Navigating the power delivery demands of next-generation optical modules

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Introduction

Higher data rates do not come with more board space, particularly in high-speed pluggable optical modules. Networks are moving from 400Gbps and 800Gbps toward 1.6Tbps and beyond, while standardized form factors such as quad small form-factor double density and octal small form-factor pluggable remain tightly constrained. As processing power and current requirements grow, power management components must handle heat within the same fixed dimensions.

At the heart of optical modules, digital signal processors (DSPs) convert electrical signals to optical and back again at multi-terabit speeds. Modern DSPs operate at core voltages below 1V while drawing substantial current, and those demands are increasing with each new generation of optical module, making it harder to deliver higher current in less space without adding losses, heat or electromagnetic noise.

One approach – integrating the magnetics directly in the power package – meets multiple design challenges at once. Power modules with integrated magnetics packaging technology use a metallic mold compound as part of the package structure. As a result, the power stage is no longer an afterthought: it has become part of the overall system architecture.

System architecture and power requirements

An optical module brings together a wide range of functions, including DSPs, clock and data recovery circuitry, gearboxes, laser drivers, photodiodes, transimpedance amplifiers, power management and control electronics. Among these, the DSP core supply is often the most demanding rail, with core voltages ranging from 0.4V to 1.0V and currents reaching tens of amperes. These loads are addressed by both high-current (>10A, red circle) and lower-current (2A/4A/6A, blue circle) power modules (**Figure 1**).

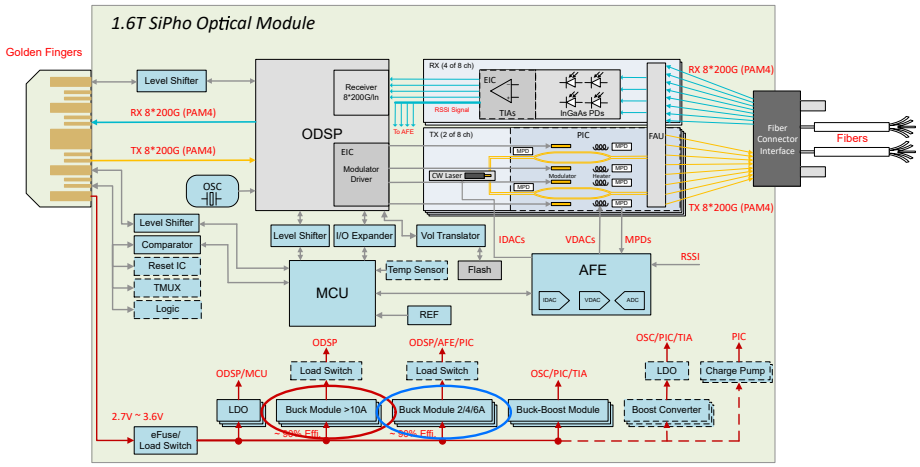


Figure 1. *System block diagram of a 1.6Tbps optical module*

At these levels, a fraction of a watt may be negligible in a larger system, but not inside a compact optical module, which typically has restricted airflow and several heat-generating components packed closely together.

One way to reduce power consumption is to adjust the DSP supply voltage to match the operating conditions. Some systems use a fixed voltage selected during characterization, while others support dynamic voltage scaling (DVS). A DSP may operate at a higher voltage when the signal quality is poor or the temperature is high, and at a lower voltage when conditions allow. The impact can be significant: reducing a 15A core rail from 0.9V to 0.5V lowers the load power by 6W, a substantial reduction when the total power budget of a module is only a few tens of watts.

DVS also means that the regulator may need more than simple voltage conversion. An I^2C interface, for example, allows the system controller to adjust the output voltage or operating mode during operation. Control flexibility alone, however, does not address the design challenge of fitting the power stage within the available space.

Why the inductor needs attention

In a conventional step-down DC/DC converter, the regulator integrated circuit (IC) and power inductor are separate components. The inductor often represents one of the largest elements in the power stage. It takes up board area and adds height, and thus requires careful placement. Furthermore, the connection between the switching node and the inductor also carries fast, high-current waveforms. Managing the resulting losses and electromagnetic interference (EMI) emissions is straightforward on a larger printed circuit board (PCB), but presents a significant challenge inside an optical module.

Inside an optical module, every few square millimeters matter. Multiple supply rails may already be competing for space with high-speed signal routing and sensitive analog circuitry. While integrating the inductor into a power module reduces the external component count, the physical implementation is paramount. Conventional integrated modules may place the inductor beside or above the silicon, which can force compromises in footprint, package height, or heat flow.

Incorporating the magnetics directly into the package improves this integration. Power modules leveraging TI's MagPack™ technology use a metallic mold material as part of the package structure around the semiconductor die and the switching circuitry. For system designers, keeping the switching node integrated inside the package eliminates the need to select and route an external inductor, simplifying the overall power module design.

The 6A **TPSM82866C** module measures 2.3mm by 3mm by 1mm and delivers up to 6A of continuous output current. This complete solution footprint occupies only 6.9mm^2 of PCB space, achieving nearly 1A per 1mm^2 – a 50% solution size reduction compared to previous generations.

To meet the increasing power and thermal demands of optical modules, TI's next-generation 50A power module offers a significant increase in current capability. While the 30A **TPSM8287B30** achieves a density of 450mA/mm^2 and serves a wide range of needs, the **TPSM8287C50** delivers 50A of current (590mA/mm^2) within a similar footprint (**Figure 2**). This enables designers to increase total current delivery by 30% without significantly expanding the power stage's footprint, meeting the current density requirements for 1.6Tbps and beyond.

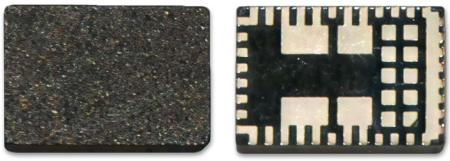


Figure 2. *TI's TPSM8287C50 power module delivers up to 50A of continuous output current in a 4.5mm-by-6.7mm-by-2.85mm footprint*

Small size is useful only if you can remove the heat

Putting more current into a smaller area raises heat density. A compact converter only helps if efficiency and thermal performance keep pace with the reduction in size. Optimizing the magnetic element in an integrated package together with the silicon helps reduce DC and AC losses, and the package itself can help spread heat away from the die.

Both advantages are important in an optical module. DSPs, lasers, and analog circuitry already contribute to the thermal load, and the fixed form factor limits cooling options. If the power stage runs too hot, your options are rather limited: reduce performance, improve the mechanical heat path, or accept less operating margin at elevated temperatures.

A current rating alone does not reveal whether a converter will work well in an optical module. Designers also need to look at efficiency at the actual operating point, temperature rise, and safe operating area (SOA). The question is not simply whether a converter can supply the current, but whether it can do so inside the real thermal environment of the module. **Figure 3** shows the SOA curve for the TI 30A TPSM8287B30 power module with a 5.0V input voltage.

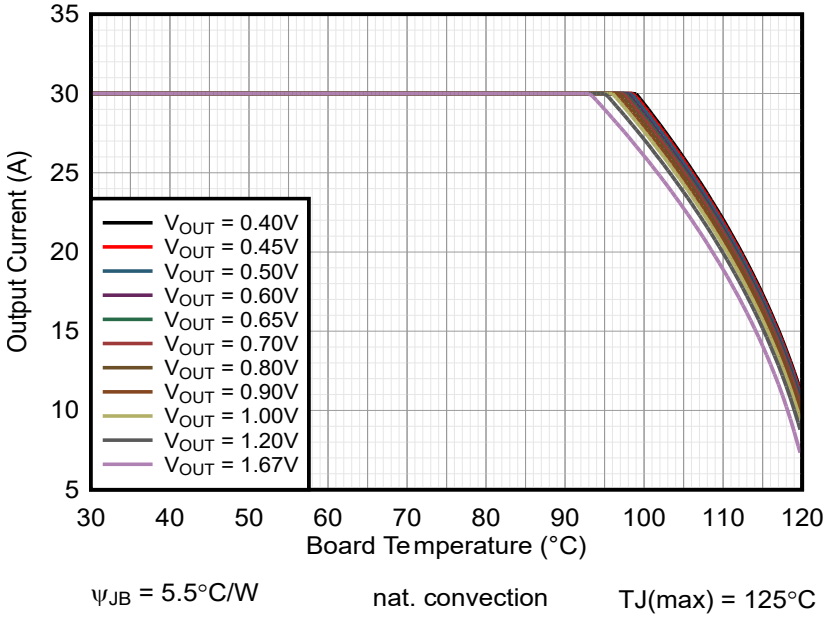


Figure 3. *SOA curve of the TPSM8287B30 power module at V_{IN} = 5.0V*

Considering EMI at the same time

The same density that creates thermal problems also introduces potential EMI concerns. Optical modules place high-current switching power supplies close to sensitive transmit and receive circuitry. In a discrete buck converter, the path between the switching node and the external inductor is a primary source of noise; at high currents and switching frequencies, even a small loop area can generate significant unwanted emissions. While adding shielding, filtering, or moving the power supply farther away from sensitive circuitry can mitigate this, each approach consumes additional board space or component count.

Integrated magnetics packaging addresses these EMI challenges by enclosing the die, inductor and switching node within a single shielded package, drastically reducing the internal switching loop area. **Figure 4** demonstrates that a 6A power module with MagPack technology maintains radiated emission levels well below both CISPR (International Special Committee on Radio Interference) 32 Class A and Class B (3m) limits across the 30MHz to 1GHz range.

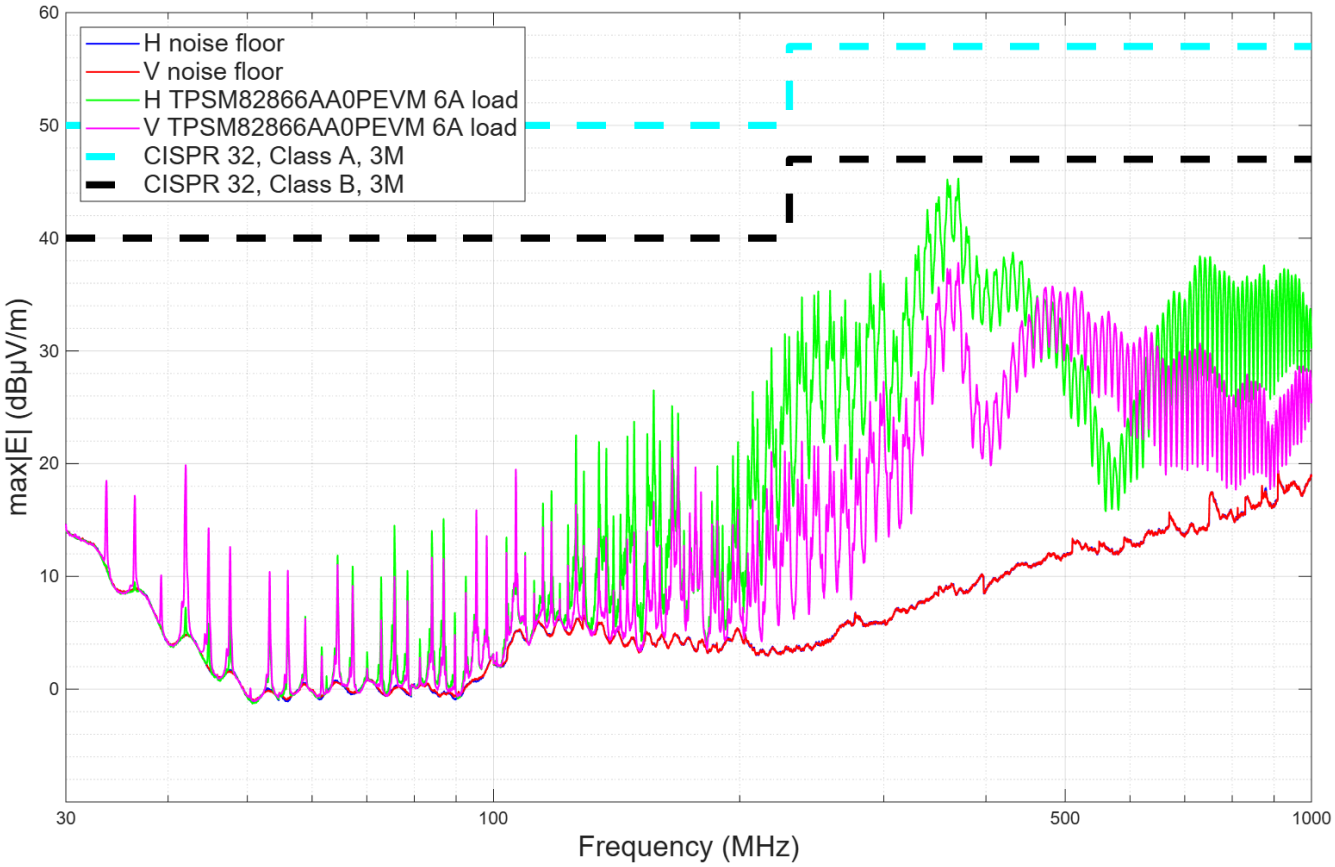


Figure 4. *Radiated EMI performance of a 6A power module with MagPack technology from 30MHz to 1GHz, demonstrating compliance with CISPR32 Class A and Class B limits*

Lower emissions are useful, but the placement flexibility that those emissions create may be just as important. If the regulator can sit closer to the DSP, the high-current path between supply and load becomes shorter, reducing the resistive voltage drop and parasitic impedance. Both factors become increasingly critical for maintaining regulation accuracy as core voltages fall below 1V. EMI affects placement, placement affects power integrity, and both influence how much board area is left for the rest of the module – an example of why design constraints cannot be viewed in isolation.

Conclusion

As optical modules move to higher data rates, power delivery becomes more tightly coupled to the mechanical, thermal and electrical design of the module. Integrated magnetic packaging, such as MagPack technology, helps address these challenges by reducing the footprint of the power stage, shortening switching paths, and improving both thermal and EMI performance.

However, integrated magnetic packaging does not replace the need for thorough design and validation. Current capability, switching frequency, compensation, control strategy, passive components and PCB placement still require careful optimization. Designers must validate the thermal behavior and EMI performance within the final enclosure, rather than relying solely on evaluation board results.

As data rates increase in next-generation optical modules, the primary limiting factor may not be the DSP or the optical components, but rather how much power can be delivered to them, quietly and efficiently, within the available space and thermal budget.

About the author

Thomas Hoffmann is a marketing engineer focused on data center and data communication modules. He has more than 30 years of experience in the electronic industry, spanning hardware design, product definition, and product promotion. Thomas holds a master's degree in electrical engineering from the Bergische Universität Gesamthochschule Wuppertal (BUGH) in Wuppertal, Germany.

Additional resources

- Read the application brief, "**Achieving High Thermal Performance in Compact Buck Power Modules**" and application note, "**Understanding SOA Curves to Operate at High Output Currents and Temperature**."
- These technical articles cover MagPack technology: "**MagPack technology: Four Benefits of New Power Modules That Can Help You Pack More Power in Less Space**" and "**Power Module Package Types and Their Benefits**."
- Watch the videos, "**TI's Power Modules Utilize MagPack Packaging Technology for Improved EMI Performance**" and "**Double the Density: Reshaping Power Modules with MagPack Technology**."

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