# Market Survey: 1kW Half-Bridge and Full-Bridge LLC Converters

## 1. Introduction to 1kW LLC Converters in Modern Power Systems

The landscape of modern power systems is increasingly defined by the demand for higher efficiency, greater power density, and enhanced reliability. In this context, LLC (Inductor-Inductor-Capacitor) resonant converters have emerged as a preferred topology, particularly for medium to high power applications. Their fundamental principle leverages a resonant tank circuit to achieve Zero Voltage Switching (ZVS) for the primary-side MOSFETs, significantly reducing switching losses and improving overall efficiency.1 This soft-switching capability also contributes to minimizing electromagnetic interference (EMI), a critical consideration in sensitive electronic environments.4 The inherent benefits of the LLC topology make it highly suitable for applications requiring robust and efficient power conversion.

The 1kW power level represents a pivotal segment in power electronics, serving as a critical building block across diverse industries. This power range is essential for telecommunications infrastructure, including the rapidly expanding 5G networks, where compact and highly efficient power supplies are vital for edge computing and base station rectifiers.2 Similarly, data centers rely on 1kW solutions for server power supply units (PSUs) to meet stringent energy efficiency standards and manage thermal loads within confined spaces.4 Industrial power supplies also frequently utilize this power level for various machinery and automation systems, demanding robust and reliable operation. The continuous drive towards reduced energy consumption and smaller form factors underscores the growing importance of optimized 1kW power solutions.

This report provides a focused market survey specifically on Half-bridge and Full-bridge LLC converter topologies operating at or around the 1kW power level. The survey primarily identifies reference designs and evaluation boards from leading semiconductor manufacturers. These offerings are crucial indicators of current technological advancements, as they often represent the cutting edge of commercially viable solutions and serve as blueprints for product development by original equipment manufacturers (OEMs) and system integrators. All data presented in this survey is rigorously supported by official white papers, datasheets, or direct web links from the respective companies, ensuring accuracy and verifiability.

For sophisticated, high-power, and high-efficiency solutions like 1kW LLC converters, major semiconductor manufacturers often adopt a strategy of providing detailed reference designs, application notes, and evaluation kits rather than complete, off-the-shelf power supply units. This approach indicates that the primary audience for these offerings consists of design engineers and system integrators who utilize these blueprints to develop their own final products. The complexity and customization frequently required at this power level mean that a universal, ready-to-use product is less common. This highlights the significant role of semiconductor companies as enablers of power electronics innovation, supplying the foundational technology and design support rather than manufacturing end-user power products in this specific segment. The market for these converters is therefore characterized by the provision of sophisticated components and intellectual property (IP) that facilitate high performance, shifting the focus from module availability to design capability and the supporting component ecosystem.

## 2. Market Overview of 1kW LLC Converter Solutions

The market for 1kW LLC converter solutions is predominantly shaped by leading semiconductor manufacturers who provide advanced reference designs and evaluation platforms. These offerings showcase the latest advancements in power conversion technology, often incorporating cutting-edge components and control strategies.

### Key Manufacturers and Their Offerings

**Texas Instruments (TI)** stands out for its contributions, particularly with digitally controlled reference designs. The **PMP41081** is a 1-kW, 400-V to 12-V half-bridge resonant DC/DC platform. Its primary function is to evaluate the load transient performance of Hybrid-Hysteretic Control (HHC) when paired with an F280039C microcontroller.6 This design is aimed at industrial AC/DC applications and server PSUs, where stable output under dynamic load conditions is paramount. Another significant offering is the

**TIDA-010081**, a compact, high-efficiency AC/DC reference design delivering 1000-W at 54-V DC. This solution integrates a front-end continuous conduction mode (CCM) power factor correction (PFC) stage with a robust LLC DC/DC converter, targeting 5G telecom power and industrial AC/DC supplies.2 A notable feature of the TIDA-010081 is its ability to operate without forced cooling, indicative of its excellent thermal management and high efficiency.2

**Infineon Technologies** maintains a strong market presence, emphasizing digital control and wide-bandgap (WBG) semiconductors. The **REF\_1KW\_PSU\_5G\_SIC** is a 12V/1kW fan-less SiC-based Power Supply Unit (PSU) evaluation board tailored for outdoor 5G Edge Computing.5 It combines a bridgeless totem-pole PFC converter with a half-bridge (HB) LLC converter, leveraging CoolSiC™ MOSFETs and full digital control to achieve high efficiency in a low-profile, fan-less design.5 Infineon also offers a

**1 kW 48 V to 12 V Telecom Quarter-Brick LLC with XDPP1100 digital controller**. This highly efficient (97.3% peak) fixed-frequency LLC converter is designed for 48 V intermediate bus converter applications, featuring high power density (564 W/in³) and the capability to deliver 80 A output current without heatsinks.4 Infineon also provides various LLC resonant mode controller ICs, such as ICE1HS01G-1 and ICE2HS01G, supporting half-bridge and full-bridge topologies.7

**STMicroelectronics** contributes with evaluation tools that demonstrate their capabilities in high-power LLC designs. The **STEVAL-DPSLLCK1** is a 3 kW full-bridge LLC resonant converter evaluation tool, showcasing their digital power control capabilities with an STM32F334 microcontroller.1 While exceeding the 1kW power level, it illustrates ST's expertise in achieving high efficiency (95.3% peak) with ZVS over a wide operating range.1 ST also offers the

**EVLSTNRG-1KW**, a 1 kW SMPS digitally controlled multiphase interleaved converter. It is important to note that this design is based on a half-bridge SAB (“single active bridge”) topology, which is distinct from an LLC resonant converter, though it serves similar applications like EV battery chargers and industrial power supplies.8

While **ON Semiconductor** offers a 10kW LLC design 10 and general application notes on LLC resonant converters 3, the provided research material does not specifically identify a 1kW Half-bridge or Full-bridge LLC converter reference design from them. Similarly,

**Analog Devices (ADI)** demonstrates a broad portfolio in power management ICs and modules, with a focus on digital power technology, robust solutions, and high power density.11 However, no specific 1kW Half-bridge or Full-bridge LLC converter or reference design was found in the provided information.

### General Trends in 1kW LLC Converter Offerings

Several overarching trends characterize the development and offerings in the 1kW LLC converter market:

* **Digital Control Dominance:** There is a clear and pervasive shift towards digital control across nearly all surveyed solutions. Microcontrollers such as STMicroelectronics' STM32F334, Texas Instruments' F280039C, Infineon's XDPP1100, and STMicroelectronics' STNRG388A are central to these designs.1 This digital capability enables advanced control algorithms, such as Hybrid-Hysteretic Control (HHC) for improved load transient response in TI's PMP41081 6, multiphase interleaved operation for balanced power delivery in ST's EVLSTNRG-1KW 9, and adaptive synchronous rectification for enhanced efficiency in ST's STEVAL-DPSLLCK1.1 This evolution from traditional analog control to digital platforms provides greater flexibility, precise control, and robust protection features, which are essential for meeting the stringent performance requirements of modern power systems.
* **Wide Bandgap (WBG) Semiconductor Adoption:** The increasing integration of WBG semiconductors, notably Silicon Carbide (SiC) and Gallium Nitride (GaN), is a significant trend. Infineon's REF\_1KW\_PSU\_5G\_SIC explicitly utilizes CoolSiC™ MOSFETs 5, and the broader discussion around LLC topologies often highlights the benefits of GaN for high-frequency soft-switched applications.13 These materials offer superior switching characteristics, allowing for higher switching frequencies, which in turn leads to smaller magnetic components and higher power density. This adoption directly contributes to achieving higher efficiencies and enables more compact power supply designs.
* **Application-Specific Designs:** Many reference designs are meticulously tailored for specific high-growth applications, reflecting the nuanced demands of various market segments. Examples include solutions optimized for 5G telecom infrastructure, data centers (servers), and industrial power supplies.2 This specialization ensures that the designs meet the unique requirements of these environments, such as high reliability, specific voltage rails, and robust operation in challenging conditions.
* **High Efficiency and Power Density:** A universal objective across all surveyed solutions is to achieve exceptional efficiency and power density. This pursuit often culminates in "fan-less" designs, as seen in TI's TIDA-010081, which operates without forced cooling 2, and Infineon's REF\_1KW\_PSU\_5G\_SIC, explicitly designed to be fan-less.5 The Infineon 1kW quarter-brick converter can deliver substantial output current without heatsinks, further demonstrating robust thermal design and high efficiency.4 Achieving such high efficiencies minimizes heat dissipation, allowing for compact designs that are crucial for space-constrained applications and improving overall system reliability by eliminating mechanical cooling components.

The increasing complexity and performance demands of 1kW LLC converters necessitate the adoption of digital control. Digital control, in turn, unlocks the full potential of wide-bandgap semiconductors like SiC and GaN by enabling precise switching control, facilitating operation at higher frequencies, and optimizing efficiency across varying load conditions. This synergistic relationship between advanced control and advanced materials is a core driver of innovation in this sector. Furthermore, the emphasis on fan-less designs is a direct consequence of achieving very high efficiency. This design choice is critical for applications in harsh environments where dust, moisture, and vibration can compromise fan reliability. It also reduces acoustic noise, improves system longevity by eliminating a mechanical wear component, and simplifies maintenance. This trend indicates a market shift towards optimizing for total cost of ownership and reliability in specific deployment scenarios, moving beyond mere power output.

## 3. Detailed Analysis of 1kW Half-Bridge/Full-Bridge LLC Converter Solutions

The following table provides a detailed tabulation of 1kW Half-bridge or Full-bridge LLC converters identified in the market survey, along with their key specifications and supporting documentation. Following the table, individual product profiles offer a more comprehensive description of each solution.

### Key Specifications of 1kW Half-Bridge/Full-Bridge LLC Converters

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
| Company | Model/Reference Design | Power (kW) | Topology | Input Voltage Range | Output Voltage | Switching Frequency (kHz) | Key Applications | Supporting Documentation Link |
| Texas Instruments | PMP41081 | 1 | Half-Bridge LLC | 340 V to 420 V DC | 12 V DC | Not specified | Industrial AC/DC, Server PSUs, Digital Power Control Evaluation | 6 |
| Texas Instruments | TIDA-010081 | 1 | LLC (AC/DC with PFC) | 85 V AC to 265 V AC (Nominal 230 V AC) | 54 V DC | 35-1000 (Resonant: 100) | Merchant Telecom Rectifiers (5G), Industrial AC/DC | 2 |
| Infineon Technologies | REF\_1KW\_PSU\_5G\_SIC | 1 | Half-Bridge LLC (AC/DC with PFC) | 230 V AC | 12 V DC | Not specified | Outdoor 5G Edge Computing, Telecom Infrastructure, Server PSUs | 5 |
| Infineon Technologies | 1 kW 48 V to 12 V Telecom Quarter-Brick LLC with XDPP1100 | 1 | Full-Bridge LLC | 42 V to 60 V DC | 10 V to 15 V DC | Fixed 310 | 48V Intermediate Bus Converters, Telecom, Datacenters, Servers, Industrial | 4 |
| STMicroelectronics | STEVAL-DPSLLCK1 | 3 (Evaluation Tool) | Full-Bridge LLC | 375 V to 425 V DC | 48 V DC | Max 380 (Startup), Closed Loop 120-250, Resonant 175 | High-Efficiency Power Conversion, Digital Power Supply Control Evaluation | 1 |
| STMicroelectronics | EVLSTNRG-1KW | 1 | Half-Bridge SAB (Not LLC) | 350 V to 420 V DC | 133 V DC | Not specified | EV Battery Chargers, UPS, Digital Industrial Power Supplies | 8 |

### Individual Product Profiles

#### 3.1. Texas Instruments PMP41081

This reference design is a 1-kW, 400-V to 12-V half-bridge resonant DC/DC platform. Its primary objective is to evaluate the load transient performance of Hybrid-Hysteretic Control (HHC) when implemented with an F280039C microcontroller.6 HHC is a sophisticated control method that combines direct frequency control and charge control, incorporating an additional frequency compensation ramp. This combination, along with an inner control loop, significantly improves the load transient response of the LLC stage. This makes the PMP41081 particularly well-suited for demanding industrial AC/DC and server PSU applications that require stable output under dynamic load conditions. Additional features include a monotonic soft-start function, ensuring controlled startup under any load, and a small output voltage ripple, contributing to the overall quality of the power output.6 The input voltage range for this design is 340 V to 420 V DC, with a nominal output of 12 V DC.6 The specific switching frequency is not explicitly stated in the provided documentation.6

#### 3.2. Texas Instruments TIDA-010081

The TIDA-010081 is a compact, high-efficiency AC/DC reference design capable of delivering 1000-W at a 54-V DC output. It achieves a peak efficiency of 95.9% at 230 V AC input.2 The circuit architecture comprises a front-end continuous conduction mode (CCM) power factor correction (PFC) stage, based on the UCC28180 controller, followed by a robust LLC DC/DC converter stage utilizing the UCC256403 controller. Synchronous rectification, managed by the UCC24624, further enhances efficiency.2 A key differentiator of this design is its ability to operate without forced cooling, which underscores its exceptional thermal management and high efficiency. This feature is particularly valuable for applications where fan noise or reliability is a concern. The design targets demanding applications such as 5G telecom rectifiers and industrial AC/DC power supplies, offering low total harmonic distortion (iTHD) and strong load transient performance.2 The input voltage range is wide, from 85 V AC to 265 V AC, with the LLC stage operating across a frequency range of 35 kHz to 1 MHz, and a resonant frequency set at 100 kHz.2

#### 3.3. Infineon REF\_1KW\_PSU\_5G\_SIC

This evaluation board represents a 12V/1kW fan-less SiC-based Power Supply Unit (PSU) specifically designed for outdoor 5G Edge Computing applications. The PSU integrates a front-end AC-DC bridgeless totem-pole PFC converter with a back-end DC-DC isolated half-bridge (HB) LLC converter.5 The strategic use of CoolSiC™ MOSFETs, combined with full digital control for both the PFC and LLC stages, significantly contributes to its high efficiency and enables a fan-less cooling concept. This fan-less capability is crucial for outdoor deployments, where environmental factors like dust and moisture can compromise the reliability of traditional fan-cooled systems, and for low-profile designs where space is at a premium.5 The overall input is 230 V AC, providing a 12 V DC output.5 While Infineon generally emphasizes high-frequency operation with SiC devices 13, the specific switching frequency for this particular product is not detailed in the provided information.5

#### 3.4. Infineon 1 kW 48 V to 12 V Telecom Quarter-Brick LLC with XDPP1100

This is a highly efficient (97.3% peak) 1 kW fixed-frequency LLC quarter-brick converter, meticulously designed for 48 V intermediate bus converter applications. The design features a primary full-bridge utilizing OptiMOS™ 6 80V power MOSFETs and a secondary full-bridge for synchronous rectification with OptiMOS™ 5 25V MOSFETs.4 This configuration, leveraging Infineon's superior power transistors, results in very low losses, enabling high power capability and enhanced efficiency and power density. The converter achieves an impressive power density of 564 W/in³ and can deliver 80 A output current without heatsinks, demonstrating robust thermal performance.4 It incorporates Infineon's XDPP1100 digital power controller, which includes a PMBus interface, offering significant flexibility for efficiency optimization, soft-start implementation, and advanced protection features. The board adheres to the standard DOSA mechanical outline, making it suitable for high-current quarter-brick applications in telecom, datacenters, servers, and other industrial settings.4 The input voltage range is 42–60 V DC, with an output voltage range of 10–15 V DC, and a fixed switching frequency of 310 kHz.4

#### 3.5. STMicroelectronics STEVAL-DPSLLCK1 (Note: 3kW Evaluation Tool)

The STEVAL-DPSLLCK1 is a 3 kW full-bridge LLC resonant converter evaluation tool. While its power rating exceeds the 1kW requirement, it serves as a valuable demonstration of STMicroelectronics' capabilities in high-power LLC designs and digital power control. The converter's primary section is a full-bridge based on MDmesh DM2 Power MOSFETs, optimized for high efficiency.1 The PWM switching frequency is digitally controlled by an STM32F334 microcontroller, allowing for precise output voltage regulation. The design operates at near resonant frequencies to maximize efficiency and achieve Zero Voltage Switching (ZVS) across its entire operating range, contributing to a peak efficiency of 95.3%.1 It incorporates comprehensive protection mechanisms, including undervoltage and overvoltage protection on both input and output, overtemperature protection, and short-circuit protection. Adaptive synchronous rectification and a light-load burst mode further enhance its efficiency across varying load conditions.1 The input DC voltage range is 375 V to 425 V, with a 48 V output. The switching frequency ranges from 120 kHz to 250 kHz in closed-loop operation, with a resonant frequency of 175 kHz and a maximum startup frequency of 380 kHz.1

#### 3.6. STMicroelectronics EVLSTNRG-1KW (Note: Half-Bridge SAB Topology, not LLC)

The EVLSTNRG-1KW is a 1 kW SMPS (Switched-Mode Power Supply) digitally controlled multiphase interleaved converter evaluation board. It utilizes the STNRG388A digital controller.8 It is crucial to note that this design is based on a half-bridge SAB (“single active bridge”) topology, which, while sharing the half-bridge configuration, is fundamentally distinct from an LLC resonant converter. The interleaved topology is a key feature, balancing power across three parallel stages and enabling high efficiency across the entire load range by dynamically activating or deactivating stages based on load demand.9 This modular approach also allows the solution to be scaled up to 3 kW with a 400 V maximum output voltage. The digital core of the STNRG388A facilitates comprehensive monitoring, control, and debugging of the board via a HyperTerminal interface.9 This evaluation board is intended for offline power conversion applications such as EV battery chargers, uninterruptible power supplies (UPS), and digital industrial power supplies.8 The input voltage range is 350 V to 420 V, with an output voltage of 133 V.8 The specific switching frequency for the SAB topology is not explicitly provided in the available documentation.

The distinction between LLC and other half-bridge topologies, such as the Half-Bridge SAB, is important for precise technical evaluation. While the ST EVLSTNRG-1KW meets the 1kW power level and uses a half-bridge, its non-LLC resonant topology means it operates on different principles and offers different performance characteristics compared to true LLC designs. Similarly, the ST STEVAL-DPSLLCK1, while being an LLC converter, is a 3kW evaluation tool, indicating that the "1kW" solutions are often part of a family of designs that can be scaled, offering a broader picture of available technologies. This highlights the importance of precise terminology in power electronics and the need to carefully filter results based on exact user requirements, while also acknowledging solutions that are *close* to the criteria.

## 4. Comparative Insights and Emerging Trends

The market survey reveals several commonalities and distinctions among the identified 1kW LLC and related converter solutions, alongside significant emerging trends that are shaping the future of power electronics.

### Commonalities and Differences Across Surveyed Converters

The **input and output voltage ranges** of the surveyed converters demonstrate a clear segmentation based on their intended system architecture. Solutions like the Texas Instruments PMP41081 and STMicroelectronics EVLSTNRG-1KW operate from a high DC bus (e.g., 340-420V DC), typically following a front-end Power Factor Correction (PFC) stage in AC/DC applications. In contrast, Infineon's 1kW 48V to 12V telecom quarter-brick is designed for a 48V DC input, serving as an intermediate bus converter.4 The output voltages also vary significantly, from 12V (TI PMP41081, Infineon REF\_1KW\_PSU\_5G\_SIC) for server and telecom applications, to 54V (TI TIDA-010081) for 5G telecom rectifiers, and even 133V (ST EVLSTNRG-1KW) for specific industrial or EV charging applications.2 This variety underscores the tailored nature of these solutions for different power delivery requirements.

Regarding **preferred topologies**, the Half-bridge LLC configuration is prevalent for its simplicity and efficiency at the 1kW power level. Full-bridge LLC is also utilized, particularly for higher power levels or when specific control characteristics are desired, as seen in the STMicroelectronics STEVAL-DPSLLCK1.1 The inclusion of the Half-bridge SAB (Single Active Bridge) topology in the STMicroelectronics EVLSTNRG-1KW demonstrates that alternative high-efficiency approaches are also employed for similar power ranges and applications, each offering different design trade-offs, such as modularity and efficiency across a wide load range through interleaving.9

The **switching frequency spectrum** varies among the designs, reflecting different optimization strategies. STMicroelectronics' STEVAL-DPSLLCK1 operates with a closed-loop switching frequency between 120 kHz and 250 kHz, with a resonant frequency of 175 kHz.1 Infineon's 1kW telecom quarter-brick utilizes a fixed switching frequency of 310 kHz for optimal efficiency.4 Texas Instruments' TIDA-010081's LLC stage operates over a wide range from 35 kHz to 1 MHz, with a resonant frequency of 100 kHz.2 Higher switching frequencies generally enable smaller magnetic components, leading to increased power density. However, they also introduce greater switching losses and more significant EMI challenges, which are effectively mitigated by the ZVS capability of LLC converters and advanced digital control techniques.14

### Notable Features and Design Philosophies

**Digital control** stands out as a fundamental enabler for contemporary 1kW LLC converters. The pervasive use of microcontrollers such as STMicroelectronics' STM32, TI's C2000, Infineon's XDPP1100, and STMicroelectronics' STNRG388A signifies a move beyond traditional analog control.1 These digital platforms are central to achieving advanced control algorithms like Hybrid-Hysteretic Control (HHC) for superior load transient response 6, implementing adaptive features such as synchronous rectification and light-load burst mode for efficiency optimization 1, and providing robust protection features. This shift empowers designers with greater flexibility, precision, and diagnostic capabilities.

The impact of **wide-bandgap (WBG) semiconductors** is increasingly evident. The integration of SiC (Silicon Carbide) in Infineon's REF\_1KW\_PSU\_5G\_SIC 5 and the general discussion around GaN (Gallium Nitride) for high-frequency topologies 13 highlight a clear trend. These advanced materials enable higher efficiencies and power densities by reducing switching losses, facilitating higher operating frequencies, and ultimately contributing to the realization of fan-less designs. This push towards WBG devices is crucial for maximizing performance and compactness in power conversion.

The designs also demonstrate a strong focus on **system integration and modularity**. Many reference designs incorporate a complete power chain, including front-end PFC stages (e.g., TI TIDA-010081, Infineon REF\_1KW\_PSU\_5G\_SIC) and auxiliary power supplies.2 This reflects a holistic approach to power system design, providing comprehensive solutions that address multiple aspects of power delivery. The adoption of standardized form factors, such as the quarter-brick (Infineon 1kW telecom quarter-brick), further indicates a move towards high-density, easily integratable modules, simplifying system assembly and scaling.4

The primary **target applications** for these 1kW LLC solutions consistently include telecom infrastructure (especially 5G), data centers (servers), and industrial power supplies.2 These segments share common demands for high reliability, exceptional efficiency, and often compact, robust designs capable of operating in challenging environments. Specific design choices, such as fan-less operation and optimized transient response, are directly driven by the stringent requirements of these demanding market segments.

Manufacturers are increasingly adopting an "ecosystem" approach, offering a comprehensive suite of components and support rather than just isolated reference designs. This includes dedicated controller ICs (e.g., Infineon's ICE series, TI's UCC series, ST's STNRG388A), power MOSFETs (e.g., CoolSiC, OptiMOS, MDmesh), gate drivers (e.g., EiceDRIVER), and sophisticated software development kits (e.g., TI's C2000WARE-DIGITALPOWER-SDK).1 This strategy aims to provide a complete solution stack, from silicon to software, simplifying the development process for designers and accelerating their time-to-market. It signifies that the market for 1kW LLCs is evolving towards integrated design platforms that offer a streamlined path to high-performance power solutions.

While the benefits of high efficiency and compactness are clear, achieving them often involves complex topologies (e.g., multiphase interleaved, totem-pole PFC) and advanced control methods (digital control, HHC). As one document notes, "High switching frequency helps to shrink the size of magnetic components... but it also leads to system complexity".14 This implies that the pursuit of higher performance necessitates increased design complexity, requiring specialized controllers and sophisticated firmware. This explains why manufacturers provide detailed reference designs and extensive application notes: to guide engineers through this complexity. The market is continually pushing for higher performance, but designers must carefully weigh these benefits against the increased development effort and component cost.

## 5. Conclusion

The market for 1kW Half-bridge and Full-bridge LLC converters is dynamic and robust, primarily driven by leading semiconductor manufacturers who provide advanced reference designs and evaluation boards. These offerings are not merely components but comprehensive blueprints that enable system integrators and product developers to create highly efficient and reliable power supplies for demanding applications.

Key findings indicate a clear dominance of digital control, which facilitates advanced control algorithms, adaptive features, and robust protection mechanisms essential for modern power systems. There is also an increasing adoption of wide-bandgap semiconductors, particularly SiC and GaN, which are instrumental in achieving higher efficiencies and greater power densities. This technological shift often culminates in fan-less designs, a critical differentiator for applications in harsh or noise-sensitive environments, enhancing reliability and reducing maintenance. The market is characterized by application-specific optimization, with a strong focus on high-growth segments such as telecommunications infrastructure (especially 5G), data centers (servers), and industrial power supplies.

The synergistic relationship between advanced digital control and wide-bandgap materials is a core driver of innovation, allowing for precise switching and optimized performance. Manufacturers are increasingly offering comprehensive "ecosystems" that include not only core components but also development tools and software, simplifying the design process for their customers. While the pursuit of higher efficiency and power density introduces design complexities, the detailed reference designs and application support provided by these manufacturers help engineers navigate these challenges.

Looking ahead, the evolution of these technologies will likely continue, driven by demands for even higher power density, greater efficiency, and enhanced intelligence in power management. This could include further advancements in predictive maintenance, enhanced fault tolerance through sophisticated digital control, and greater integration of power stages. Ultimately, these 1kW LLC converter solutions serve as critical building blocks for the next generation of energy-efficient and high-performance electronic systems, underpinning the infrastructure of an increasingly electrified world.

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