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Meta title: AI PSU LLC Resonant Planar Transformer Guide: Leakage Reuse, Magnetic Integration, Low Profile | ProMagTech
Meta description: Why AI server power (AI PSU) 48V/12V LLC resonant converters favor the planar transformer: multilayer PCB windings + flat ferrite core, leakage reused as resonant inductor Lr, magnetic integration, low profile, low HF loss. Includes core/winding/electrical comparison tables, applications and FAQ. Figures are public reference values, confirm per project.
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TECHNICAL GUIDE / AI PSU PLANAR TRANSFORMER

AI PSU LLC Resonant Planar Transformer: A Technical Guide

Leakage reused as the resonant inductor, magnetic integration, low profile — why AI compute power chooses the planar transformer

1. Core Conclusion

The 48V→12V core DC-DC in AI server power supplies (AI PSU) widely uses the LLC resonant topology. Above ~500kHz, a conventional wire-wound transformer is limited by skin effect, proximity effect, uncontrolled leakage, poor heat dissipation and bulk, and struggles to meet high-density low-profile demands. The planar transformer (multilayer PCB-etched windings + flat ferrite core) is the better solution; its value reduces to four points:

> **In one line:** 1. Leakage reuse: the planar structure's leakage is controllable and can be reused directly as the LLC resonant inductor Lr, removing the external resonant inductor and raising integration.
>
> 2. Magnetic integration: magnetizing inductance Lm and resonant leakage Lr are integrated together, reducing part count and simplifying the resonant tank.
>
> 3. Low profile, high density: PCB windings plus a flat core are inherently thin with a short Z-axis heat path, fitting brick/OAM low-profile packages.
>
> 4. Production consistency: automated PCB etching gives winding-parameter spread markedly below hand winding, aiding current sharing across paralleled modules.

The sections below cover structure, core and winding schemes, electrical parameter reference ranges, applications and FAQs. All parameters are public-industry or typical engineering reference ranges, to be confirmed per project by topology, power and package — not a product rating commitment.

2. Core Structure Design

A planar transformer assembly typically comprises the core, multilayer PCB windings, insulation and shielding layers, a thermal base and the locating package. Core selection and PCB stack-up are the keys to LLC fitness.

2.1 Core selection (by power)

Table 2-1 Planar core types and LLC fitness (qualitative classification)

Core type	Power range	LLC fitness advantage	Typical AI PSU scene
EE planar core	Small–medium	Easy gap tuning, wide Lm range, fits half-bridge LLC	Single AI-card aux power, edge compute power
PQ flat core	Medium–large	Low profile, symmetric flux, large cooling face, consistent leakage	Main server 48V→12V high-power LLC
Matrix integrated core	Large	Multi-winding flux cancellation, good sharing, integrable resonant inductor	Rack AIDC cluster central supply

(Power bands are qualitative; actual boundaries vary widely with topology, frequency and cooling, and must be confirmed per project.)

Core material is generally a high-frequency ferrite (e.g. PC95/PC96 class, ~200kHz–1MHz) or an ultra-high-frequency material (~1MHz–3MHz). Saturation flux density Bs and high-frequency loss Pcv should follow the chosen grade's vendor datasheet, and be verified under real conditions (waveform, bias, temperature) — see our dedicated article on core-loss vs datasheet deviation.

2.2 PCB winding stack-up (LLC interleaving)

LLC planar transformers commonly use primary-secondary interleaving (P-S-P-S), for three core purposes:

3 purposes of P-S-P-S interleaving

▶ **Raise coupling, control leakage** — Interleaving maximizes primary-secondary coupling so leakage is controllable and precisely reused as the LLC resonant inductor Lr

▶ **Lower inter-layer parasitic capacitance** — Sectioned/fanned windings cut inter-layer capacitance, suppressing LLC high-frequency common-mode noise and resonant spikes

▶ **Improve HF loss** — Copper thickness matched to skin depth (e.g. copper skin depth ~66μm at 1MHz) avoids high-frequency eddy loss

Copper thickness is typically 1oz (~35μm) to 3oz (~105μm), chosen by the skin depth at the operating frequency; the low-voltage high-current secondary often parallels multiple PCB layers to lower DC resistance and share current.

2.3 Magnetic integration

With a built-in distributed magnetic shunt/gap, the magnetizing inductance Lm and resonant leakage Lr can be integrated into one part, removing the separate resonant inductor. Gap precision directly affects batch parameter consistency and current sharing across paralleled modules, making it a key process control point in planar-transformer production.

3. Key Electrical Parameters (public reference ranges)

The table summarizes common electrical parameter reference ranges for AI PSU LLC planar transformers. Note: all values are public-industry or typical engineering reference ranges, used for selection direction only, and do not represent any specific product's rating; final values must be confirmed per project.

Table 3-1 LLC planar transformer electrical parameter reference ranges

Parameter	Reference range	Design constraint / note
Operating frequency	~200kHz–3MHz	Si often ≤500kHz, GaN often ≥1MHz
Turns ratio Np:Ns	Per gain & voltage ratio	48V→12V often near 4:1, matching LLC gain
Magnetizing inductance Lm	Per topology design	Ratio to Lr affects light-load ZVS and circulating loss
Resonant leakage Lr	Reuse intrinsic leakage	Removes external resonant inductor; control tolerance
Inter-layer capacitance	Lower is better	Interleave + shield to suppress, helps EMI
Insulation withstand	Per safety standard	Primary-secondary isolation per IEC 61558 etc., adequate creepage
Efficiency band	HF LLC can reach high efficiency	Confirm by measurement; varies with load and frequency
Operating temperature	Commonly -40°C to 125°C	Core derating at high temp; inductance drifts with temp

Important: The table gives reference ranges, not product specs. Actual figures for an LLC planar transformer depend heavily on the specific topology, power level, package and cooling. We do not provide 'generic ratings' detached from project conditions — any final parameter should be confirmed under your real operating conditions.

4. Physical Size & Package (low-profile fit)

AI PSU has strict low-profile demands (e.g. OAM accelerator height limits on the power supply). Planar transformers fit brick power packages with a flat structure; common forms grade by brick spec, with exact size and power defined per project:

Low-profile package forms (qualitative grading)

▶ **Auxiliary level** — Ultra-thin small footprint, for single AI-card aux supply

▶ **Main-power level** — Brick package, height-limited (e.g. OAM height limit)

▶ **Cluster-supply level** — Larger footprint, for rack central supply

▶ **Matrix-integrated level** — Large magnetic-integration form, for multi-rail rack-spec supply

Structural tolerances (core assembly, PCB alignment, gap, overall thickness) directly affect parameter consistency and assembly fit, and are a production process focus. A full-plane thermal pad is usually reserved on the bottom, compatible with thermal pads and liquid-cooled bases; the Z-axis heat path is shorter than a conventional wire-wound transformer, aiding temperature-rise control at low profile.

5. Typical Applications

LLC planar transformers mainly land in these AI compute-power supply scenarios:

Table 5-1 Typical applications and value

Application	Role	Planar transformer value
AIDC data-center power	48V→12V bus LLC conversion	Low profile high density, replaces discrete magnetics, raises integration
OAM/accelerator-module PSU	Open accelerator module supply	Ultra-thin low profile, fits height-limited server packages
Edge AI compute power	Industrial gateway / automotive domain LLC isolation	Wide-temp, anti-interference, reliable isolation
Storage-coupled AI power	800V storage auxiliary step-down LLC	High isolation, long-term reliable operation

The core value of LLC plus a planar transformer lies in: full-load ZVS soft switching lowering switching loss, the built-in resonant inductor reducing part count, PCB etching giving high production consistency, and built-in shielding with low parasitic capacitance improving EMI. The magnitude of each effect depends on design and conditions and must be confirmed by measurement.

6. Industry Technology Trends

Planar magnetics for AI compute power are evolving along several directions:

4 evolution directions of the planar transformer

▶ **Higher frequency** — As GaN/SiC spread, frequency iterates toward the MHz range and the transformer trends thinner

▶ **Deeper magnetic integration** — LLC transformer + PFC inductor + EMI inductor move toward single-part multi-rail integration

▶ **Simulation-driven customization** — Electromagnetic-thermal-mechanical multiphysics optimizes windings and gaps, shortening iteration

▶ **High-voltage platform fit** — High-voltage-insulation planar architectures for 800V storage / automotive OBC become a general scheme

7. FAQ

Q1: Why is LLC suited to a planar transformer rather than a wire-wound one?

Because LLC needs a controllable resonant inductor Lr, and a planar transformer's leakage can be controlled precisely by PCB interleaving and reused directly as Lr, removing the external resonant inductor. The planar structure is also low-profile, dissipates heat well and has high production consistency — matching high-frequency high-density AI PSU needs. A wire-wound transformer, at high frequency, has large skin/proximity loss, hard-to-control leakage and bulk, fitting poorly.

Q2: If leakage is reused as Lr, how is the tolerance held?

Leakage is set by the PCB stack-up geometry, and PCB etching's dimensional consistency far exceeds hand winding, so batch leakage tolerance is relatively controllable. Even so, it must be locked through stack-up design, gap precision and process control, and verified in production to ensure current sharing when modules are paralleled. Exact tolerance should be confirmed per project requirement.

Q3: Can I put the efficiency and temperature-rise figures from the table straight into my spec?

Not recommended. The figures here are public reference ranges for selection direction; your spec values must be determined under real conditions, based on your specific topology, power, frequency, package and cooling. Writing generic reference values into a spec as product ratings creates risk at the customer's validation stage.

8. Related Resources & Contact

Related technical resources

Topic	Link
Why the core loss on the datasheet is wrong for your operating point	core-loss-datasheet-vs-real-operating-point
800V HVDC bus inductor design guide	aidc-800v-hvdc-bus-inductor-design-guide
Server power density wall	server-power-density-flat-wire-thermal-limit

Contact ProMagTech: SHENZHEN PROMAGTECH CO.,LTD. designs custom LLC resonant planar transformers and power magnetics for AI PSU, AIDC and storage platforms.

Send your LLC requirements — input/output voltage, power, switching frequency, gain range, package height limit, cooling method and target efficiency — and we will propose a planar-transformer solution with achievable parameters for your real conditions, rather than generic template values.

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Disclaimer: All electrical and structural parameters in this article are public industry ranges or typical engineering reference values, not ratings or performance commitments of any specific product. Final specifications must be confirmed per project by topology, power, package and cooling under real operating conditions. The design can be adapted to the safety requirements of the customer's market (e.g. IEC 61558, UL 62368-1, CE, RoHS).