Design

By
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Properly designing an enclosure requires smart thinking at many levels. And with the increasing density of embedded electronics today, heat dissipation is becoming one of the more critical aspects. The modularity of small form factor (SFF) systems means there is no one-size-fits-all, which further increases the complexity of thermal management in today's embedded computing systems.

But by relying on proven design principles that incorporate a whole system view, it is possible to produce custom-tailored enclosures for modern electronics applications, while keeping design costs to a minimum as well as heat profiles in check.

The term SWaP, which stands for size, weight and power, is morphing—as industry requirements are—to include C. Some may associate the C with costs, but for the purpose of this discussion, C is for cooling. SWaP-C therefore, factors in the thermal challenges of housing electronics. And that's a far more relevant design principle that must be addressed in the complex environment of today's SFF modular embedded systems.

ENVIRONMENTAL CONSIDERATIONS

SFF systems have paved a new path for the use of embedded electronics and as components have shrunk, an increasing number and types of systems have made their way into rugged and mobile applications. Systems need to withstand more intense vibration, shock and EMI parameters and still function effectively.

Originally viewed as merely the means of protecting components and keeping them in place, today's enclosures have become an integral part of the overall system. Every design element is analyzed to see how it can positively contribute to the system's operation and protection. And all of this affects the ruggedization of enclosures.

As more systems are designed for mobile use, thermal challenges become more complex. Computer systems often are required to withstand ongoing—and varying—levels of temperature, vibration, dust and moisture. So, the humble electronic enclosure must not only protect the electronics within, but also meet the demands of today's applications in terms of size, weight and power as well as cooling (SWaP-C). Fortunately, enclosure design has kept pace with these intensifying application demands. (**Figure 1**)

This is most notable in SFF systems, where flexible sizing parameters enable systems to fit into a wider variety of spaces, while keeping costs down on small volume applications as well as enclosure design that better mitigates a number of environmental elements... especially heat.

Embedded system designers are recognizing ways to optimize heat dissipation through the enclosure itself. The reason systems can be used in more compact environments is thanks to shrinking electronics. And this

FIGURE 1
This family of rugged enclosures is designed for fanless embedded computing, capable of handling environmental requirements across multiple platforms from intelligent transportation systems and in-vehicle surveillance to multi-media and building automation systems.

decrease in component size is due to two main factors:

1. More functionality is being integrated into specific components themselves. So, where you used to place a diode as well as a transducer, now you have one integrated component, saving board space. This means more components—but also more heat—can be added to a system.
2. Things have just gotten smaller overall. Think of the gigabytes of memory that can fit on a component less than half the size of a postage stamp versus the seemingly behemoth size of a 1 MB chip from a few years ago. As the overall real estate condenses, this, of course, leaves less space for heat to be dissipated.

As the number and density of components have increased, the system needs more power. Meanwhile, more integration is required to enhance functionality. And more shielding is mandated to protect the electronics. This has put tremendous amounts of heat into these smaller packages, making the demand for proper cooling a priority (**Figure 2**).

FIGURE 2
The increasing complexity and density of electronic circuitry have driven the thermal profile of virtually every embedded computing system.

HEAT MITIGATION TECHNIQUES

Air cooling still dominates enclosure cooling, with conduction cooling running a close second. But newer concepts, such as liquid and vapor, are emerging. This opens different avenues for effective thermal management tailored to specific applications. Regardless of the method, the first—and one of the most important—steps, is to understand total power dissipation as well as identify localized system "hot spots."

Addressed early in the design phase, obstacles can easily be overcome. When using airflow as the cooling method, for example, some common mitigation techniques for enclosure design include:

- Properly direct and optimize incoming air by lowering air leakage in the fan mounting area
- Avoid radical bends that impede air movement, thereby minimizing airflow restrictions
- Air baffles or plenums can optimize air flow and eliminate hotspots

As newer cooling concepts progress, designers are discovering the unique challenges and mitigation techniques for each. But while air-cooled designs still dominate, there are some "rules of thumb" that help lay a clear path for optimum cooling using this method:

- Make sure the air flow cutout on a fan mounting plate is larger than the fan's inlet diameter
- Place objects in the air inlet area more than 1/2" from the fan diameter
- Select fans and blowers that 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, but a modular design can offset some of the costs, such as reducing noise with variable speed temperature regulated fans, monitoring fan fail conditions and increasing system operation via tachometer and locked rotor output fans.

There will be other design elements with less flexibility, such as if a honeycomb filter allowing more than 90% airflow at the opening is needed for EMC, as it is far more expensive than simple perforations. Or if the design requires a certain air filter that protect electronics and offers noise attenuation, but hinders airflow. This may conflict with maximizing airflow, but a modular design can compensate in other areas for a cost-effective, SWAP-C optimized enclosure.

Thermal simulation software can also provide a means to input all program variables and verify adequate system cooling prior to fabrication. For even more insights, building and testing a thermal "mock up" will show how well the cooling structure performs if time and budget allow.

COST-EFFECTIVE CUSTOM

Balancing the need for a highly-customized design to meet a specific application with the typical low volumes for prototypes and small projects can be a daunting task. On the one hand, you look to maximize packaging density and performance. However, the typically high costs—particularly during prototyping—for tooling has thwarted the development of cost-effective, custom-tailored enclosures.

Historically, custom enclosure design has been associated with significantly increased time to market and more risks, with single sourcing and obsolescence of custom parts topping the list of pitfalls. But modular enclosure design provides a multitude of cost-effective possibilities that can meet the speed, flexibility, load and other design factors critical to system operation.

As electronics keep shrinking and heat envelopes creep upward, engineers need a myriad of design elements—from mechanical constraints, cooling requirements and power distribution to system monitoring, reliability (MTBF) and maintainability (MTTR)—to satisfy any given environment's demands. Knowing where to draw on that expertise, and how to best integrate modular concepts into an enclosure design, means designers can develop systems ready for the environmental and technical demands of today's embedded applications.

For detailed article references and additional resources go to: www.circuitcellar.com/article-materials

RESOURCES
Elma Electronic | www.elma.com

Tim Bretz is division manager for Elma's EC&IC division where he's responsible for the Optima Stantron cabinets as well as Elma's component, subrack and cases products. For more than 25 years, Tim has held key sales and product management roles with electronic packaging and enclosures as well as other high-tech companies.

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