

MODERN DESIGN CONSIDERATIONS FOR AC/DC ISOLATED POWER SUPPLIES BELOW 90W WITHOUT ACTIVE PFC

TECHNICAL WHITE PAPER

Compact isolated AC/DC supplies below 90W demand credible engineering across magnetics, control, compliance, and thermal performance even when active PFC is not required.

AC/DC Isolated Power Supplies Below 90W Without Active PFC

Below 90W, isolated AC/DC power supplies continue to occupy a critical position in adapters, embedded electronics, industrial controls, and connected systems. Although active power factor correction is often omitted in this power range, modern converters are still expected to deliver strong efficiency, low standby power, robust EMI performance, and credible global compliance.

1. Overview

Modern design considerations in compact high-efficiency power adapters, including topology selection, switching behavior, electromagnetic interference (EMI) mitigation, and the adoption of Gallium Nitride (GaN) technology.

Below 90W, isolated AC/DC power supplies continue to play a critical role in power adapters, embedded electronics, industrial controls, and connected systems. Although active power factor correction (PFC) is often omitted at this power level, modern converters are still expected to achieve high efficiency, low standby power consumption, robust EMI performance, and reliable compliance with global regulatory standards.

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Introduction

Modern design considerations, topology choices, switching behavior, EMI control, and the role of GaN in compact high-efficiency adapters.

Below 90W, isolated AC/DC power supplies continue to occupy a critical position in adapters, embedded electronics, industrial controls, and connected systems. Although active power factor correction is often omitted in this power range, modern converters are still expected to deliver strong efficiency, low standby power, robust EMI performance, and credible global compliance.

Regulatory and Efficiency Landscape

Even when active PFC is not explicitly required, low-power offline converters operate within a far more demanding regulatory environment than in the past. Global efficiency frameworks such as DOE Level VI, EU Ecodesign requirements, and regional codes of conduct have pushed designers toward extremely low no-load power consumption and high average efficiency across practical load conditions. As a result, architecture selection must account for efficiency constraints from the earliest stages of the design process, since allowable losses in the controller, transformer, rectification stage, and auxiliary bias circuitry are now significantly smaller than they once were.

This shift has also changed how technical credibility is evaluated in the market. A modern power solution is expected to demonstrate not only regulatory compliance but also engineering discipline in addressing real-world operating conditions. These include standby performance, thermal margin under high-line input, conducted EMI behavior, and consistent regulation across wide load variation. In practice, a sub-90 W design without active PFC can still represent a highly optimized and sophisticated implementation and should not be mistaken for a legacy low-complexity converter.

Topology Evolution and Selection

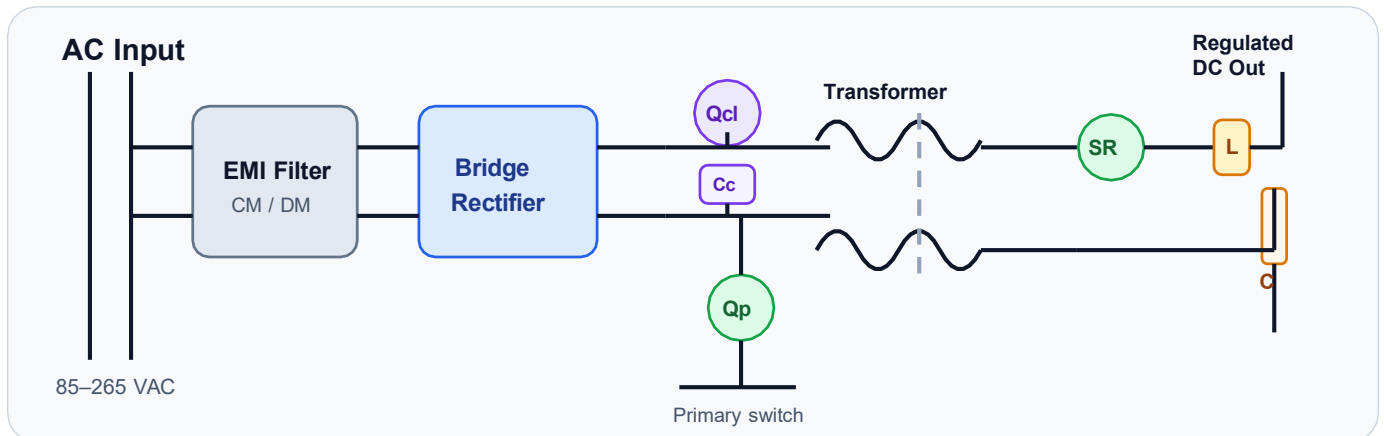
The flyback converter remains the dominant isolated topology below 90 W because it combines transformer isolation, architectural simplicity, and favorable cost efficiency within a single-stage power architecture. However, the modern flyback converter differs substantially from its earlier hard-switched implementations. Conventional designs imposed higher switching stress, dissipated leakage energy inefficiently, and struggled to achieve the efficiency levels demanded by contemporary regulatory and thermal constraints.

For higher-performance applications, the Active Clamp Flyback (ACF) topology has emerged as a preferred solution because it recovers leakage energy while enabling soft-switching operation. This reduces switching losses, lowers stress on the primary switch, and supports higher operating frequencies with improved overall efficiency. Quasi-resonant (QR) flyback converters also remain highly relevant where designers seek a balanced compromise between performance, complexity, and cost. In these implementations, valley switching can significantly reduce turn-on losses without the additional circuitry and control complexity associated with a full active-clamp architecture.

FIGURE

Representative Active Clamp Flyback Topology

Simplified primary and secondary arrangement illustrating bridge rectification, active clamp network, transformer isolation, synchronous rectification, and output filtering.



Switching Behavior and Waveforms

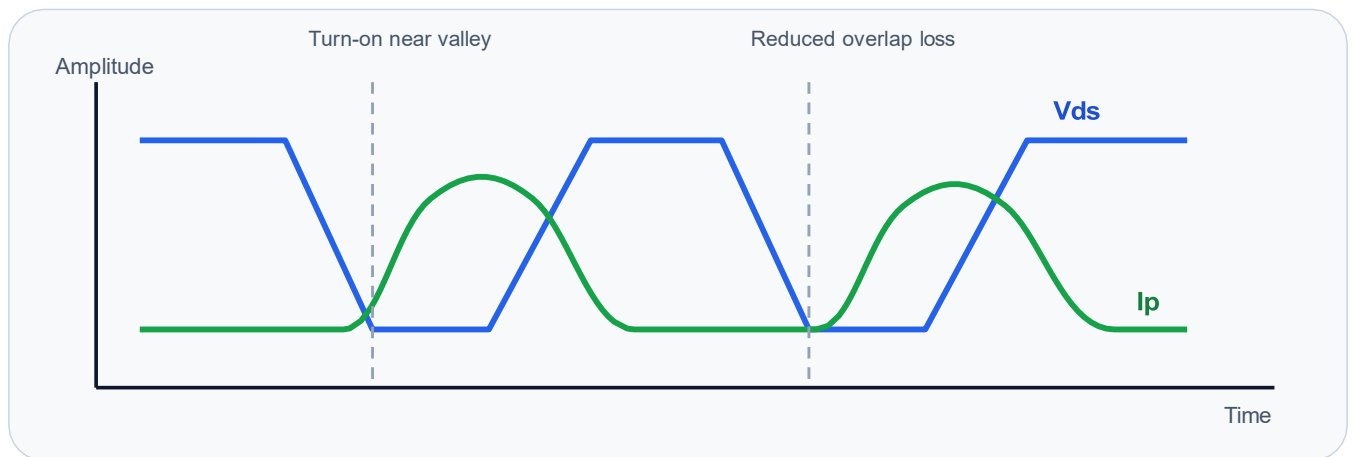
The most significant distinction between legacy and modern offline converters is often found in their switching behavior. Hard-switched systems incur substantial losses whenever voltage and current overlap during turn-on and turn-off transitions. In contrast, ACF and QR topologies are designed to minimize this overlap by controlling the switching instant so that the primary transistor turns on when the drain voltage is near its minimum. This soft-switching behavior forms a practical foundation for the efficiency improvements achieved in many contemporary converter designs.

Waveform quality influences far more than efficiency alone. Reduced switching stress lowers device heating, simplifies EMI mitigation, and contributes to long-term reliability. As a result, switching waveforms are not merely laboratory observations; they represent one of the clearest technical indicators of a mature and well-optimized power architecture.

FIGURE

Indicative Zero-Voltage Switching Behavior

Drain-to-source voltage falls before the primary switch current rises, illustrating the reduction of turn-on loss under soft-switching conditions.



Adoption of Wide Bandgap Semiconductors

Gallium Nitride (GaN) has emerged as one of the defining enablers of modern compact AC/DC power design. Compared with conventional silicon MOSFETs, GaN devices offer faster switching transitions and significantly lower switching losses, enabling higher-frequency operation with improved efficiency. Higher switching frequency, in turn, permits reductions in transformer size, stored magnetic energy, and overall converter volume while maintaining strong thermal and electrical performance. From a market perspective, the significance of GaN lies not only in improved efficiency metrics, but also in the architectural advantages that these devices make possible.

In sub-90W applications, GaN adoption is particularly compelling because its advantages align closely with market demands for smaller adapters, improved thermal behavior, and higher energy efficiency without requiring large or complex magnetic structures. Although silicon-based solutions remain viable in cost-sensitive segments, GaN-enabled flyback platforms increasingly define the benchmark for premium compactness and high-efficiency performance.

Electromagnetic Interference Considerations

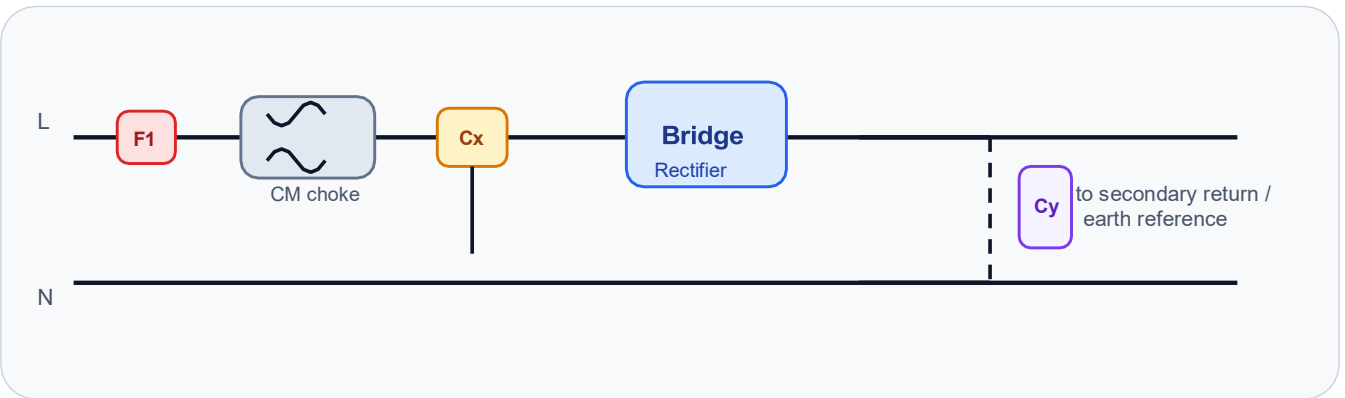
As switching frequencies increase and transition edges become faster, EMI becomes progressively more difficult to manage. In many practical products, EMI performance serves as a defining indicator of engineering maturity because it reflects the combined effectiveness of topology selection, PCB layout, grounding strategy, parasitic management, and filter implementation. A converter that achieves high efficiency but struggles to satisfy compliance requirements does not constitute a robust product platform.

Effective EMI mitigation begins with minimization of high di/dt current loops and careful separation between noisy and sensitive circuit regions. Shielded transformers, common-mode chokes, X and Y capacitors, and controlled drain-node geometry are commonly employed to suppress conducted and radiated emissions. In more advanced implementations, spread-spectrum frequency modulation can reduce peak spectral energy, improving compliance margins without requiring disproportionately large passive filtering components.

FIGURE

Simplified Conducted EMI Input Filter

Representative arrangement showing fuse protection, common-mode choke, X capacitor, bridge rectifier, and Y capacitor return path for a low-power offline front end.



Thermal Management and Power Density

Greater power density is one of the clearest commercial advantages of modern converter design, but it also increases thermal concentration that must be managed carefully. Reliable operation depends on maintaining acceptable semiconductor junction temperatures not only under nominal conditions, but also during high-line operation, elevated ambient temperatures, and restricted airflow. Thermal credibility is established through conservative design margin, effective heat spreading, reduced parasitic loss, and practical awareness of enclosure constraints.

Designers increasingly rely on higher-frequency operation, integrated power stages, advanced thermal interface materials, and optimized PCB copper distribution to control localized hot spots. Planar magnetics may also contribute in compact platforms by improving manufacturing consistency and enabling flatter thermal conduction paths. The most effective thermal solutions are often among the least visible aspects of a power product, yet they strongly influence field reliability, operational lifetime, and long-term brand trust.

Output Requirements and Application Trends

The output requirements for low-power AC/DC supplies have become increasingly dynamic with the widespread adoption of USB-C Power Delivery (PD) and other programmable power ecosystems. Although fixed-output adapters remain important, many contemporary applications now require multiple negotiated voltage levels, fast transient response, and stable regulation under abrupt load variations. These demands have expanded the importance of control-loop design and increased the need for accurate secondary-side regulation.

For manufacturers and system integrators, this trend means that power-supply quality is judged not only by efficiency at a single headline operating point, but also by behavior during realistic application transients. Transient response speed, overshoot control, load regulation, and compatibility with downstream electronics all contribute to perceived product quality and to the credibility of the underlying power architecture.

Safety and Isolation

Safety remains a foundational requirement in every offline converter, regardless of power level. Isolation is not merely a regulatory obligation; it is essential for protecting users, safeguarding connected electronics, and ensuring reliable operation across diverse global installations. Compliance with standards such as IEC 62368-1 and ISO 13485 require careful attention to creepage and clearance distances, insulation systems, transformer construction, and fault-protection strategy.

Robust safety design also strengthens market credibility because it reflects disciplined engineering at both the component and PCB-layout level. When the safety architecture is implemented correctly, it supports long-term reliability, simplifies certification activities, and reduces deployment risk as products scale across regions and application market.

Conclusion

Isolated AC/DC power supplies below 90W have evolved far beyond the simplistic category they once occupied. Even without active PFC, modern designs are expected to achieve high efficiency, ultra-low standby power consumption, compact form factors, and strong regulatory compliance. These capabilities are enabled through advanced flyback topologies, soft-switching techniques, wide-bandgap semiconductors, and improved control of EMI and thermal behavior.

For companies publishing technical knowledge content, the most credible message is not that low-power offline conversion has become easier, but that it has become more sophisticated. The technologies used in today's leading sub-90W solutions reflect a deeper level of engineering integration, where topology selection, switching behavior, regulation strategy, thermal management, EMI performance, and manufacturability are combined into a coherent, reliable, and commercially scalable power platform.