

Designing DC-DC Power Systems: Internal Design vs. Off-the-Shelf Modules

1. Introduction

The framework for evaluating point-of-load (POL) converter strategies has evolved dramatically over the past two decades. This includes tradeoffs between internal design and merchant module procurement across cost, risk, and reliability dimensions. With the rise of POL converters like Advanced Energy's LGA80D and LGA110D, the balance has shifted decisively toward configurable solutions.

The LGA110D and LGA80D modules streamline power system development, especially when time-to-market is critical. With current densities of ~ 201 and ~ 162 A/in² respectively, they're ideal for compact, high-performance designs.

These modules offer:

- High efficiency (up to 96%)
- Compact footprints $\sim 1" \times 0.5"$ (LGA80D), ~ 27.5 mm x 12.8 mm (LGA110D)
- Stackable outputs (up to 320 or 440 A)
- PMBus configurability for flexible voltage settings

Table of Contents

1. Introduction
2. Design Process
3. Cost Factors
4. Experience Factors
5. Conclusion
6. Reference

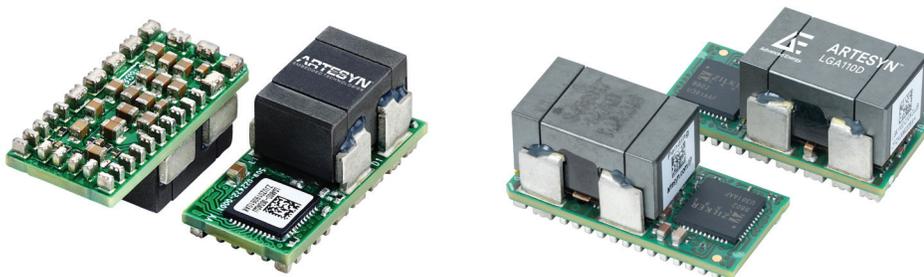


Figure 1. Advanced Energy's LGA80D and LGA110D modules

System designers are faced with four options for their DC-DC converters when determining the power needs for their end product. The options are:

1. Internal design and manufacturer, defined in this paper as internal design
2. Purchasing off-the-shelf modules from merchant power supply companies, defined as buying off the-shelf
3. Subcontracting design (with either internal or external manufacturing)
4. Some combinations of the above three

This paper will focus on the discussion of options 1 and 2. It is intended to aid customers in deciding which of the two best meets their needs. Comparisons of performance, cost, and time-to-market are made. The overriding assumption is that the lowest cost of ownership is the target, although it is recognized that other important factors exist.

For all of the design options listed above, many form factors are available for the converter. If a custom design is required, it can be laid out on the system board or built on a dedicated PCB, like an off-the-shelf solution. Orientation to the system PCB (e.g. a motherboard) can be vertical or horizontal. There are many connection options: single-inline-package (SIP), edge-card, and surface mount, to name just a few.

In terms of electrical topology, either linear or switch-mode technology can be used. While this paper concentrates on switch-mode DC-DC converters, a similar comparison could be made for linear designs.

Many factors should be considered when choosing between internal designs and off-the-shelf purchases. This paper splits these factors into two groups: The first group, referred to as *cost factors*, relates to the raw cost of the converter. The second group, *experience factors*, relates to the experience and

knowledge base of the organization developing the power supply. Of course, the two groups of factors are interrelated, but the cost factors are separated since cost is often of prime concern in decision-making.

2. Design Process

Before examining the technical details, let's briefly review the design process used in two scenarios:

1. Off-the-shelf power supply solutions, typically provided by merchant vendors such as Advanced Energy, and
2. Internal designs, developed by system manufacturers for their own end products.

In the discussion below, the term *customer* refers to the system design team within the company that integrates on-board power into the final product.

2.1 Internal Design Responsibilities

Key responsibilities of customers include:

- Sourcing components and PCBs
- Performance testing of the power supply—usually as part of the system or system board testing
- Assembling and tuning the converter onto the system board
- Ensuring long-term reliability

This approach often extends the design timeline, with engineering prototype development alone taking up to six months. Delays in layout, component sourcing, or debugging can further impact time-to-market.

Design ownership also requires the customer to address questions such as:

- Is there sufficient internal expertise for design, testing, and troubleshooting?

- Can the project timeline accommodate converter development and qualification?
- How will long-term reliability be assured?

2.2 Qualification

Finished products from merchant power supply companies undergo a rigorous development and qualification process to ensure converter reliability and robustness. This includes comprehensive testing across input voltage ranges, output loads, and operating temperatures, along with stress testing to verify design margins. These checks and balances are designed to detect and correct any design or manufacturing issues prior to mass production.

Advanced Energy ensures its board mounted power (BMP) modules meet stringent reliability standards through its qualification process.

Advanced Energy's Reliability Highlights

- Proven expertise in high-density power conversion
- Dedicated reliability engineering (RE) teams
- Qualification tailored to Class I (standard) and Class II (enhanced) products
- Qualification reports include test conditions, results, conclusions, and corrective actions

Core Design Qualification Tests

- Visual and parametric testing: detection of physical and electrical issues
- Mean time between/before failure (MTBF) prediction: based on Telcordia SR-332 and IPC-9592
- Derating analysis: validation of thermal and electrical stress margins
- Life test high-temperature operating bias (HTOB): simulation of extended operational life under high-temperature bias

- Non-operating temperature cycling (NTOC) and power and temperature cycling (PTC): thermal cycling to expose material and performance weaknesses
- Highly accelerated life test (HALT) and software qualification for high-risk and firmware-enabled designs
- Reflow evaluation: assurance of solder joint integrity post-assembly
- Mix-build qualification across multiple sources: assurance of supply chain flexibility
- Qualification reports include conditions, results, and corrective actions shared with design and program teams: transparency and continuous improvement

3. Cost Factors

The total cost of ownership for a DC-DC converter design is typically segmented into three major categories: routine cost, post-design cost, and risk cost. Each plays a critical role in determining the economic viability and operational efficiency of the power solution.

3.1. Routine Cost

Routine cost represents the foundational and predictable expenses incurred during the design, development, and qualification of a DC-DC converter. These costs are applicable whether the converter is internally designed or sourced as an off-the-shelf module. Routine costs are typically estimable early in the project lifecycle and are critical to budgeting and cost analysis.

3.1.1 Bill of Material (BOM) cost

Using the LGA110D module as an example, we analyze the distribution of material costs. It is highly volume-sensitive, meaning that higher production volumes lead to significant cost reductions.

For example, Figure 2 shows that active electrical components (63%), mechanical (16%), and magnetics (11%) dominate the cost structure. The next comparison (Figure 3) illustrates how these costs trend across different production volumes.

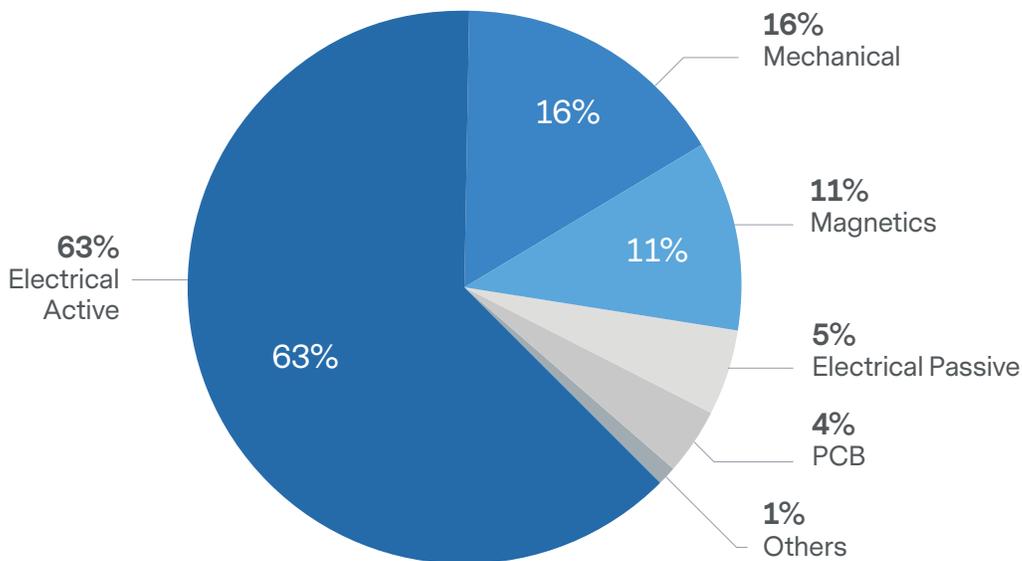


Figure 2. Cost distribution of components for LGA110D

Figure 3 demonstrates the strong correlation between production volume and material cost.

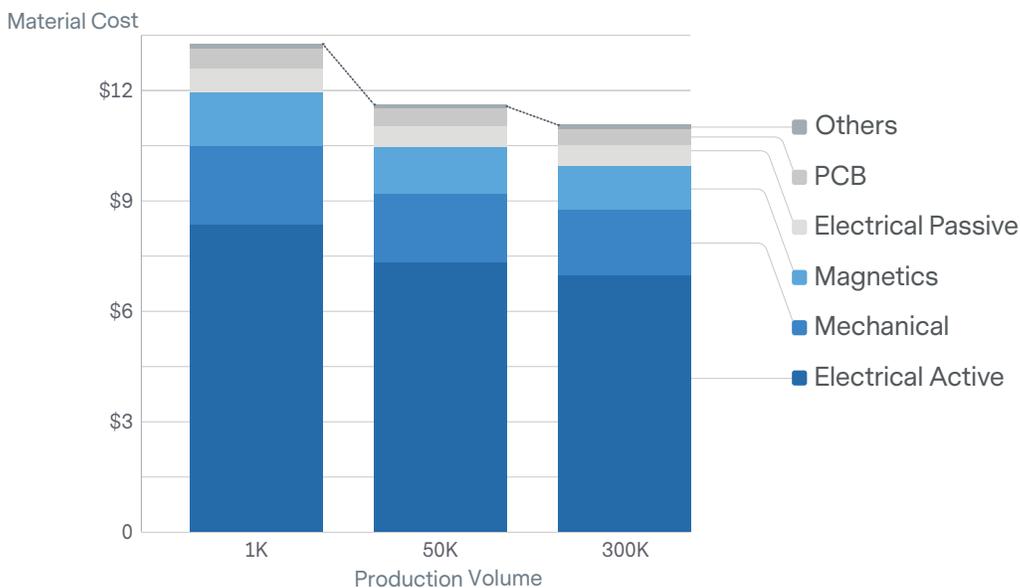


Figure 3. Material cost vs. production volume

- At a production volume of 1000 units, the total material cost is approximately \$13.29 per unit, serving as the baseline.
- At 50,000 units, the cost drops to around \$11.66 per unit, representing a 12.3% reduction from the baseline.
- At the highest volume of 300,000 units, the cost further decreases to about \$11.23 per unit, achieving a 15.5% reduction compared to the initial cost.

This trend shows that higher production volumes reduce per-unit material costs. However, this view focuses only on material cost and does not account for other cost factors.

3.1.2 Engineering Prototype Time and Cost

Engineering prototypes require significant time and resources. In addition, their cost is highly sensitive to production volume; lower volumes lead to higher per-unit costs.

Power supply companies save time and money by creating product lines that share many parts and can be easily adjusted for different needs. Because they serve many customers, they can produce large quantities, which helps lower the cost of each unit.

On the other hand, when a customer designs their own power supply internally, it often starts from scratch. This takes more time, requires more people, and costs more, especially if only a small number of units is needed. Without the advantage of shared designs or bulk production, the cost per unit can be much higher.

3.1.3 Costs of Procurement, Inventory, and Kitting

Internal designs require the sourcing and management of multiple components, which increases complexity and cost. Each additional component

adds to the procurement workload, inventory tracking, and kitting operations. If multiple suppliers are used, the complexity multiplies. Studies show that internal designs can incur 20 to 30 times higher process costs compared to purchasing a single off-the-shelf module.

LGA modules benefit from:

- Vendor economies of scale
- Standardized platforms
- Global availability

This simplifies inventory management and supports second sourcing which ensures continuity in production planning.

3.1.4 Cost of Assembly and Test

There will be minor differences in the system level assembly and test times between a converter module and a discrete design, but these are likely to be negligible, so they are considered insignificant in this analysis.

3.1.5 Cost of Reliability

Reliability testing is more challenging for internal designs, especially when the system architecture is embedded within broader system logic. Testing is often limited to system-level conditions, which may not expose all failure modes. Off-the-shelf modules undergo qualification, including stress testing, environmental screening, and compliance verification. Failures in internal designs can lead to costly diagnosis, repair, and customer dissatisfaction, making reliability a significant cost factor.

3.1.6 Management Cost

Internal design initiatives require comprehensive project management across multiple functional areas. This includes direct coordination with component

suppliers to manage availability and obsolescence risks, continuous engagement with engineering teams to drive design iterations and ensure compliance with technical specifications, and alignment with procurement to optimize sourcing strategies. These activities introduce significant management overhead, including resource allocation, schedule control, and risk mitigation.

3.1.7 Comparison of LGA110D Module and On-Board Discrete Design

LGA110D Module	Buying a Module at 50Kpcs Lifetime Usage	Internal Design at 50Kpcs Lifetime Usage	Internal Design at 300Kpcs Lifetime Usage
Material Cost / Bill of Material (BOM)			
a. Off-the-Shelf BOM	\$20.00	\$0.00	\$0.00
b. Internal Design BOM	\$0.00	\$13.00	\$9.00
Purchase, IQC, Inventory, Kitting	\$0.15	\$2.65	\$1.85
Build, Test, Burn-in Cost	\$0.50	\$4.00	\$4.00
Reliability Cost (Amortized Cost Contribution)	\$0.25	\$2.50	\$1.85
PCB Real-Estate (Based on \$ Value of PCB Usage)	\$0.66	\$4.45	\$4.45
Development Cost	\$50,000	\$500,000	\$500,000
Qualification Cost	\$0.00	\$50,000	\$50,000
Sustaining Cost	\$0.00	\$20,000	\$20,000
Amortized Engineering Cost	\$1.00	\$11.40	\$1.90
Total Cost	\$22.56	\$38.00	\$23.05

Figure 4. Cost analysis: purchase vs. internal design across usage volumes

This example compares a current production module with internal design estimates at different volumes. It highlights how non-material costs, such as development and qualification, make internal design significantly more expensive at low volumes. Only at high volumes ($\geq 300K$) does internal design become more cost competitive. While the estimates are not exact, they highlight the importance of considering all cost factors in design decisions.

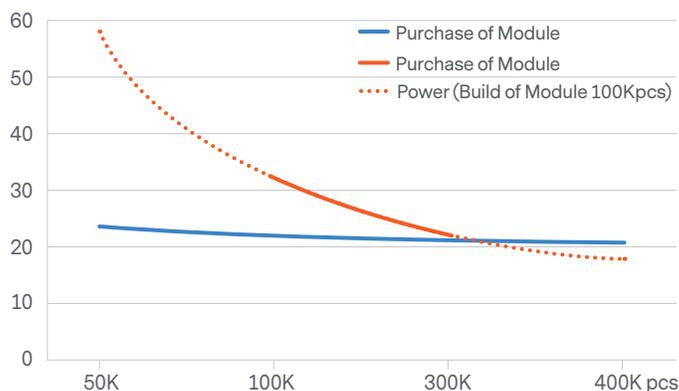


Figure 5. Cost of module vs. discrete design

The graph shows that module purchase costs remain steady across volumes, while internal build and power costs decrease as volume increases. This suggests that cost efficiency depends on production scale, and both options should be assessed based on specific volume and cost considerations.

3.2 Post-Design Cost

Post-design cost captures the downstream expenses that emerge after the converter has been deployed which includes:

- Replacement complexity is particularly involved in field scenarios where system-level boards may need to be swapped out.
- Field repair complexity involves diagnosing and resolving failures, which can be more challenging for internally designed converters due to limited modularity.
- Rework complexity refers to the cost of modifying designs or processes to address issues discovered post-deployment, often requiring PCB changes or updates to system-level integration.
- End-customer dissatisfaction arises when DC-DC converter failures result in system downtime, complex board-level replacements, or post-deployment redesigns that compromise reliability and serviceability.

Post-design costs are influenced by the robustness of the design. More robust designs typically result in lower post-design costs.

3.3 Risk Cost

Risk cost is the most unpredictable and potentially impactful category. It represents the financial exposure associated with development delays, design errors, and integration challenges. These risks can lead to missed market windows, increased engineering cycles, and reduced customer satisfaction. Off-the-shelf solutions typically mitigate risk through extensive pre-qualification and proven design platforms, whereas internal designs may face higher uncertainty due to limited testing coverage and resource constraints.

4. Experience Factors

When a power supply is designed, developed, and produced in a company that specializes only in that product, the strength of years of experience adds to the robustness of the design. That kind of expertise may be hard to put a price on, but it adds value and is worth highlighting in this discussion.

4.1 Design Expertise

Power supply companies have design expertise across various power supply topologies and technologies, positioning them at the forefront of innovation in the industry. Their accumulated knowledge, which is gained through years of experience, adds significant value to each new product.

In addition to design expertise, internal support teams, such as Advanced Engineering, Component Engineering, and Advanced Manufacturing Engineering, contribute specialized knowledge that is often unavailable in internally developed solutions.

4.2 Test and Process

Advanced Energy applies rigorous qualification standards to its power modules, including thermal, electrical, and mechanical stress tests. With dedicated reliability teams and tailored testing for each product class, they ensure consistent performance, qualification and characterization before reaching the end user.

4.3 Component Quality and Sourcing

Deep expertise in selecting components and suppliers that balance cost, performance, and long-term availability ensures consistent product quality and reliable delivery over time.

Buying off-the-shelf offers flexibility because customers can compare products from multiple suppliers. This opens second sourcing possibilities and having alternative suppliers helps maintain a stable supply chain and keeps pricing competitive. In contrast, internal designs often lack this flexibility. Unless the design is modular and allows for interchangeable parts, finding a backup supplier can be difficult, increasing the risk of delays and price increases.

Advanced Energy manages these risks by partnering with trusted vendors and qualifying components for long-term use. Many components have multiple approved sources, giving customers more options and helping avoid shortages. By actively monitoring market trends and preparing backup plans, such as alternate sourcing and inventory strategies, they ensure dependable performance even when there are supply chain issues.

4.4 Prototype Time

Mass-produced power modules offer rapid sample availability for testing. Even if an exact match isn't available, users can quickly adapt to existing platforms to meet specific requirements. In contrast, internal designs often start from scratch, resulting in development cycles that can be two to three times longer. Modular solutions also allow independent PCB changes, providing flexibility during system development.



Figure 6. Evaluation kit for the LGA110D module

This flexibility is further enhanced by the availability of comprehensive demo boards and evaluation kits, such as those supporting the LGA80D and LGA110D modules. These kits provide essential tools for customers during early-stage development, including GUI-based configuration software, real-time telemetry monitoring, programmable output settings, controlled fault testing, and integrated I²C/PMBus communication interfaces. Such features enable users to evaluate module performance, optimize control parameters, and experiment with different configurations without altering the physical design.

5. Conclusion

The decision between designing a DC-DC converter in-house or purchasing an off-the-shelf module hinge on a balance of cost, time, reliability, and complexity. As power demands grow and system requirements become more demanding, the advantages of modular solutions become increasingly compelling.

- Faster time-to-market, thanks to pre-qualified designs, demo boards, and evaluation kits that streamline development and reduce risk
- Higher power density, enabling compact and efficient solutions for high-current applications
- Superior reliability, backed by qualification processes and dedicated reliability engineering teams
- Reduced design complexity, especially critical as transient loads and current densities increase
- Lower total cost of ownership, with economies of scale, simplified procurement, and minimized post-design and risk costs
- Ease of maintenance, avoiding component-level end-of-life (EOL) issues and requalification efforts
- Second sourcing flexibility, ensuring supply chain resilience and competitive pricing

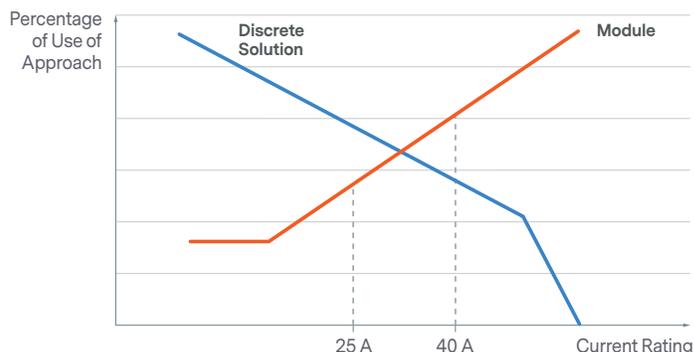


Figure 7. Use of discrete vs. module solutions relative to current demand

Figure 7 shows that as current requirement exceeds 25 A, design priorities shift. Discrete solutions, ideal for lower currents, begin to struggle with heat, layout complexity, and reliability. That's where power modules step in which offers integrated thermal management, simplified design, and scalable performance for demanding applications.

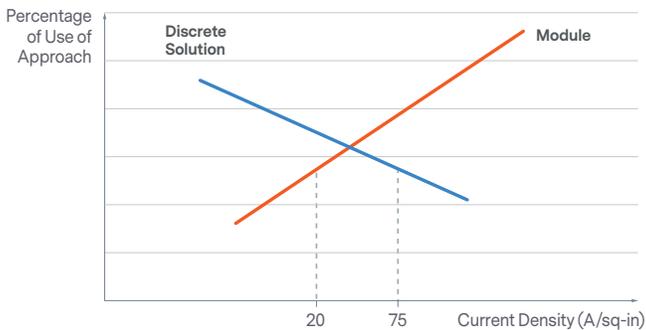


Figure 8. Comparison of discrete solution and module usage based on current density

High current density applications demand compact, thermally efficient power delivery. Power modules are ideal for these environments, offering reliable performance with minimal design effort. Discrete solutions, suitable for densities below 20 A/in², often struggle with thermal and layout challenges at higher levels. For densities above 75 A/in², power modules are preferred due to their superior thermal management and space efficiency.

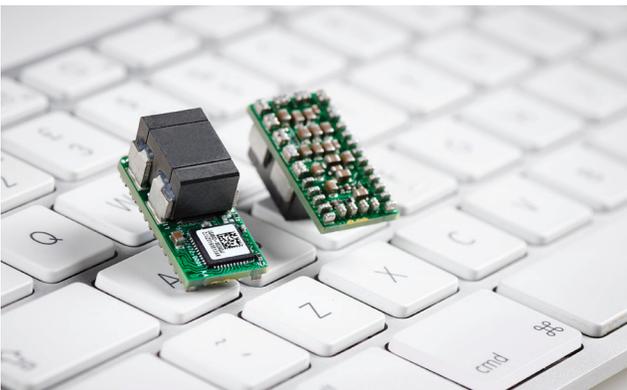


Figure 9. LGA80D module delivering ~162 A/in² current density

As system complexity and power demands rise, modular DC-DC converters offer a compelling solution. They deliver speed, reliability, and scalability, making them ideal for modern applications where performance and time-to-market are critical. While discrete designs still have a place in high-volume or highly customized systems, the trend is clear: modules are the future of high-performance power delivery.

To learn more about Advanced Energy DC-DC BMP module offerings, visit advancedenergy.com.



For international contact information,
visit advancedenergy.com

powersales@aei.com (Sales Support)
productsupport.ep@aei.com (Technical Support)
+1 888 412 7832

ABOUT ADVANCED ENERGY

Advanced Energy (AE) has devoted more than three decades to perfecting power for its global customers. We design and manufacture highly engineered, precision power conversion, measurement and control solutions for mission-critical applications and processes.

Our products enable customer innovation in complex applications for a wide range of industries including semiconductor equipment, industrial, manufacturing, telecommunications, data center computing, and medical. With deep applications know-how and responsive service and support across the globe, we build collaborative partnerships to meet rapid technological developments, propel growth for our customers, and innovate the future of power.

PRECISION | POWER | PERFORMANCE | TRUST

Specifications are subject to change without notice. ©2025 Advanced Energy Industries, Inc. All rights reserved. Advanced Energy® and AE® are U.S. trademarks of Advanced Energy Industries, Inc.